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European Provision Of Regional Impact Assessment on a

Seasonal-to-decadal timescale

Deliverable D33.1

Report on survey of end-user needs for improved uncertainty and confidence level information

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Deliverable Title	*Report on survey of end-user needs for improved uncertainty and confidence level information*	
Brief Description	*This report summarises and discusses the findings of Task 33.1: a survey of end-user needs regarding the provision of information about confidence and uncertainty in seasonal-to-decadal climate information.*	
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1. Executive Summary

In order to gain insight into how EUPORIAS stakeholders (and other interested organisations) utilise and wish to receive information about confidence and uncertainty in climate forecasts an online survey was conducted. This survey addresses four key questions: 1) How do current users of seasonal-to-decadal climate information perceive the accessibility, understandability and usefulness of this information?; 2) In what form do current users of seasonal-to-decadal climate information receive information about forecast uncertainty, and what forms of information would they like to receive that they currently do not?; 3) How do respondent organisations approach uncertainty?; and 4) When it comes to receiving information about uncertainty, what formats do respondents prefer?

Our findings, based on 44 complete and 6 partially complete surveys, demonstrate that, amongst current users, seasonal and interannual/decadal climate forecasts are perceived to be more useful than they are accessible or understandable, indicating a need to provide information in a format that renders it more readily comprehensible. When it came to receiving information about confidence and uncertainty in seasonal-to-decadal climate forecasts the information formats most commonly received were ranges of values, confidence levels, and verbal descriptions of likelihood. While few reported currently receiving information about how well earlier forecasts have matched observed climate, a large minority indicated that they wished to obtain this type of information. As it is standard practice for forecasts to be accompanied by information regarding reliability, this suggests that current methods of communicating it are not always well understood by recipients.

Responses to questions regarding current organisational approach to uncertainty indicated that a majority of respondent organisations were concerned with rare but severe events and “worst case” weather and climate scenarios (rather than disregarding low likelihood events); although a majority also indicated that they tended to focus on those events most likely to occur. Sectoral differences were also in evidence with respect to how organisations liked to receive and utilise uncertain information. For instance, preference for information formats that facilitate Yes/No decision making was strong amongst those in the water and energy sectors, but not amongst those in health.

With respect to preference for different information formats, maps, error bars and fan graphs were the most favoured forms of visual representation. Meanwhile formats that represent likelihood using proportion were least favoured. It should be noted however that preference for visualisations representing spread (e.g. error bars) was associated with greater self-reported comfort with statistics. Those less comfortable with complex statistics rated these formats less favourably. While maps were the most widely favoured form of visual representation, concerns were raised about the possible counterintuitive use of colour.

Our findings highlight the importance of a) ensuring that information regarding confidence and uncertainty is presented in a manner that is readily comprehensible; b) taking into account the types of decision making this information will be utilised in; and c) fully testing visualisations to ensure that they are interpreted as intended. They also suggest that while standard measures of spread may be favoured and well understood by a majority of EUPORIAS stakeholders (many of whom explicitly report having technical roles), those

with less statistical familiarity may be less inclined or able to effectively utilise them. We outline the implications of these results for future Work Package 33 tasks.

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. Detailed Report

3.1. Background

To successfully communicate confidence and uncertainty in climate predictions to end users, one must consider how end users perceive, interpret and utilise this information. As Knopman (2006) stresses, approaches developed in the social and cognitive sciences, provide us with methodologies for addressing the question of how uncertainties are understood by decision makers; thus allowing the development of communication and decision tools that enhance the value derived from scientific information. In this report we discuss the findings of a survey examining end-user needs for improved uncertainty and confidence level information with respect to seasonal-to-decadal climate predictions.

The question of how information regarding confidence and uncertainty can be most effectively communicated in the context of seasonal-to-decadal climate predictions is not one that can be addressed based solely upon the existing literature. Prior research in the field of risk communication indicates the importance of taking into account factors such as a) institutional ethos with respect to ambiguity, change in protocol, and false alarms (e.g. Allen and Eckle, 2011; Demeritt et al., 2010); b) how information is used in an operational context (e.g. Demeritt et al., 2007; McCown et al., 2012; Todini et al., 2005); c) user expertise (e.g. Gregory et al., 2012; Ibrekk & Morgan, 1987); d) level of precision and statistical detail required (Pate-Cornell, 1996); and e) differences in terminology (Carey & Burgman, 2008; Christensen et al., 2003). However, while this provides us with a framework for examining user needs and preferences, it does not present ready-made solutions in this specific context.

In terms of information presentation in the context of climate and meteorology more generally, a trade-off between richness (level of detail, spatial resolution, and temporal resolution), robustness[1] (accuracy, reliability and the appropriate reflection of skill), and salience (ease with which information can be used and understood) has been recognised (Stephens et al., 2012). Increased richness may render information less easy to understand, and reduce robustness; while some may find information on robustness difficult to interpret. Hence, the need to establish what users' preferences are when it comes to information about confidence and uncertainty, how they wish to use said information, and whether this information is accurately interpreted, is of key importance. With respect to visualisations in particular, work in various fields points to a need to consider whether the information is provided in a manner that a) is intuitive and "fits" perceptual processes (e.g. Nelson et al., 2009); b) enables information recipients to easily extract the correct 'gist' of the information (e.g. Reyna, 2008); c) facilitates the type of judgement or decision being made (e.g. Edwards et al., 2012; Ibrekk & Morgan, 1987); and d) uses colour in a manner consistent with pre-existing connotations (e.g. Stoverinck, 2011).

In this task (T33.1) we begin to address these issues by exploring how users and potential users of seasonal-to-decadal climate predictions approach uncertainty, and what their preferred information formats are.

[1] In this report the term "robustness" will sometimes be used as a general term to refer to the related but distinct concepts of accuracy, reliability, and skill.

3.2. General introduction

The overarching objective of Work Package 33 is to develop best practice in the communication of uncertainty and confidence. This survey represents an initial step towards achieving this goal. In order for the development (Task 33.3) and testing (Task 33.4) of methods of communicating uncertainty to be better informed by user needs and preferences, we seek here to gain a greater understanding of how EUPORIAS stakeholders (and other interested organisations) deal with confidence and uncertainty within their organisations, and how they would prefer to receive information about uncertainty in climate variables and indices. This survey therefore seeks to address the following questions:

1. How do current users of seasonal-to-decadal climate information perceive the accessibility, understandability and usefulness of this information, and how does this differ from perceptions of other types of climate information (and uncertain information more generally).

2. What forms of information about confidence and uncertainty in seasonal-to-decadal climate forecasts do present users currently obtain, and what forms of information would they like to receive that they currently do not?

3. How do respondent organisations approach uncertainty? (i.e. tolerance for false alarms, focus on central tendency versus rare yet severe events, in-house use of information, use in decision making)

4. When it comes to receiving information about uncertainty, what formats do respondents prefer? Is this associated with format familiarity and comfort with statistics?

Through exploring these issues this task enables us to gain insight into how respondents in various sectors approach uncertainty and what their preferred means of receiving information about it are.

3.3. Survey methodology

3.3.1 Participant recruitment

EUPORIAS stakeholders and organisations who had expressed an interest in the work of the EUPORIAS project were approached via email with a request to fill in the survey. In total 50 respondents began the survey, with 44 providing full completions.

3.3.2 Survey design

The survey, built using Qualtrics, had five sections (see Appendix IV for a full list of survey questions):

1. Organisational details and perception and use of climate information
2. Organisational approach to uncertainty
3. Representations of uncertainty
4. Details of seasonal-to-decadal climate information use or non-use
5. Respondent details (optional)

Section 1: Organisational details and perception and use of climate information

In the first section respondents were asked about the sector their organisation belonged to, their role within their organisation[2], and their organisation's use of forecasts. Respondents were asked whether their organisation obtained climate information at timescales of less than one month in the future (weather forecasts), one month to one year in the future (seasonal) , one year to ten years in the future (decadal), or more than ten years in the future (long term). They were also asked to list up to three additional types of forecast that their organisation made use of (e.g. economic growth, consumer demand, crop yield). Once the types of forecast(s) used by respondents' organisations had been captured, respondents were asked to rate the accessibility, understandability, and usability of each obtained on a 5 point scale (going from 1 “Not at all” to 5 “Very much”). Questions about climate forecasts and additional forecasts were included so that perceptions of seasonal-to-decadal information could be compared to these – in some cases more established – forms of uncertain information.

Respondents were given the opportunity to provide further comment after completing each scale.

Section 2: Organisational approach to uncertainty

In this section respondents were asked a) about their organisation's approach to dealing with a) uncertain information in general (8 questions); and b) uncertainty in the context of climate and weather (3 questions). Questions took the form of statements that respondents were asked to rate their agreement with on a 5 point scale (1 “Strongly disagree” to 5 “Strongly agree”). Statements examined tolerance for uncertainty, focus on unlikely yet severe events, information preferences, and the trade-off between false alarms and failure to detect.

[2] In order to minimise the possibility of duplication and responses being solicited from those who had already completed the survey respondents were also asked to provide their name, email, and the name of their organisation. However, these questions were optional.

The 11 items were presented in three blocks. After completing each block respondents were given the opportunity to provide further comment.

Section 3: Representing uncertainty

In this section respondents were asked about their information preferences and their familiarity with various forms of representing uncertainty. Respondents indicated 1) whether they used statistical information in their day-to-day work (and if so what kind); 2) their comfort with using statistical and numeric information (ranging from 1. “Not comfortable at all” to 5. “Comfortable with using advanced statistical tests (e.g. Monte-Carlo simulations, data modelling”); 3) preferences for numeric representations (e.g. percentages versus frequencies versus standardised probabilities); and 4) which visual representations of uncertainty they had some experience of using in their work.

In this section respondents were also presented with seven visualisations (bar graph, pie graph, error bars, fan graph, spaghetti graph, bars representing terciles, and map) depicting uncertainty in a seasonal forecast. Of the visualisations, the six graphs depicted a (fabricated) stream flow forecast based on the output of 28 model simulations, created for use in this survey. The map meanwhile was taken from an example seasonal temperature forecast for Europe. For each visualisations respondents were then asked to rate their agreement with a series of statements on a series of 5 point scales (1 “Strongly disagree” to 5 “Strongly agree”). Statements focussed on the likeability, understandability, and familiarity of visualisations. After rating each visualisation respondents were given the opportunity to provide their own comments.

It should be noted that in order to standardise the type of information being presented (and thus ensure that respondents were basing their ratings on the visualisations themselves) all representations reflected model output only and were not accompanied by information about forecast skill.

Section 4: Details of seasonal-to-decadal climate information use or non-use

Based upon their responses to the questions about climate information use in Section 2, respondents were divided into three categories: 1) “Current users of seasonal-to-decadal climate information”; 2) “Non-users of seasonal-to-decadal climate information”, and 3) “Don't know”.

Those in the first category (i.e. current users) were asked a) which climate variables or indices they received seasonal-to-decadal information for; b) how often their organisation's used forecasts at various timescales; c) what type of information they received regarding uncertainty in seasonal-to-decadal forecasts; d) how often their organisation used this information in their decision making; and e) whether they were satisfied with the information about uncertainty in seasonal-to-decadal forecasts they were currently receiving (and if so what additional information might be required). At the end of each block of questions respondents were given the opportunity to provide further comment.

Those in the second category (i.e. non-users) were asked a) which climate variables or indices their organisation would be interested in receiving seasonal-to-decadal forecasts for; and b) why they didn't currently use said forecasts. Again, at the end of each block of questions respondents were given the opportunity to provide further comment.

Those in the final category "Don't know" (i.e. those who did not know whether or not their organisation used climate information at a seasonal-to-decadal timescale) skipped directly to Section 5.

Section 5: Additional respondent details

In the final section respondents were asked to provide details about themselves (e.g. demographic information, educational background, years spent in current profession). These questions were optional and primarily included so that a general picture of respondents' technical backgrounds could be obtained.

3.4. Procedure for analysis

As sampling was restricted to stakeholder organisations and those who had expressed an interest in EUPORIAS the total number of respondents was relatively small. Thus, our analysis of the quantitative data gathered in the survey is primarily descriptive in nature, focussed on providing an overview of how the sample as a whole (and within specific sectors) responded. However, simple inferential tests have been used where they were felt to be appropriate.

In certain sections multiple inter-item correlations are examined. Normal procedure for such analyses would be to divide the critical value of alpha (p) by the number of associations examined (Bonferroni correction), in order to control for the increased likelihood of a Type 1 error. Due to the relatively small size of the sample however, this procedure renders even strong associations non-significant. Hence, for our correlational analyses, we have here opted to indicate where $p < .05$ and comment on the overall strength of the association (as measured by Pearson's r or Spearman's rho). We have done this aware of the increased potential of a Type 1 error, and thus sound an appropriate note of caution in our interpretation of the results.

44 respondents completed the survey in its entirety, with an additional 6 providing partial completions. In order to capture as much knowledge of end-user's approach to dealing with uncertainty as possible, unique partial completions have not been excluded from our analysis. In cases where the same individual completed (or partially completed) the survey more than once, quantitative data from the first full completion only was retained.

Of the initial 50 respondents, 36 reported that their organisations were EUPORIAS stakeholders, 10 reported belonging to non-stakeholder organisations, while an additional 4 respondents stated that they were unsure. With respect to sector specific analysis and discussion, we decided to perform a sector-by-sector examination of the quantitative responses for those sectors represented by at least 4 (complete) responses for the sake of robustness: these included water, energy, health, forestry and tourism.

Where appropriate we quote respondents' written responses to open-ended questions. It should therefore be noted that in some of these quotes terms such as "reliability" and "accuracy" may reflect general usage amongst laypeople rather than technical definitions.

3.5. Respondents

3.5.1. Sector

Of the initial 50 respondents, 16 reported that their organisation covered multiple sectors. For the purposes of this analysis we have endeavoured to code organisations according to their primary sector wherever such a thing can be said to exist. However, some organisations cannot be confined to a single sector (e.g. local governmental organisations) and have thus been coded as multi-sectoral. A breakdown of the sample by sector can be found in Table 1 below. As one can see the water sector is most heavily represented in the sample, followed by energy, health, forestry, and tourism.

Table 1: Proportion of respondents by sector

	Survey started (n=50)		Completed responses(n=44)	
Sector	n	%	n	%
Water	10	20	9	20
Energy	7	14	6	14
Health	6	12	6	14
Forestry	6	12	6	14
Tourism	4	8	4	9
Multi-sectoral	4	8	2	5
Agriculture	4	8	3	7
Climate services	3	6	3	7
Roads	2	4	1	2
Food Security	1	2	1	2
Finance	1	2	1	2
Environment	1	2	1	2
Emergency planning	1	2	1	2

3.5.2. Individual characteristics

38 out of 46 (83%) of respondents reported that they used statistical information in their day-to-day work. A breakdown of respondents' self-reported comfort with using statistical information is given in Table 2. As one can see, the majority of respondents stated that they were comfortable using more complex statistical information *or* statistical tests; with a minority stating that they were uncomfortable using statistical information or comfortable with using simpler forms of statistical information only. With respect to education, 2 out 42 (5%) reported that high school represented their highest level of academic education, 7 (17%) reported having an undergraduate qualification only, and 32 (76%) reported having a postgraduate qualification. Of 19 respondents who listed their degree subject(s) 17 (89%) listed having a scientific or technical qualification; while the remaining 2 (11%) had qualifications relevant to tourism. Examination of respondents' self-described roles within their organisation revealed just over half listed explicitly technical roles (e.g. scientist, hydrologist, engineer, technical manager). However, this does not mean that those who listed other roles had posts that did not require technical knowledge

Table 2: Reported comfort with statistical information (n=46)

	n	%
(1) I am not comfortable using statistics or numerical information	2	4
(2) I am comfortable using basic statistics and numerical information (e.g. means, percentages, frequency counts)	9	20
(3) I am comfortable using more complex statistics and numerical information (e.g. confidence levels, probability distributions)	19	41
(4) I am comfortable using standard statistical tests (e.g. correlations, t-tests)	8	17
(5) I am comfortable using more advanced statistical techniques (e.g. Monte Carlo simulations, mathematical modelling)	8	17

It should be noted that while the present analysis uses self-reported comfort with statistical information as a rough proxy for statistical knowledge and expertise it will not represent a perfect measure. Discomfort may not solely stem from a lack of knowledge, although it is to be imagined that comfort will largely correspond with familiarity and knowledge. Hence, any association between statistical comfort and other measures will be cautiously interpreted.

As it was observed that comfort in using basic inferential statistics (category 4) might not necessarily denote a higher level of statistical knowledge than comfort with using probability distributions and confidence interval (category 3), categories (3) and (4) were merged. Categories (1) and (2) were also merged owing to the small number of respondents in the former. Thus a recoded three level scale of statistical comfort was derived.

3.6. Use of climate information

3.6.1. Prevalence

The number of respondents stating that their organisation makes use of weather and climate information for lead times of less than, 1-12 months, 1-10 years and over 10 years is illustrated in Figure 1 below. As might be imagined, the most frequently used information was that for lead times of less than four weeks. Seasonal information (lead times of 1-12 months) was used more frequently than either interannual/decadal (lead times of 1-10 years) and long term climate (lead times of over 10 years) information. As one might expect, long term climate information was used by more organisations than information at an interannual/decadal timescale. However, the proportion of respondents who stated that they their organisation made use of interannual/decadal information was surprisingly high. Only a small minority of respondents reported being unaware of whether or not their organisation used seasonal or interannual/decadal information

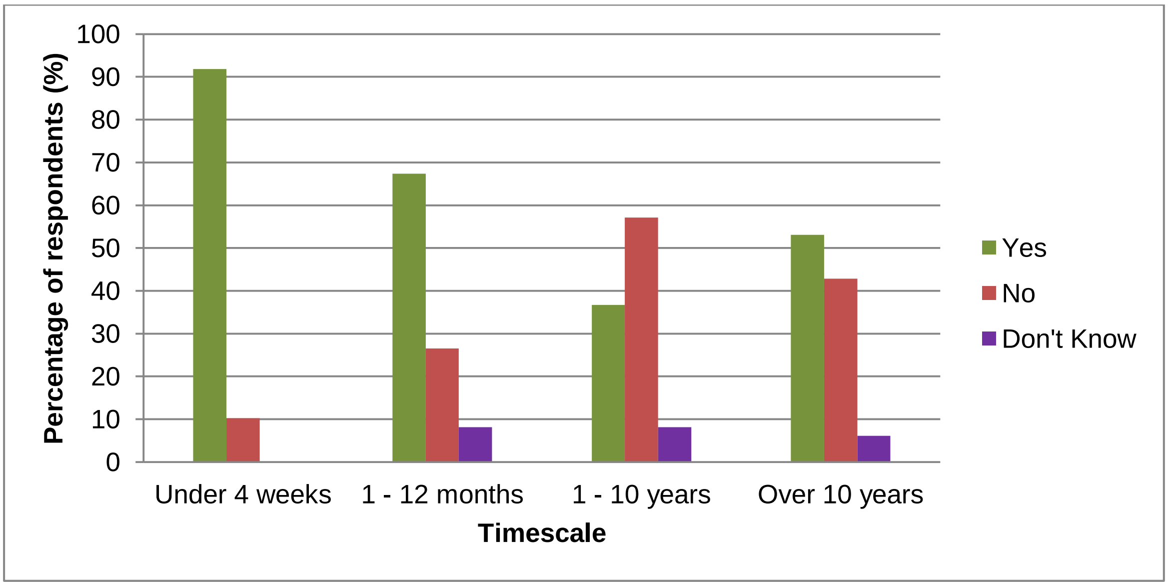


Figure 1 Response to the question: *"Does your organisation make use of any of the following types of weather and climate information?"*(n = 50)

3.6.2. Ratings of accessibility, understandibility and usefulness

For each timescale that participants reported that their organisation received climate information for they were asked to rate, on a five point scale, **ease of access** (1 = "not at all easy to find" – 5 = "very easy to find"), **ease of understanding** (1 = "not at all easy to understand", 5 = "very easy to understand"), and **usefulness** (1 = "not at all useful" – 5 = "very useful"). An additional "don't know" option was also available. A summary of the average ratings given is detailed in Table 3 below, along with the frequency with which the "don't know" option was selected.

In order to compare perceptions of climate information to perceptions of other types of prediction about future states, participants were asked to list up to three additional forecasts that their organisation used. A variety of different forecasts and projections were

listed by respondents. However, two that were listed frequently enough to enable a meaningful comparison were economic growth and consumer demand forecasts. Average ratings are also detailed in Table 3.

Table 3: Mean ratings of accessibility, understandability and usefulness for climate information and other forecasts used by respondents

	"Easy to find"			"Easy to understand"			"Useful"		
	Mean	(sd)	Don't know	Mean	(sd)	Don't know	Mean	(sd)	Don't know
Climate and weather information									
Up to one month (n = 45)	3.6	(1.2)	2	3.8	(1.0)	3	4.6	(0.8)	1
1-12 months (n = 33)	2.4	(1.2)	2	2.8	(1.2)	4	4.3	(1.0)	2
1-10 years (n = 18)	1.8	(0.8)	1	2.4	(0.9)	3	3.9	(0.8)	1
Over 10 years (n = 26)	2.3	(1.1)	1	2.4	(1.1)	2	3.7	(0.9)	-
Other									
Economic growth forecasts (n = 13)	3.2	(1.3)	2	3.5	(1.2)	2	4.1	(0.9)	-
Consumer demand forecasts (n = 12)	3.3	(1.2)	1	3.3	(1.3)	1	4.7	(0.5)	-

sd (standard deviation)

Climate and weather information for lead times of less than one month were rated as being easier to access than those at a seasonal (1 – 12 month), interannual/decadal (1 – 10 year), or long term (over 10 years) timescale. Both seasonal and long term climate information was rated as being more accessible than interannual/decadal. Economic growth and consumer demand forecast were also rated as easier to find than seasonal, interannual/decadal, and long term climate information.

Weather forecasts for less than one month were rated as being easier to understand than seasonal, interannual/decadal and long term climate information, as were economic growth and consumer demand forecasts.

With respect to usefulness, mean rating for climate information decreased with lead time. Both interannual/decadal and long term climate information were rated as less useful than economic growth or consumer demand forecasts.

Table 4 below details a series of Wilcoxon Sign Rank[3] tests statistically comparing ratings of accessibility, understandability, and usefulness for seasonal and interannual/decadal climate information with the other forecasts listed. Owing to the presence of multiple comparisons the critical value of p is lowered from .05 to .007 for each rating scale using a Bonferroni correction. However, owing to the small sample size, instances where $p < .05$ is are also flagged. It should be stressed that as the number of participants is very low – based on only those respondents who reported that their organisation used the types of information listed – a null result should not be taken as an indication than no difference exists. These statistics are presented to illustrate where the most substantiated differences lie.

Weather forecasts were rated as **easier to access** than seasonal or interannual/decadal. For the difference between ratings of accessibility for seasonal and interannual/decadal forecasts $p < .05$, but it failed to reach adjusted significance.

Difference in rating of **ease of understanding** between short-term and seasonal climate information reached significance, along with the difference between short-term and interannual/decadal information. While adjusted significance was not reached, $p < .05$ for the difference in understandability between seasonal and interannual/decadal, and seasonal versus long term information.

With respect to **usefulness**, seasonal climate information was rated as being significantly more useful than interannual/decadal or long term forecasts. Interannual/decadal climate information was also rated as more useful than long term climate information. This difference was not significant at the adjusted level of $p = .007$, but $p < .05$.

[3] This paired samples technique is used in lieu of alternatives allowing the comparison of more than 2 conditions due to the fact that very few respondents used all the types of information listed.

Table 4: Comparison of forecasts on measures of accessibility, understandability and usefulness

	Seasonal (1-12 months)		Interannual/Decadal (1-10 years)	
	z	n	z	n
Accessibility				
Weather (up to one month)	-3.4*	30	-2.9*	15
Seasonal (1-12 months)	-	-	-2.2#	14
Long term climate (over 10 years)	-1.2	16	-1.7	16
Economic growth	-1.0	7	-	-
Consumer demand	-1.9	10	-	-
Understandability				
Weather (up to one month)	-3.5*	28	-2.8*	13
Seasonal (1-12 months)	-	-	-2.1#	12
Long term climate (over 10 years)	-2.3#	15	-1.0	14
Economic growth	-1.1	7	-	-
Consumer demand	-0.7	10	-	-
Usefulness				
Weather (up to one month)	-1.4	30	-1.8	15
Seasonal (1-12 months)	-	-	-2.6*	14
Long term climate (over 10 years)	-3.0*	16	-2.2#	15
Economic growth	0.3	8	-	-
Consumer demand	-1.40	10	-	-

Significant at .05 * Significant at adjusted level of .007

NOTE: Ratings for interannual/decadal forecasts could not be compared to those for economic growth or consumer demand owing to small number of respondents who utilised both forms of information.

Table 5 details the intercorrelations between ratings of accessibility, understandability and usefulness amongst respondents. As one can see, **perceived accessibility correlated strongly with perceived understandability** for all forms of information listed (though where participant numbers were very small this failed to each adjusted significance). However, the **association between both accessibility and usefulness, and understandability and usefulness was comparatively small**. Again, failure to reach statistical significance here is, in some instances, likely to be the result of a small sample size. However, it appears that perceived usefulness is not as strongly associated with the accessibility or understandability of climate information, as accessibility and understandability are with one another.

Table 5: Intercorrelation between ratings of accessibility, understandibility, and usefulness for forecasts and projections (Spearman's rho)

	Accessibility-Understandibility		Accessibility-Usefulness		Understandability-Usefulness	
	ρ	n	ρ	n	ρ	n
Climate and weather information						
Up to one month	.62**	42	.27	42	.30	41
1-12 months	.66**	28	.11	29	.05	28
1-10 years	.74**	15	.25	16	.33	15
Over 10 years	.58**	22	-.08	24	.48*	23
Other						
Economic growth forecasts	.73*	10	.07	11	.05	11
Consumer demand forecasts	.69*	11	.19	11	. 52	11

*Significant at .05 **Significant at .01

3.6.3. Sector breakdown

Table 6 below details the number of organisations using climate information at a seasonal to interannual/decadal timescale within the five sectors with n ≥ 4 respondents. Amongst those in the water and energy sectors use of climate information at a seasonal (1 – 12 month) timescale was far more common than use of climate information at an interannual/decadal (1 – 10 year) timescale. This was not the case amongst the other sectors, where use of information at a 1 – 10 year timescale was rated as being used slightly more frequently amongst those in the forestry and tourism sectors (though the small sample size should be stressed).

Table 6: Use of seasonal-to-decadal climate information by sectors (only sectors with 4 or more respondents included)

	Seasonal (1 – 12 months)			Interannual/decadal (1 – 10 years)		
	Users	Non-users	Don't know	Users	Non-users	Don't know
Water (n=10)	7	3	-	3	7	-
Energy (n=6)	5	-	1	1	4	1
Health (n=6)	5	1	-	4	1	1
Forestry (n=6)	3	3	-	4	2	-
Tourism (n=4)	1	2	1	2	2	-
Total	*21*	*9*	*2*	*14*	*16*	*2*

With respect to the accessibility, understandability and usability of climate information at a seasonal (1 – 12 month) scale, mean ratings were generally similar across sectors (see Figure 2). Although for those in the forestry sector rating of accessibility was somewhat lower than that of other sectors. This possibly reflects the perceived accessibility of the different climate variables/indices of interest across sectors (again however, the small sample size should be stressed). Due to the low number of respondents within each sector who indicate that they use interannual/decadal forecasts, a similar comparison for forecasts at this timescale is not feasible.

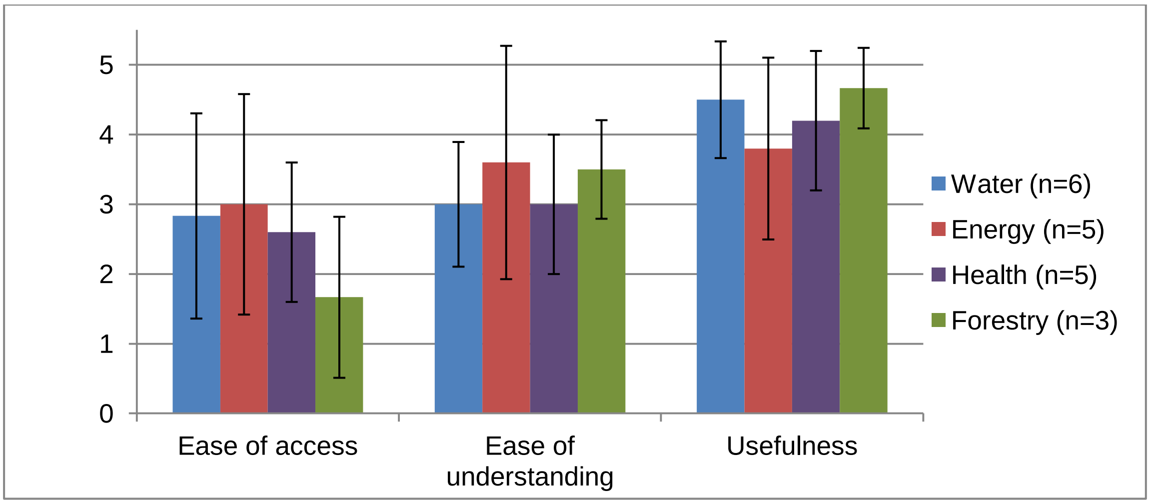


Figure 2 Mean rating of accessibility, understandability and usefulness of climate information at a seasonal (1-12 month) timescale by sector. Error bars represent standard deviations. Where respondents answered "Don't Know" with respect to rating ease of access, ease of understanding or usefulness their responses are omitted.

3.6.4. Respondent comments

As previously mentioned, after being presented with each of the three rating scales (accessibility, understandability, usefulness) respondents were given the chance to provide further, open-ended comment.

Accessibility

With respect to rating how easy information was to find/access, one respondent mentioned that they felt the scales were not specific enough:

> *"Too broad a question. It not only depends on the forecasted variable(s), but even more so on the context (e.g. global circulation model output)"*.

Another pointed out that even when forecasts are easy to find, cost of purchase and download time may render them less accessible.

> *"…it's not difficult to find these forecasts but they are expensive, which lowers their accessibility."* (On weather forecasts and forecasts for up to a few months in the future)

> *"They are free but the downloading is not as easy as for the former forecast (long and painful)"* (On data regarding long term climate simulations available from the IPCC)

Understandability

With respect to ease of understanding, three respondents made additional comments. Two raised the issue of the need for expertise to understand forecasts, with one of them mentioning that they did not feel that the question was relevant to them as they employed experts to translate information into a form that was relevant to their organisation. A third respondent – who indicated that their organisation used climate information at timescales of 1 – 10 years and above 10 years along with forecasts pertaining to economic, social and disease variables – stated that their experience was that long term forecasts:

> *"….tend to be well described and based on defined models, even if there are wide confidence intervals."*

Usefulness

In additional comments on 'usefulness' two respondents directly related usefulness to forecast robustness (using the phrasing "reliability" and "accuracy" respectively). One noted that while they felt that decadal simulations would be useful to their clients, these were not currently used as they lacked sufficient reliability.

> *"For real decadal simulations, it would be also useful for our [CLIENT BASE] but we do not use them since they are not reliable at all."*

In contrast another respondent indicated that they felt that the question was too broad and that all information *"mattered somehow"* in some context.

General comments on usage

Remarking on how forecasts at longer timescales were used in their organisation, one respondent took the opportunity to note that:

> *"Longer term forecasts are used for strategic thinking. Their use for medium term and strategic planning demand more detailed information at appropriate geographical scale"*

This indicates that how forecasts are used by this respondent organisation is contingent on spatial resolution.

3.6.5 Discussion

Amongst our sample perceived forecast accessibility was – for all forecast types – strongly associated with ease of understanding. However, while both perceived accessibility and understandability tended to be positively associated with perceived usefulness, said associations were less strong and generally non-significant (though this latter point can perhaps be attributed to the small number of respondents in each correlational group). The accessibility/understandability association may be attributable in part to those with greater expertise (a factor mentioned in respondents' comments on understandability) having both more knowledge as to where to find and how to interpret information. It is also possible that those forecasts that are easiest to find tend to be presented in a more user-friendly manner.

Amongst our respondents weather forecasts were deemed to be more accessible and understandable than seasonal, interannual/decadal, or long term climate information. Interestingly however seasonal climate information was judged to be about as accessible as long-term climate information, but more easily understood (though this latter difference did not reach adjusted statistical significance). Interannual/decadal climate information was deemed to be the least accessible form of climate information, though it was not on average rated to be less understandable than long term information.

The fact that the perceived usefulness of climate information diminished with lead time could reflect perceived skill/accuracy/reliability (as suggested by respondents' comments). It may also reflect, in some cases, the time horizons of interest in organisational planning (i.e. temporally nearer events being of more concern than those that are more distant in time). Although, as shall be discussed in Section 7.3.1, when current users of seasonal-to-decadal climate information were how frequently they used forecasts with different lead times, responses indicated climate information with lead times of 6-10 years was used more frequently than information with lead times of 7-12 months, 1-2 years, and 3-5 years. In all cases however, it is striking that ratings of usefulness were far higher than ratings of accessibility or understandability for all forms of climate information, emphasising the need for accessibility and ease of understanding to be increased.

With respect to perceptions of climate versus non-climate forecasts, the number of respondents who reported obtaining both climate information at a seasonal timescale *and* either of the non-climate forecasts was low, thus limiting our capacity for within-groups comparison. However, it is interesting to note that mean rating of understandability for economic growth forecasts was higher than that for seasonal climate information. This could be the result greater familiarity (due to within-organisation expertise or current frequency of use), or the manner in which information is presented.

The sectoral breakdown provided in 3.2.3 does not suggest strong variations between sectors with respect to perceptions of the accessibility, understandability, and usefulness of seasonal forecasts; with the exception of those in the forestry sector rating

them as substantially less accessible (possibly a result of differences in climate and climate impact variables of interest). However, as the number of users per sector is small, firm conclusions cannot be drawn.

Key Points: Accessibility, understandability and usefulness

- Seasonal and interannual/decadal forecasts are considered to be less easy to understand than forecasts with lead times under a month.
- Perceived usefulness of climate information diminishes with increasing prediction lead time.
- Perceived accessibility is closely related to perceived understandability. Perceived usefulness however is less strongly associated with these.
- Seasonal and interannual/decadal forecasts are considered to be more useful than they are accessible or understandable.

3.7. Use of climate information with lead times of 1 month to 10 years

3.7.1 Current users

3.7.1.1. Variables and timescales of interest

Figure 3 below details the climate variables current users of climate information at a seasonal-to-decadal timescale receive information about, while Figure 4 details the frequency with which information at different timescales is used in decision making. As one can see, land temperature was the variable for which information was most commonly obtained, followed (in order) by rainfall, extreme indices, riverflow, wind, sea temperature, crop yields and cloud cover. Two respondents indicated that they received information for another variable: one respondent naming "frost frequency", another "geopotential").

As one might imagine, use of climate information in decision making declined as timeframe increased. Although a slightly greater proportion of respondents indicated that they used information at a 6-10 year timescale than a 3-5 year timescale. The proportion of respondents who indicated that their organisation 'often' or 'very often' used information was under 50% for all timescales aside from 1-3 months, where it was just over (55%).

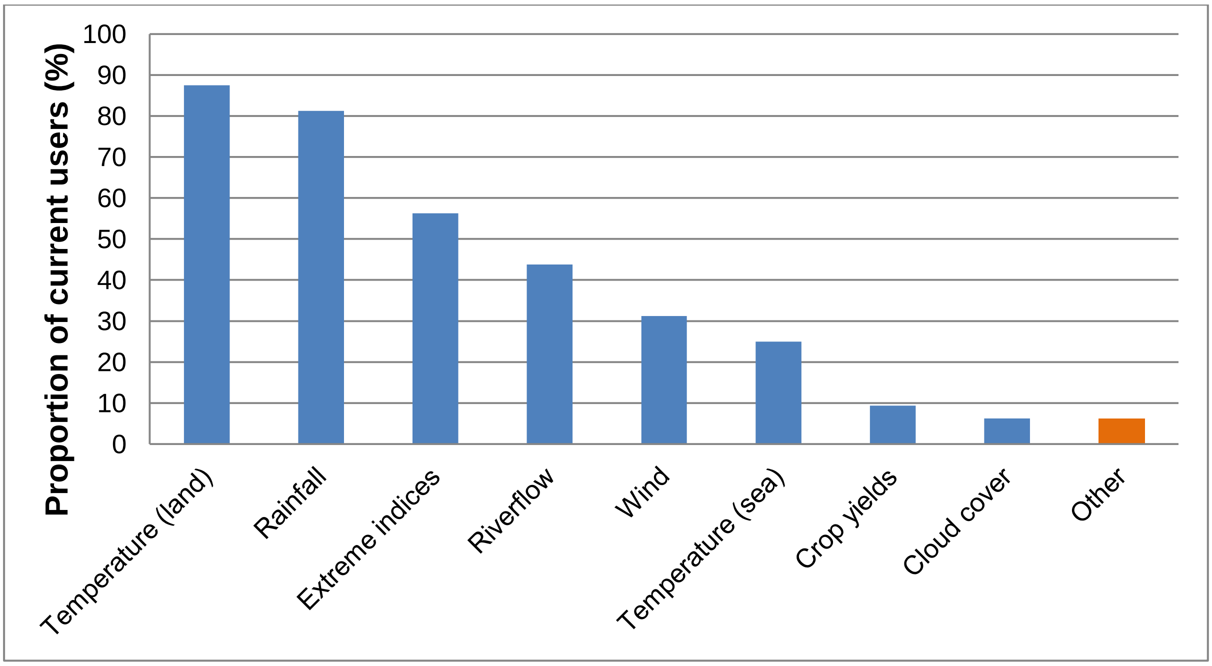


Figure 3 Climate variables and indices for which current users receive seasonal or decadal information (n = 32).

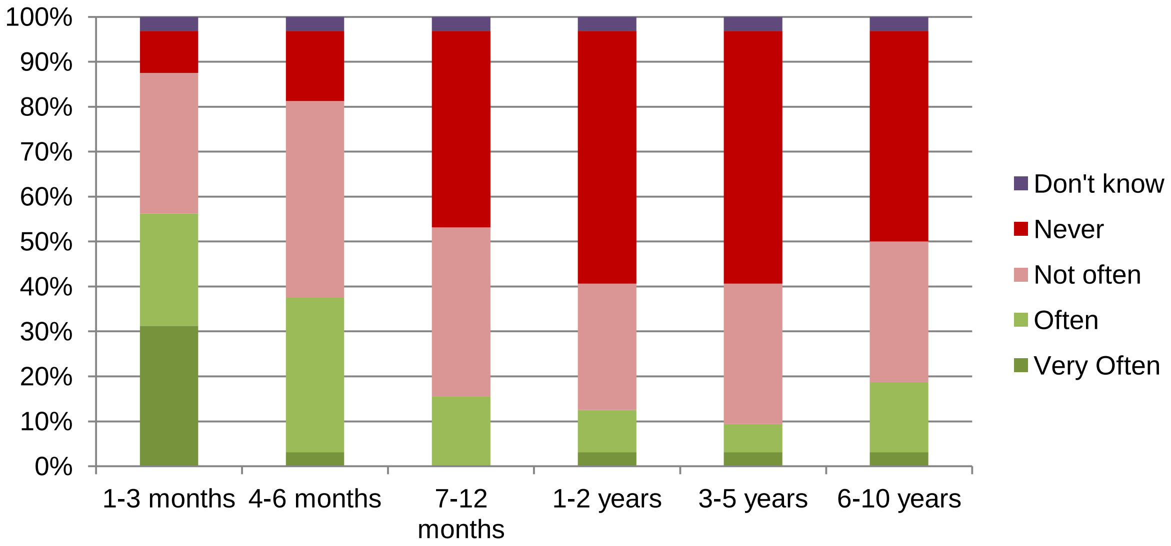


Figure 4 Frequency with which climate information at different timescales is used by respondent organisations (n=32).

When given the opportunity to provide open-ended comment on frequency of use six respondents chose to do so. Two mentioned that they were unsure how to define 'often'. Two mentioned that frequency of use was contingent on availability and current need (one of these indicated that they had opted to interpret the phrase 'often' to denote the importance placed on this information rather than frequency per se). The remaining two noted that infrequency of use at certain timescales was the result of forecasts (at appropriate geospatial scale) being difficult to obtain.

3.7.1.2. Information obtained

Figure 5 depicts the proportion of current users who report that their organisations obtained information about uncertainty in climate forecasts in various forms. When questioned about whether their organisation received information in these formats respondents selected one of four responses "Yes", "No", "No, but we would like to" [4], or "Don't know". Respondents were therefore not able to select both "No" and "No, but we would like to". Ranges of values was the most commonly obtained type of information, followed (in order) by Confidence intervals, Verbal descriptions of likelihood, Raw data, Probability distribution, Information about possible sources of error, and Information about how well earlier forecasts have matched observed climate. Only one respondent reported that their organisation obtained information regarding Indicators of signal strength, though the high proportion of "Don't Know" responses may suggest that this description was not well understood.

With respect to information that was not currently obtained, but which respondents' organisations would like to receive, Information about possible sources of error and Information about how well earlier forecasts have matched observed climate were the most commonly selected. Over 30% of respondents indicated a wish to receive the latter. Only one respondent indicated that their organisation does not currently receive raw data would

[4] It was explicitly stated on the survey that it should be kept in mind that not all of the information formats listed would necessarily be available for all climate variables at all timescales.

wish to. This suggests a split between organisations who do “in house” risk analysis and data modelling (and are already proficient at obtaining this data), and those who do not.

Respondents were asked to describe any other forms of information they received regarding uncertainty in seasonal-to-decadal climate forecasts. Formats mentioned included health impacts, details of factors influencing models, written reports, percentage reliability (described by respondent as *“probability of forecast happening”*) and terciles.

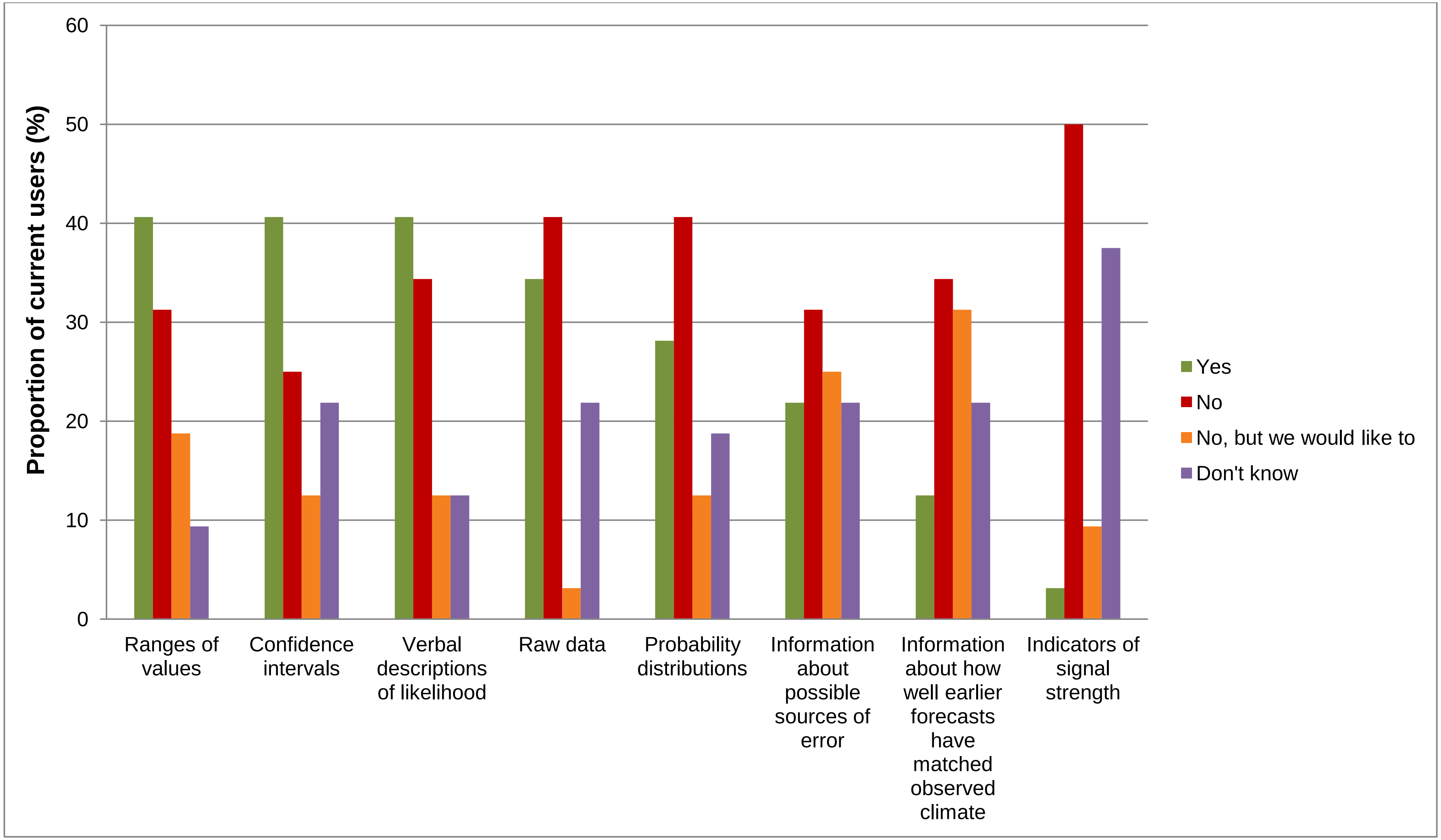


Figure 5 Forms of information regarding uncertainty in climate forecasts received and not received by current users of seasonal-to-decadal climate information (n=32).

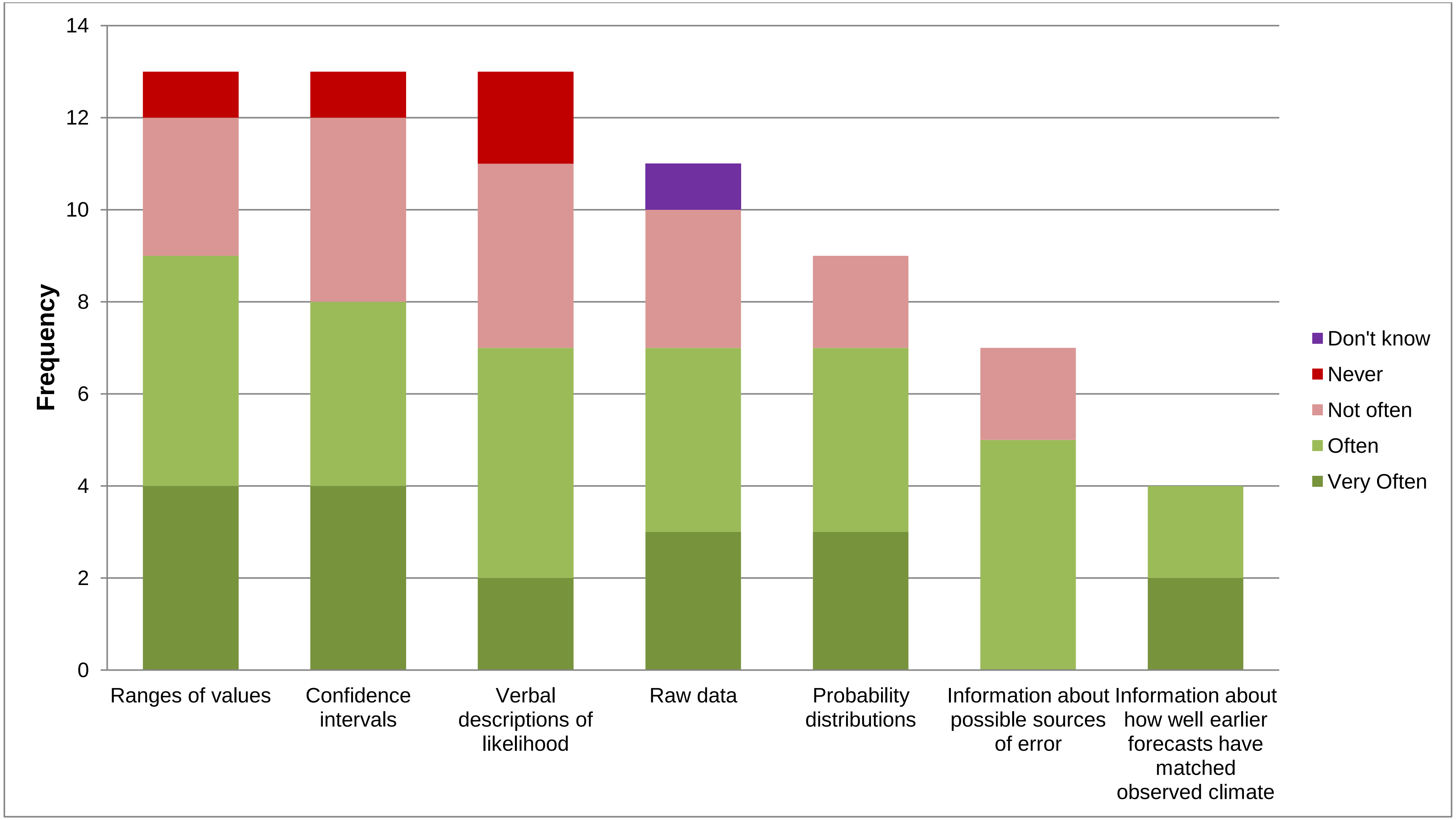


Figure 6 Frequency with types of information regarding uncertainty in climate forecasts are used in organisational decision making (n=32).

For each predefined form of information mentioned in Figure 5 respondents who indicated that they obtained this were asked to rate the frequency with which this information was used in their organisation’s decision making. Responses are illustrated in Figure 6 above. As one can see from the proportion of “Not often” and “Never” responses given for each type of information, those forms of information that were most commonly obtained were not always frequently utilised in decision making. Although in absolute terms, Ranges of values and Confidence intervals were utilised most frequently.

When given the opportunity to give further comment on forms of uncertain information received, one respondent stated:

> *“The problem is not so much that we don't get uncertainty information, but rather that the uncertainty information is often not correct (lack of "reliability")”*

3.7.1.3 Satisfaction with current information provision

Current users were asked whether they were satisfied with the information they were currently receiving with respect to seasonal to interannual/decadal climate information. Of the 32 respondents classified as current users 10 indicated that they felt that current provision met their needs, 18 indicated that it did not meet their needs, and 4 chose not to respond to this question.

When those who indicated that their information needs were not being met were given opportunity to comment on how provision might be improved, responses predominantly pertained to properties of forecasts themselves such as higher spatial resolution (n=4), robustness (n=2), and the reduction of uncertainty (n=1). Some however made reference to information provision. Two respondents indicated that they wished to receive more detailed information on performance: one mentioning a desire to receive information regarding *“limiting factors for forecasts in different climatological situations”*, *“getting better information on forecast quality of former forecasts*”, and *“getting information on persistence/stability of forecasts*”. The other wanted *“better communication of forecast reliability”.*

Two respondents also expressed a desire to receive information in a form that could be fed into their own modelling/analysis:

> *“Would like to have them as input in our daily hydrological model forecast run.”*

> *“We need high frequency model outputs (3h) that we then process.”*

Additional forms of information to which access was desired were information on past climate, and access to more than one model *“to compare sources”*; while one respondent indicated a wish for *“a more user friendly graphical-depiction”*.

3.7.2 Non-users

The proportion of non-users indicating that their organisation would be interested in receiving seasonal to interannual/decadal information for a listed set of climate variables is detailed in Figure 7 below. Rainfall, chosen by all non-users, was the most commonly selected variable, followed (in order) by land temperature, riverflow, wind, extreme indices, crop yields, and cloud cover. No non-users indicated a desire to receive sea temperature. Three respondents indicated that their organisation would like to receive other climate variables or indices.

These were given as “Snowfall and extreme winter weather events”, “Soil freeze depth”, and “Tree growth, Soil parameters (pH)”.

Respondents were asked to indicate their reasons for not currently using seasonal to interannual/decadal information. Responses to this question are given in Figure 8 below. As one can see, “....too much uncertainty in these forecasts for them to be useful in our decision making” was the most frequently selected reason, followed (in order) by the matter not being discussed within the respondent’s organisation, the non-availability of forecasts for events or indices of interest, and the information available not being precise enough for use in decision making. One respondent indicated that information was not provided in a way that their organisation could use. In a follow up question, they stated that they had to “...think about respective models with respect to our main interests”, suggesting that they could not integrate the information available into their existing models.

Of those respondents (n=5) who reported that no forecasts were available for events/indices of interest, three were those who listed “Other” variables in response to the preceding question.

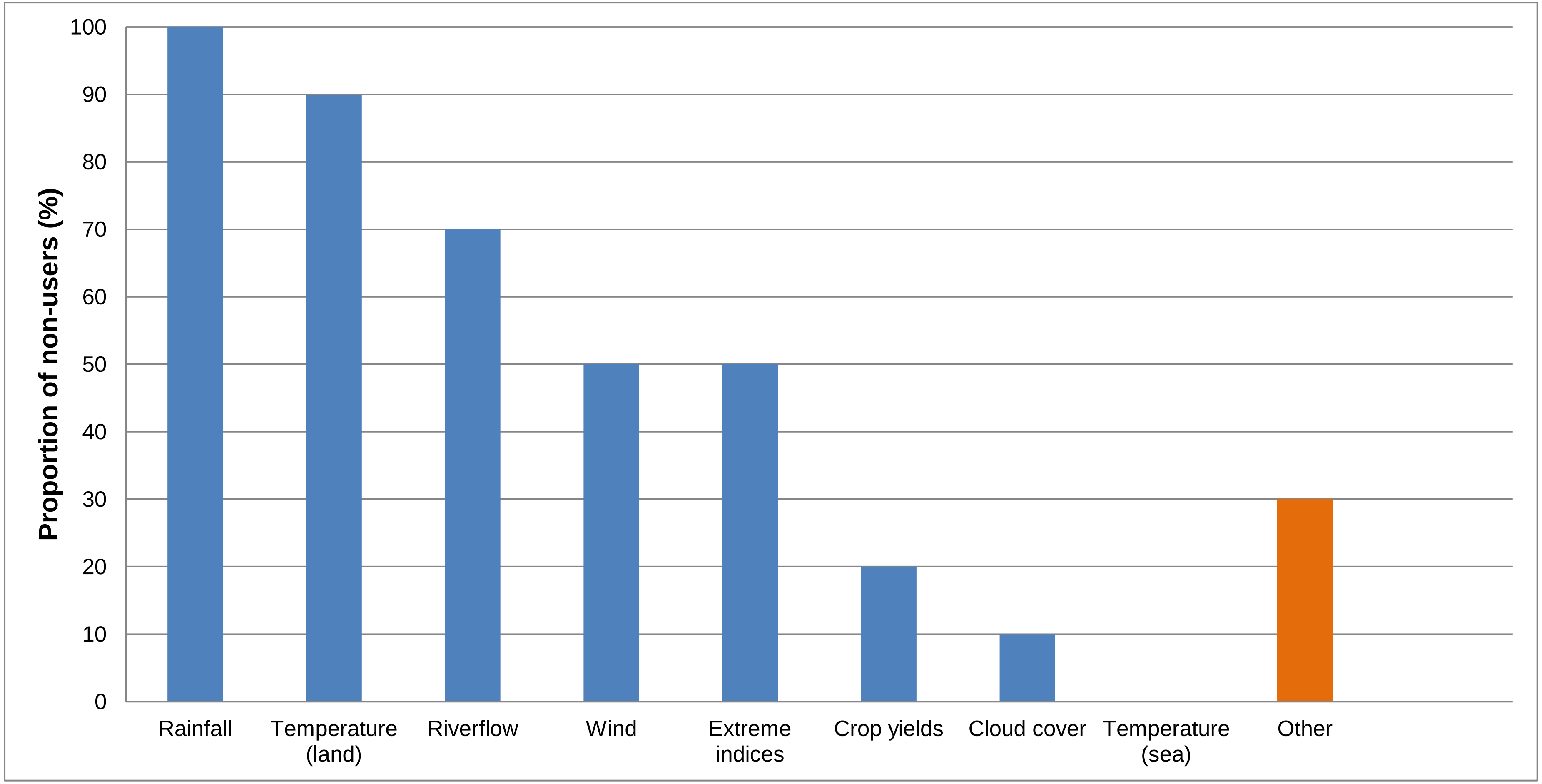


Figure 7 Climate variables and indices for which non-users would be interested in receiving seasonal-to-decadal information (n=10).

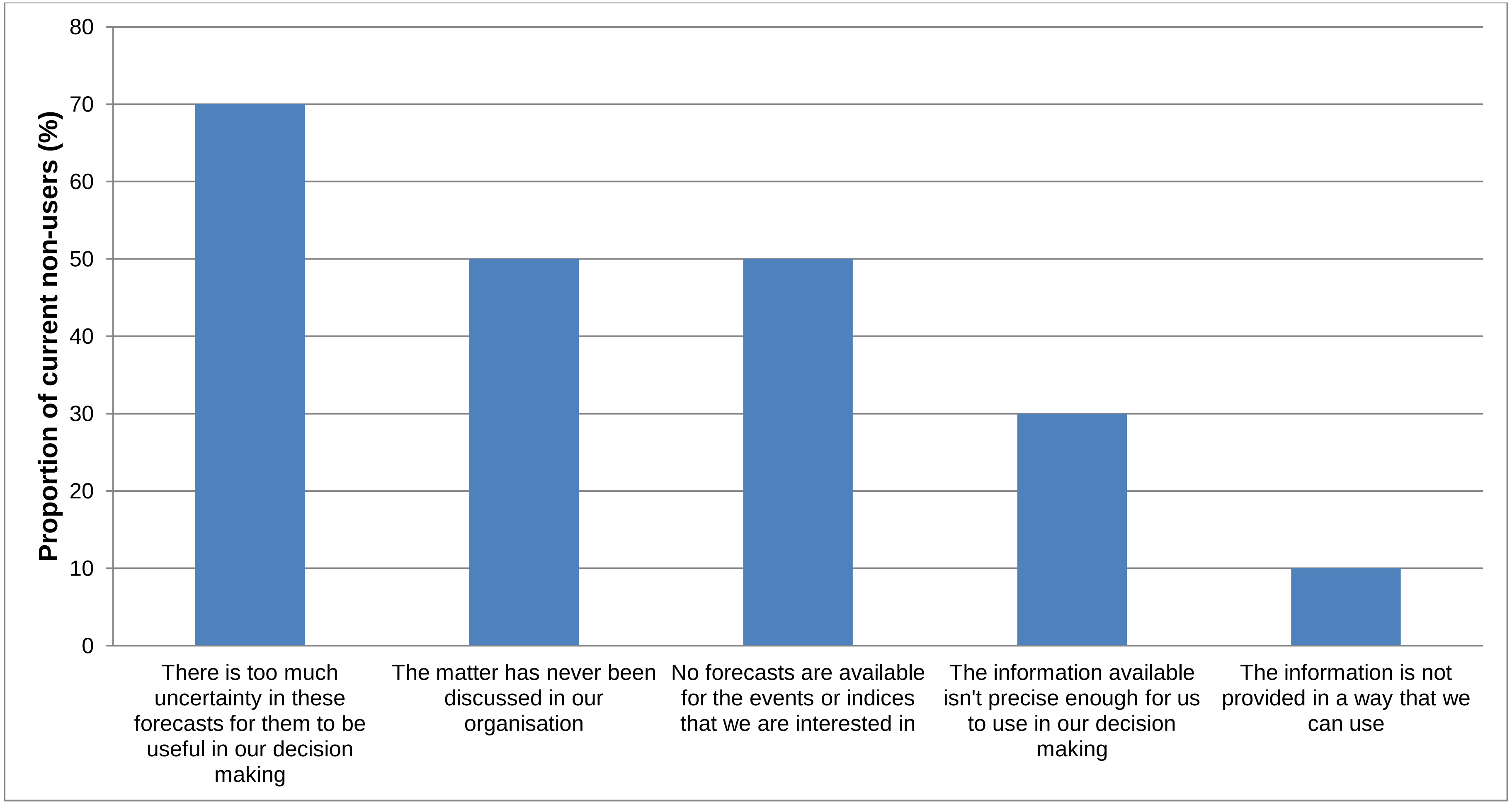


Figure 8 Reasons for not presently using seasonal-to-decadal climate information amongst non-users (n=10)

3.7.3. Discussion

Those respondents who report being current users of seasonal-to-decadal climate information indicate that they seek out information on a variety of climate variables, indices and impacts: with temperature and precipitation being the most common. With respect to timeframes of interest one sees a sharp decline in frequency of use after 1-3 months; with use further declining with each time increment in time until the 6-10 year mark, where use increases. This pattern may reflect a shift from information use in shorter term operational contexts, to longer term strategic planning.

In terms of the types of information obtained by respondents ranges of values, confidence levels, verbal information, and raw data represented the most commonly obtained forms. However, those who reported using these representations most frequently also tended to report using other forms of information. It is notable that while comparatively few respondents indicated that they received information about how forecasts performed relative to observed climate, many would like to do so. This was reiterated by some respondents when asked to describe how information provision could be changed to meet their needs. As it is already standard practice for this information to be provided with forecasts, our findings strongly suggest that the way in which it is currently presented is not well understood by some recipients. As just over 30% of current seasonal-to-decadal forecast users indicated that they did not receive this information, but wished to, a clear need to address this is apparent. It is also notable that, with one exception, respondents who did not already receive raw data did not wish to. This suggests a split between organisations proficient in performing 'in house' analysis (who already receive data in this form) and organisations that require data in a form that has been processed and analysed.

Amongst non-users the most common reasons given for not using seasonal-to-decadal forecasts was the existence of "too much uncertainty" in said forecasts and the matter not being discussed within respondents' organisations. Only one respondent made reference to information provision; indicating that the information was not available in a form that could be integrated into their existing models. Hence, it appears that for most of the non-users in the sample the format of information provision was not a common reason for non-use.

Key Points: Current use of seasonal-to-decadal climate forecasts

- Amongst current users of seasonal-to-decadal climate forecasts, frequency of use diminishes with increasing lead time until the 6 – 10 year bracket.
- The most commonly received forms of information about uncertainty in climate forecasts at this timescale are ranges of values, confidence levels, verbal descriptions of likelihood and raw data.
- While few respondents report receiving information about how earlier forecasts have compared to observed climate a sizable minority indicate that they would wish to. As information on reliability is usually provided as standard, this suggests that work is needed to ensure that end-users are able to recognise and understand this information.
- Few organisations that do not already receive raw data wish to obtain it.

3.8. Organisational approach to uncertainty

Figures 9 and 10 below indicate level of agreement with statements regarding organisational approach to dealing with 1) uncertainty in general; and 2) uncertainty in the context of climate information. As one can see, a majority of respondents agreed or strongly agreed that their organisation planned for rare yet severe events, and considered worst case scenarios with respect to weather and climate. Only a minority (26%) explicitly indicated that their organisations tended not to focus on low likelihood events, although a majority (60%) agreed or strongly agreed that their organisations were most concerned with those risks most likely to occur. Relatively few respondents (34%) agreed with the statement *“We need to know what will happen, not what might happen”*, indicating some acceptance of uncertainty amongst most organisations.

With respect to information usage, 48% of respondents indicated that their organisation did its own risk modelling, though when it came to weather and climate information only 2% agreed or strongly agreed that they just needed raw model data so that they could perform their own analyses. A clear majority (74%) indicated that time pressure necessitated that decisions often be made before they had all the information that they might wish, while 68% indicated that their organisation liked to receive information in a form that facilitated Yes/No decisions. In terms of statistical confidence 28% agreed or strongly agreed that their organisation had clear guidelines as to how much was required before action was taken; however, as 14% responded as “Don’t know/Not applicable” and 16% as “Neither agree nor disagree”, it is possible that a greater proportion of participating organisations do have such in some capacity.

In terms of trade-offs between false alarms and failure to act, just under half of respondents (48%) agreed or strongly agreed with the statement that *"When it comes to predicting extreme weather events we are willing to accept more false alarms if it means that a greater number of real extreme events are detected in advance”*. 16% disagreed or strongly disagreed with this statement, while 16% neither agreed nor disagreed (possibly suggesting ambivalence).

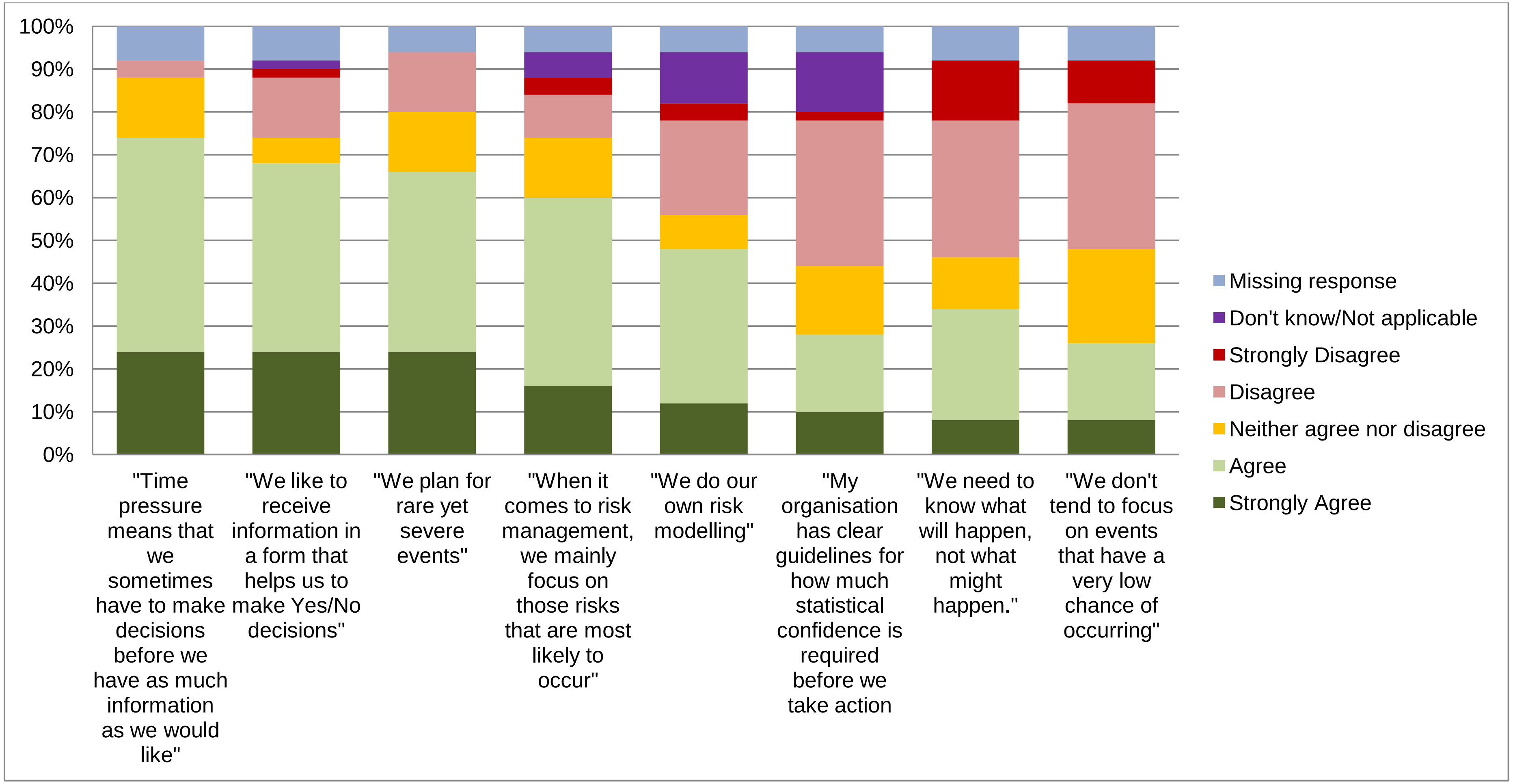


Figure 9: Level of agreement (%) with eight statements regarding organisational approach to uncertainty (n = 50)

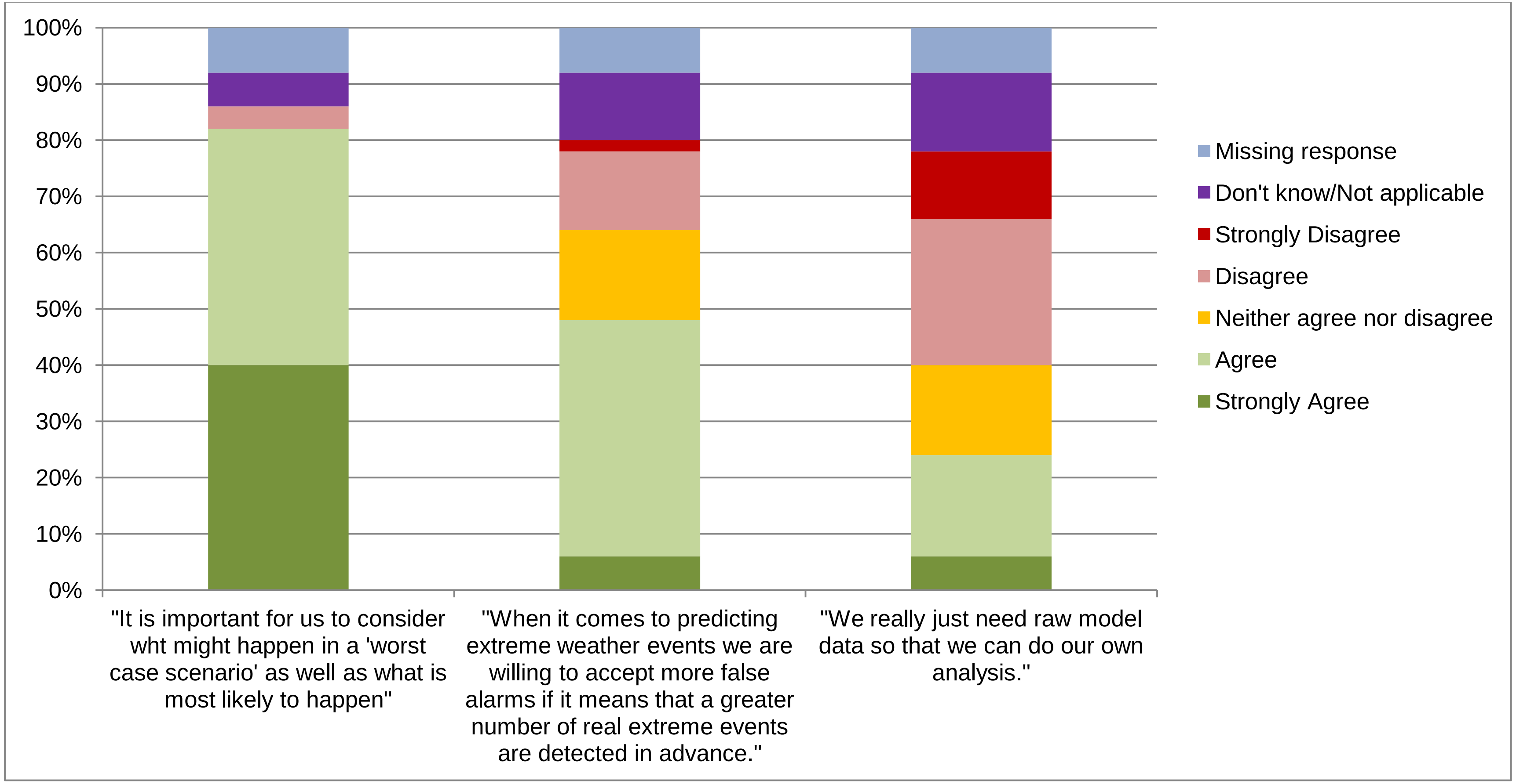


Figure 10 Level of agreement (%) with three statements regarding organisational approach to uncertainty in climate and weather information (n = 50)

Table 7: Intercorrelations between agreement with statements regarding organisational approach to uncertainty (Spearman's ρ)

	"My organisation has clear guidelines for how much statistical confidence is required..."	"When it comes to risk management, we mainly focus on those risks that are most likely to occur"	"We do our own risk modelling"	"Time pressure means that we sometimes have to make decisions before..."	"We need to know what will happen, not what might happen."	"We don't tend to focus on events that have a very low chance of occurring"	"We like to receive information in a form that helps us to make Yes/No decisions"	"It is important for us to consider what might happen in a 'worst case scenario'..."	"...we are willing to accept more false alarms if it means that a greater number of real ...."	"We really just need raw model data so that we can do our own analysis."
"We plan for rare yet severe events"	.15	-.22	.27	.13	-.19	$-.32^{*}$	$-.36^{*}$	$.35^{*}$	-.06	.12
"My organisation has clear guidelines..."		-.01	$.42^{*}$	-.15	.10	-.11	.06	.06	.20	-.18
"When it comes to risk management..."			-.02	.16	-.09	.08	.20	.25	.12	.10
"We do our own risk modelling"				.00	-.23	$-.45^{**}$	.06	$.41^{*}$	-.03	.18
"Time pressure means that we sometimes..."					.23	-.04	$.28^{\#}$	.18	.22	.08
"We need to know what will happen...."						.24	$.54^{**}$	-.16	.01	-.08
"We don't tend to focus on events that ..."							.16	$-.36^{*}$	-.13	.12
"We like to receive information..."								-.01	$.30^{\#}$	-.10
"It is important for us to consider what..."									.11	.21
"...we are willing to accept more false alarms..."										$-.29^{\#}$

$^{\#}$Significant at .1 *Significant at .05 **Significant at .01

Table 7 details the intercorrelations between level of agreement with the 11 statements regarding organisational approach to uncertainty/utilising uncertain information.

Respondents who agreed that their organisation planned for rare yet severe events also tended to agree that their organisation considered worst case climate/weather scenarios. Agreement with both these statements was negatively associated with agreement on the statement that: *“We don't tend to focus on events that have a very low chance of occurring”* Thus it can be surmised that respondents were consistent in their reporting of organisational attitude towards preparing for unlikely but potentially severe events.

Agreement with the statement that one’s organisation does its own data modelling is positively associated with both planning for rare yet severe events and considering worst case scenarios with respect to weather and climate. It is also negatively associated with agreement with the assertion that one’s organisation doesn’t tend to focus on events with a low chance of occurring. As one might expect, respondents who indicated that their organisations did their own risk modelling were also more likely to indicate that their organisation had guidelines as to the statistical confidence required for decisions to be made.

Those who indicated that time pressure necessitated that decisions be made before they had as much information as they would like tended to demonstrate greater agreement with the statement*: "We like to receive information in a form that helps us to make Yes/No decisions",* although the association was not significant at the.05 threshold (p = .06). Agreement with this latter statement was also positively associated with a greater stated need for certainty (as represented by agreement with the statement*: “We need to know what will happen, not what might happen”*) and negatively associated with the assertion that one’s organisations plans for rare yet severe events. Interestingly however it was also positively associated with willingness to accept a greater number of false alarms if a greater number of extreme events could be detected; although once again the association did not reach the significance threshold of .05 (p = .06). Hence, it would seem that while a desire to receive information in this form corresponds with lower acceptance of uncertainty in some cases; it may also be associated with a greater tolerance for false positives in others. It might also be posited that those under time pressure tend to prefer information formats that facilitate quick decision making.

3.8.1 Respondent comments

On commenting on “knowing what will happen rather than what might happen”, two respondents explicitly indicated that (while such a state might be desired) it is recognised to be an impossibility with respect to the operations of their organisation.

> *“…we wish to know what will happen but that´s absolutely uncertainly.”*

> *“I believe is impossible to know what will happen, in an appropriate time span.”*

With regard to information preferences, three respondents commented on the statement regarding the wish to receive information in a form that facilitates Yes/No responses. One indicated that while they used this form of information, it was not the only form used:

> *“…we do not constrain ourselves to using that kind of info only. So we also appreciate other types of information.”*

Another indicated that while this format might be desired: *“…forest related decisions seldom are in such a situation.”*

One respondent in climate services indicated that they were responsible for translating data into such a format.

> *“Our job is to interpret all the available information (with confidence intervals) so as to synthesize it ourselves into a Yes/No decision.”*

Another comment from a climate services respondent indicated that, in the context of their work, trade-offs between false alarms and failed detection would depend on individual clients. Another, also in the climate services sector, mentioned that they would like to receive:

> *“Data or products allowing models performance evaluation at local/regional scale”*

Amongst those respondents who opted to comment on these questions, some made general assertions about how their organisations utilised data in risk management. One respondent indicated that when it came to risk *“heavy tails matter”* and stressed the importance of not underestimating dependencies. Another respondent asserted that within their organisation risk analysis was *“made under the consideration of severity and probability to occur”.*

3.8.2 Approach to uncertainty by sector

Responses to the 11 questions regarding organisational approach to uncertainty were examined on a sector-by-sector basis (see Appendix I for a full descriptive report). Owing to the small number of respondents per sector, caution should of course be exercised when drawing inferences from these findings (especially in the case of tourism where n = 4). However, notable patterns of response do emerge.

With the exception of forestry, a majority of respondents in each sector agreed that their organisation planned for rare yet severe events; with those in the water sector indicating the highest overall level of agreement. Consistent with this, forestry was the only sector for which a majority agreed with the statement: *"We don't tend to focus on events that have a very low chance of occurring"* (although a majority of respondents in energy and tourism agreed that their organisation tended to focus on those events that were most likely to occur). When it came to worst case weather and climate scenarios however, there was general agreement across all sectors that respondent organisations felt it important to consider these; with 100% of respondents from energy and health agreeing or strongly agreeing.

Sectors varied in the degree of "in-house" risk analysis and data processing conducted. All energy sector respondents indicated that their organisation did its own risk modelling, with 67% also indicating that they had clear guidelines as to how much statistical confidence was required before action could be taken. A majority of those in the water sector and half of those in the health sector indicated that they did their own risk modelling (though few indicated that guidelines about statistical confidence existed within their organisations). Across all sectors only a minority of respondents indicated that, when it came to weather and climate information, their organisation just needed raw data. Agreement was however relatively strong amongst water sector respondents, with 40% indicating that this was the case for their organisation.

Across all sectors a majority of respondents indicated that time pressure meant that their organisation had to make decisions before they had all the information they would like. With respect to information format, all energy respondents, and most water and forestry respondents indicated a wish to receive information in a form that facilitated Yes/No decisions. Amongst those in the health sector however only one respondent (17%) indicated a wish to receive information in this form. This may reflect differences in the type of decision made by those in different sectors.

Tolerance for false alarms was greatest within the health sector, consistent with adoption of a precautionary approach to potential hazards. Elsewhere however, tolerance for false alarms varied heavily within individual sectors.

3.8.3. Discussion

Responses to the questions regarding approach to uncertainty tended to be consistent. Those who indicated concern regarding rare yet severe events and worst case scenarios, disagreed that their organisation primarily focussed on low likelihood events (although a majority respondents indicated that their organisation tended to focus on those risks most likely to occur). The fact that proportionally few respondents agreed with the statement *"We need to know what will happen, not what might happen"* suggests that most organisations have some acceptance of uncertainty. However, the marginally-significant association

between agreement with this statement and stated wish to receive information in a format that facilitates Yes/No decision making, may suggest that – when designing methods of communicating uncertainty – care needs to be taken to avoid creating the illusion of certainty.

When it came to information use, a majority of respondents across sectors agreed that time pressure limited the amount of information that they were able to consider when making decisions. From an uncertainty communication perspective, this would seem to underline the need to provide information in a manner that can be quickly interpreted and utilised. The marginally significant association between agreement that time pressure limited information use and desire to receive information in a form that facilitated Yes/No decision making, could point to a desire to simplify choice due to time pressure. However, it is also possible that correlation reflects sectoral differences in preference and the types of decision being made. Those in the water and energy sectors indicated both high agreement with the notion that time pressure was a limiting factor on information use and widespread preference for receiving information in a form that facilitates Yes/No decisions. Those in the health sector meanwhile unanimously agreed that time pressure meant that they sometimes had to make decisions without all the information they would like, but did not on the whole demonstrate a clear preference for receiving information in a form that facilitates Yes/No decision making.

Sectoral differences were also apparent when it came to risk analysis within organisations. All respondents from the energy sector indicated that their organisations did its own risk modelling, with most indicating that their organisation had clear guidelines as to the amount of statistical confidence required for decision making. This high degree of formalisation was not as widely present amongst those in other sectors; although a majority of those in water and half of those in health indicated that their organisations did their own risk modelling. Those in the water sector were however the most likely to indicate that their organisation just wanted raw data (40%), with few in the other four sectors agreeing. Hence, while many organisations indicated that they did their own risk modelling, a clear majority indicate a desire for some form of processing and interpretation.

Tolerance for false alarms varies considerably both within and between sectors. Consistent with a higher focus on precautionary measures, health sector respondents demonstrated widest within-sector agreement that a greater number of false alarms could be tolerated if it meant that more extreme weather events were detected in advance. Amongst other sectors however, a more mixed picture emerged, indicating a need to consider tolerance for false alarms on an organisation by organisation basis when constructing communications.

Key Points: Approach to uncertainty

- Most respondents indicated that time pressure meant that decisions sometimes had to be taken before they possessed all the information they might like. This underlines the need for information to be presented in a manner that can be quickly and easily interpreted.
- A majority of respondents indicated that their organisation is concerned with rare but severe events, and worst case weather and climate scenarios; as opposed to disregarding events with a very low likelihood of occurring. However a majority agreed that they were more concerned with those events most likely to occur.
- While it was relatively common for organisations to do their own risk modelling, few respondents indicated that, when it came to weather and climate, their organisation just wished to receive raw data. Although it should be noted that a sizeable minority of water sector respondents indicated that this was the case.
- Preference for information formats that facilitated Yes/No decision making was generally strong amongst those in utilities (energy and water) but not health.
- With the exception of the health sector, where a precautionary approach to risk is in evidence, tolerance for false alarms varies within sectors.

3.9. Data preferences

3.9.1. Current use of data presentation formats

As previously stated, when asked whether they used statistical or information in their day-to-day work the majority of respondents (83%) indicated that they did. A majority indicated that they were comfortable using measures of spread and/or basic statistical tests. Indeed, the educational background reported by respondents indicates that a majority of the sample did have some form of scientific or technical background. Those who indicated that they used statistical information in their day-to-day work were asked what kind of numeric or statistical information they used. Figure 11 below details the overall proportion of respondents who reported using six types of statistical/numeric information (note that those who stated that they did not use statistical or numeric information in their day-to-day work were not presented with this question). As one can see, amongst those reporting that they used statistical/numeric information in their day-to-day work percentages (82%) and measures of averages (82%) were the most commonly used form of information, followed in order of prevalence by measures of spread (76%), frequency counts (74%), and exceedance thresholds (68%). Fewer reported using probability distributions (61%). Although the overall proportion of respondents using the latter form of information was still relative high, this indicates that – as one might expect – measures of averages are more commonly used than full probability distributions. A McNemar test indicated that this difference in rate of usage was statistically significant ($p < .05$).

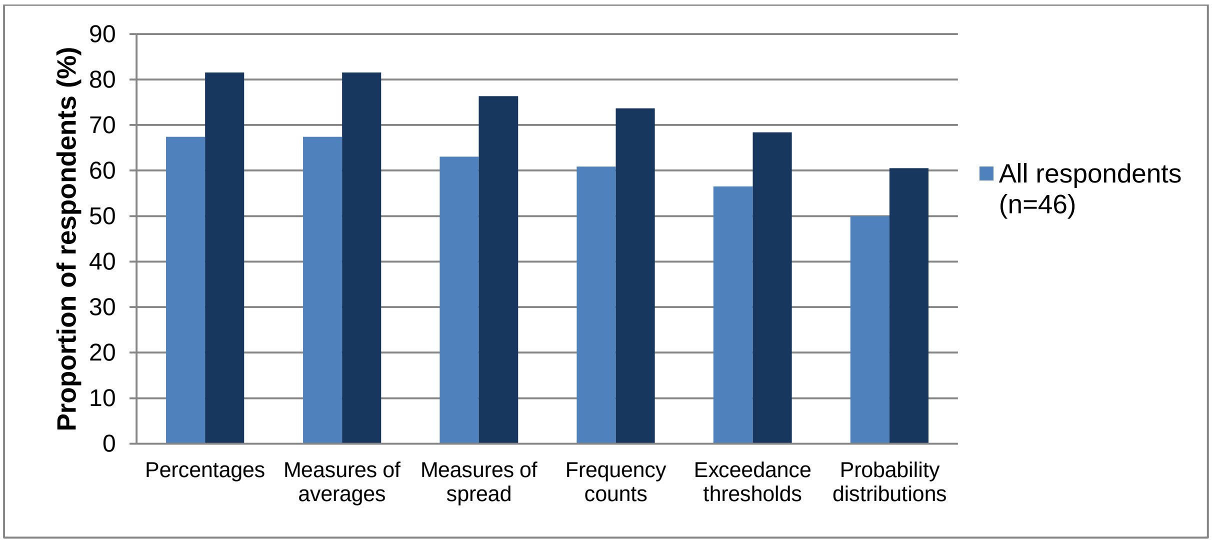


Figure 11 Proportion of respondents reporting that they use specific types of statistical/numeric information in their work.

3.9.2. Numeric representations of uncertainty

Respondents were asked whether they would prefer to receive likelihood information in the form of percentages (“30% chance of rain”), frequencies (“3 in 10 chance of rain”), standardised probabilities (“.3 chance of rain”), or another (“other”) representation. **An overwhelming preference for percentage representation was demonstrated**, with 39 out of 46 (85%) choosing this alternative. Of the remainder, 3 (7%) selected the frequency format, 1 selected the standardised probability format (2%), while 3 (7%) chose “other”. Of

the three "other" responses, one respondent indicated that they had no preference and that any of the representations would be acceptable; one stated that they would prefer the information to be presented as *"70% chance of it not raining"*; and one indicated that they would wish to have more information *"Expected rainfall per 24 hours in mm with upper and lower CI"*.

3.9.3. Visualising uncertainty

Respondents were presented with seven methods of visualising uncertainty: bar graph, pie graph, error bars, fan graph, spaghetti graph, map, and a graph representing terciles in bar graph form (i.e. proportion of model simulations predicting above average, average, and below average monthly values). Six of these visualisations were based on the same underlying data, a hypothetical seasonal streamflow forecast comprising 28 model simulations. The map however was taken from an example of seasonal temperature forecast for Europe. Full illustrations of these visualisations can be found in Appendix II. For each visualisation respondents rated their agreement with six statements on a five point scale going from 1) "Strongly disagree" to 5) "Strongly agree". A rating of 3 represents "Neither agree nor disagree" and thus indifference.

1. *"This type of graph/map is useful"*
2. *"I would use this type of graph/map in my decision making"*
3. *"I would share this type graph/map with a colleague, for them to use in their own decision making."*
4. *"This graph/map is easy to understand"*
5. *"I like this graph/map."*
6. *"I use graph/maps like this in my work."*

Figures 12 to 17 below details respondents' mean level agreement with each statement for each visualisation, along with 95% confidence intervals.

1. *"This type of graph/map is useful"*

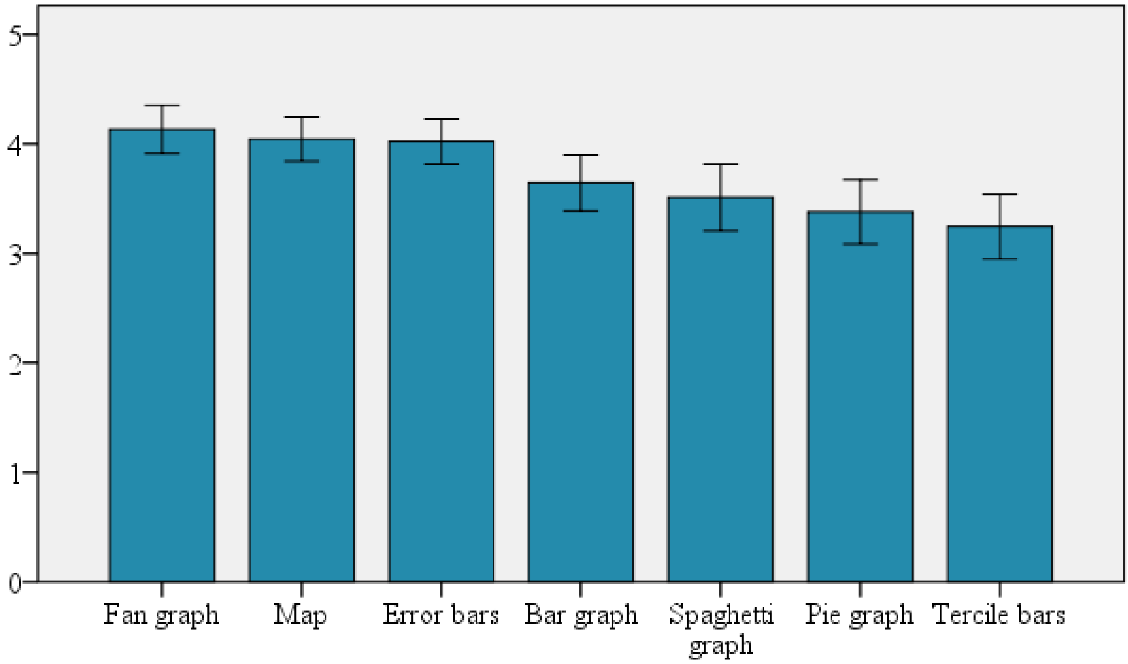


Figure 12 Mean agreement with the statement: "This type of graph/map is useful" (n = 45)

2. *"I would use this type of graph/map in my decision making"*

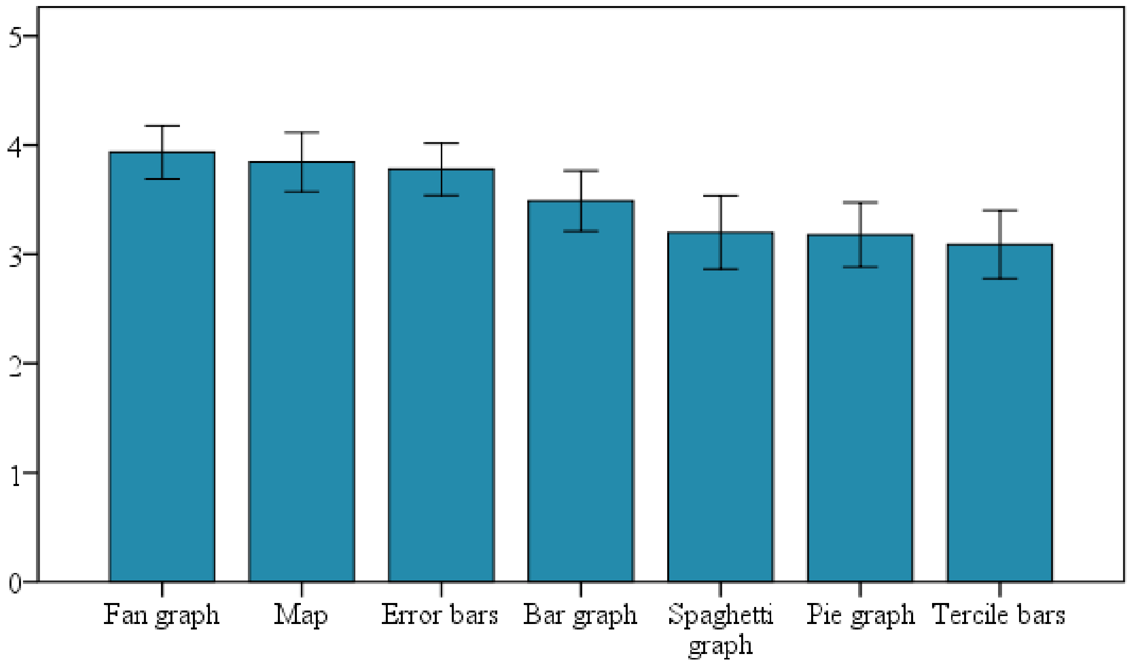


Figure 13 Mean agreement with the statement: "I would use this type of graph/map in my decision making" (n =45)

3. *"I would share this type graph/map with a colleague, for them to use in their own decision making."*

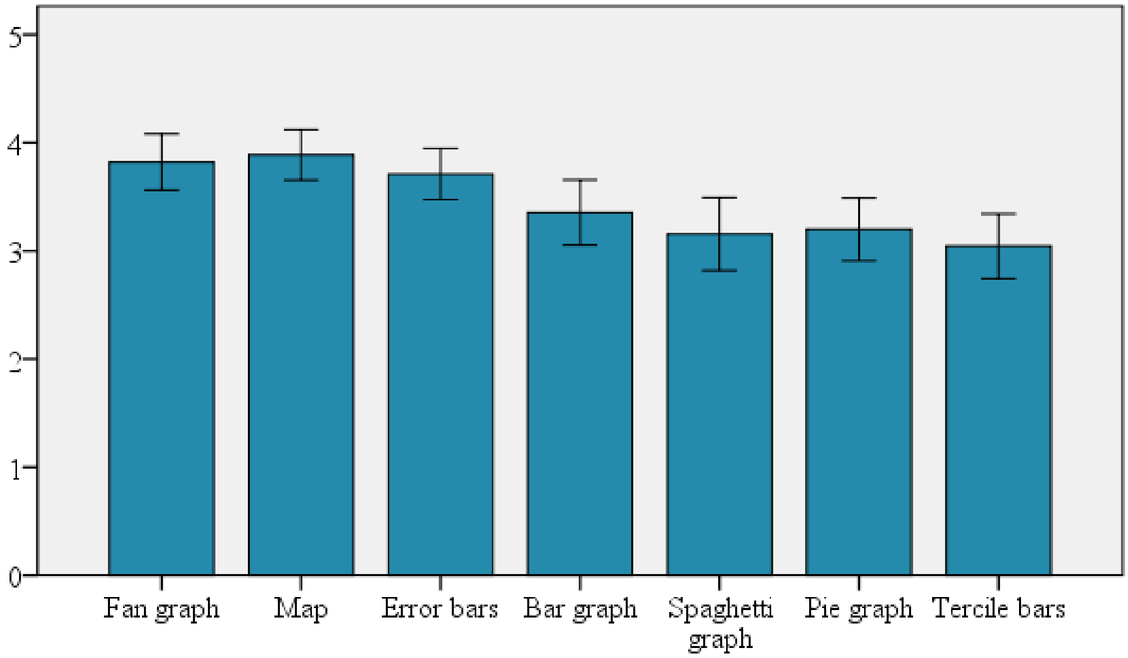


Figure 14 Mean agreement with statement: "I would share this type graph/map with a colleague, for them to use in their own decision making." (n =45)

4. *"This graph/map is easy to understand"*

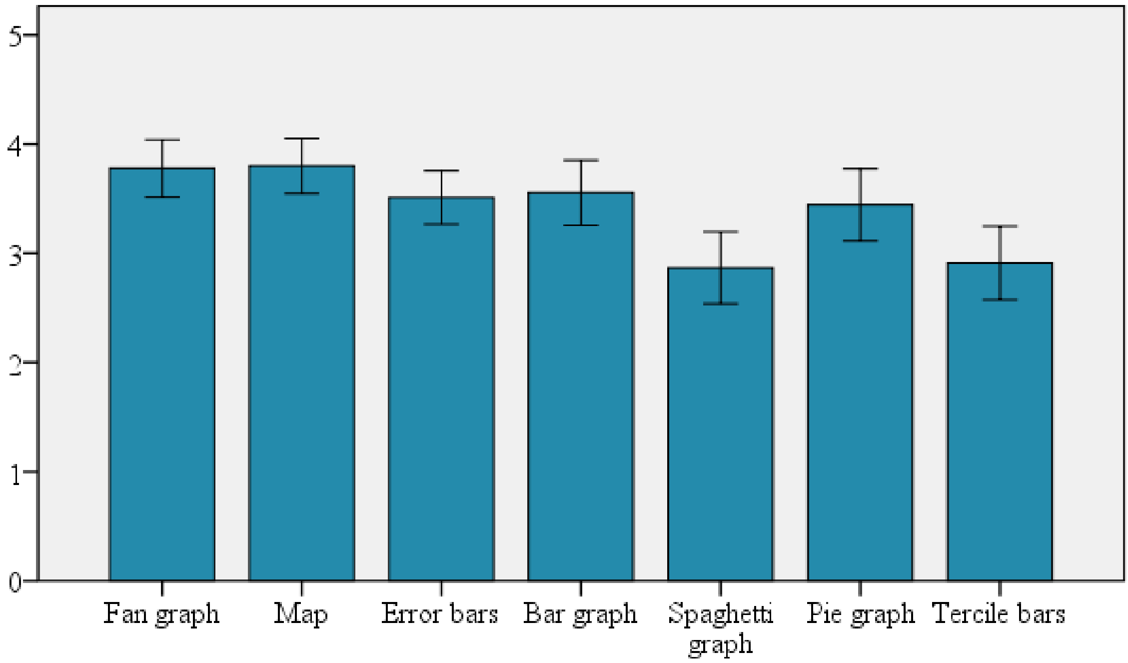


Figure 15 Mean agreement with the statement: "This graph/map is easy to understand". (n =45)

5. *"I like this graph/map."*

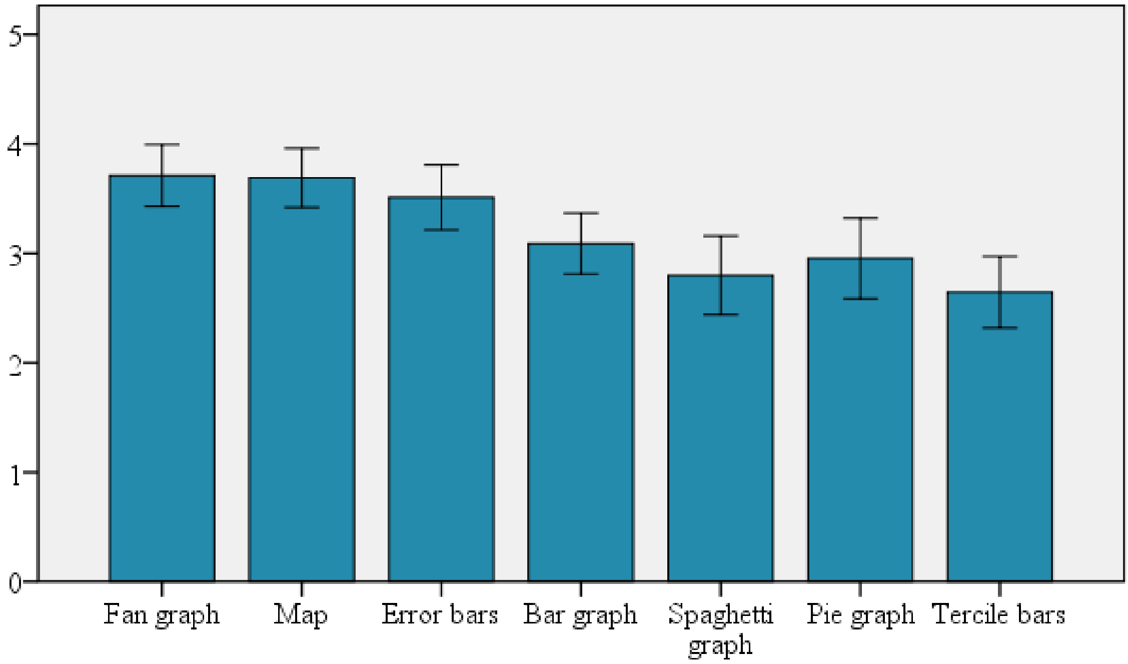


Figure 16 Mean agreement with the statement: "I like this graph/map". (n =45)

6. *"I use graphs/maps like this in my work."*

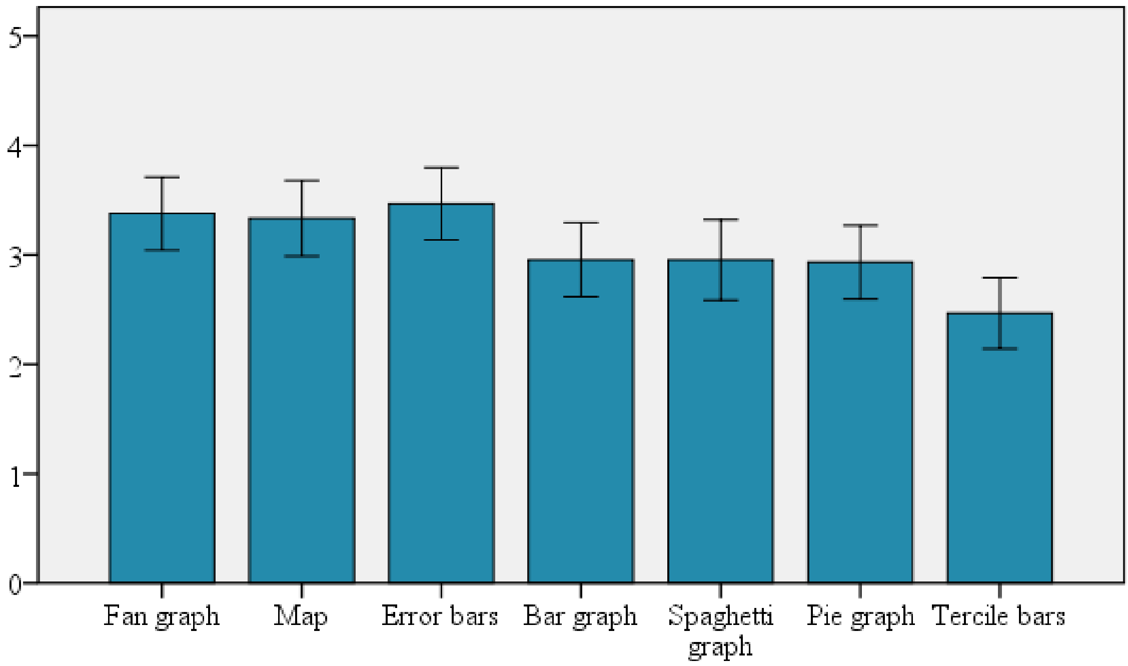


Figure 17 Mean agreement with the statement: "I use graphs/maps like this in my work" (n =45)

Responses to the six statements indicate a general preference for the fan graph, map, and error bars. For all statements, mean rating for these visualisations exceeds the indifference level of 3, indicating greater agreement than disagreement. On average respondents rated these visualisations as more useful, more likely to be used in respondents' decision making, more likely to be shared with colleagues for use in their decision making, better liked, and more likely to be in current use. This suggests that respondents' preferred visualisations tend to be those that they are most widely used.

The tercile bars, pie graph and spaghetti graph were the least favoured alternatives on usefulness, willingness to use oneself, willingness to share and likeability, with the bar graph occupying an intermediate position. When it came to agreement with the statement *"I use graphs/maps like this in my work"* all four fell below indifference level.

With regard to the statement *"This graph/map is easy to understand"*, the map and fan graph, received the greatest level of agreement. They were followed by the bar graph, error bars, and pie graph, which received similar ratings. The spaghetti graph was rated as the least easily understandable, followed by the tercile bar.

Intercorrelations between levels of agreement with the five statements regarding preference were high for each individual visualisation (see Appendix III), supporting the notion that the statements were 'tapping into' an overall measure of general favourability. Correlations with the statement regarding current use of visualations tended to be weaker (though still strong overall). A series of Cronbach's alpha tests were used to assess whether ratings on the five preference statements could be used to form an internally consistent summary score of 'favourability' for each of the visualisation. This was indeed found to be the case. For all seven visualisations, Cronbach's alpha exceeded .8, indicating high internal consistency. Summary scores for favourability were then calculated for both current self-reported users of seasonal-to-decadal climate information and non-users (see Table 8).

Table 8: Mean favourability rating (standard deviation in brackets) of each type of visualisation amongst users and non-users of S2D climate information, along with correlation between favourability and comfort with statistics

	Current S2D climate information users (n = 32)	All others (n = 13)	Overall	Correlation with statistical comfort rating (ρ)
Map	4.0 (.6)	3.7 (.9)	3.9 (.7)	-.22
Fan graph	4.0 (.8)	3.6 (.7)	3.9 (.7)	.24
Error bar	3.9 (.6)	3.3 (.6)	3.7 (.7)	.38**
Bar graph	3.5 (.8)	3.3 (.9)	3.4 (.8)	.26
Pie graph	3.3 (.9)	3.1 (1.0)	3.2 (.9)	-.21
Spaghetti graph	3.2 (.9)	2.8 (1.0)	3.1 (1.0)	-.02
Tercile bar	3.1 (.9)	2.6 (.9)	3.0 (.9)	.08

Significant at .1   * Significant at .05

As one can see, the map and fan graph received the highest favourability rating followed by the error bars. This same pattern was in evidence for both current users and other respondents. While mean rating amongst non-users and those who were uncertain as to whether their organisation used S2D was lower for all visualisations, a multivariate ANOVA revealed no significant difference ($F(7, 37) = 1.26$, $p = .30$). Given the small number of respondents in the non-user group this is however perhaps unsurprising.

The table also details the association between overall favourability rating and comfort with using statistics. Comfort with statistics was positively associated with favourability rating for the error bar, fan graph and bar graph (though the association only reached $p < .05$ for the error bar). It was also negatively associated with favourability ratings for the pie graph and map; though in these cases the correlation was non-significant at the .05 level ($p > .1$).

Table 9: Correlations between favourability score for each type of visualisation (Pearson's r)

	Pie graph	Error bar	Fan graph	Spaghetti graph	Tercile bar	Map
Bar graph	.08	.23	.05	.29*	.25	-.22
Pie graph		-.19	-.16	.18	.64*	.20
Error bar			.47**	.26	.05	.11
Fan graph				.34*	.08	.11
Spaghetti graph					.34*	.24
Tercile bar						.37*

*Significant at .05 **Significant at .01

The intercorrelations between favourability ratings for each form of visualisation (see Table 9 above) show a strong association between rating for the error bar and fan graph: demonstrating that those who liked one representation of spread liked the other. It is also notable that preference for the tercile bar associated strongly with preference for the pie graph; possibly indicating that rating of these representations reflects attitude towards using discrete proportions (rather than spread) to represent likelihoods. The positive association between rating of the map and tercile bar may reflect preference for (or against) the representation of values as average, above average and below average in general.

3.9.3.1 Respondent comments on visualisations

Bar graph

One respondent indicated that they were uncertain as to how model simulations were being incorporated, indicating that they found the format unclear. Another commented that the x-axis should read *"Predicted river flow (m3/s)*" (as oppose to simply River flow (m3/s). The respondent reiterated this when presented with the error bar visualisation.

Pie graph

While this style graph was relatively unpopular amongst the sample as a whole, only one respondent commented. Their comment (below) indicates that they felt that the graph was non-intuitive, in terms of the use of colour and the positioning of the categories. A desire for cumulative information was also expressed.

> *"Colours do not represent the risks. The hierarchy is not obvious to understand (from right to left). Need of cumulative information but it can be derived from the graph"*

Error bars

As mentioned above, when presented with this visualisation one respondent reiterated the need to use the phrasing *"predicted river flow"* rather than "river flow" regarding the wording of the axis. One other comment was received for this visualisation in which the respondent indicated that while they found this graph more informative than the preceding bar graph and pie graph, they would like to have information about threshold exceedance.

> *"More information is displayed even though we would like some information about probabilities/frequencies over given thresholds for a given month."*

Fan graph

Response to this form of visualisation was generally positive. However, the lack of absolute minimum and maximum values (100% confidence interval for the 28 simulations) was critiqued, as was the fact that it was *"difficult to read the real values associated with the probabilities"* (suggesting that the y-axis did not contain sufficient detail). Other respondents commented on the tightness of the prediction *("I am surprised by the tight confidence limits of the prediction"*); with one expressing a concern that the graph could lead people to underestimate the amount of uncertainty in the prediction:

> *"The graph seems easy understandable, but I think that it could mislead the user to underestimate the uncertainty as it looks like a typical 14 day forecast"*

This is perhaps the result of the scaling of the graph (giving the impression of very narrow confidence levels as a consequence of a sharp increase on the y-axis) and the fact that 95CI was used (rather than displaying the absolute minimum and maximum for the 28 simulations)

Spaghetti graph

When presented with the spaghetti graph two respondents indicated that while all information was provided, it was "messier" and more difficult to interpret than the preceding fan graph.

> *"A bit more messy than the earlier, but more information. Which to prefer depends on what information is needed"*

> *"Too much information to be interpreted. However, everything is displayed and available. No information is lost."*

Tercile bars

Overall the tercile bars were the least favoured of the 7 visualisations. One respondent commented that they would prefer the information to be presented as *"3 bars side by side for each month"*. Such a change would perhaps mean that it would be easier to identify the precise proportion of simulations that predict below average, average, and above average values. Another respondent suggested that while such a visualisation might be suitable for

presenting some variables such as temperature and precipitation, it may not be useful for river flow management as it cannot be related clearly to thresholds:

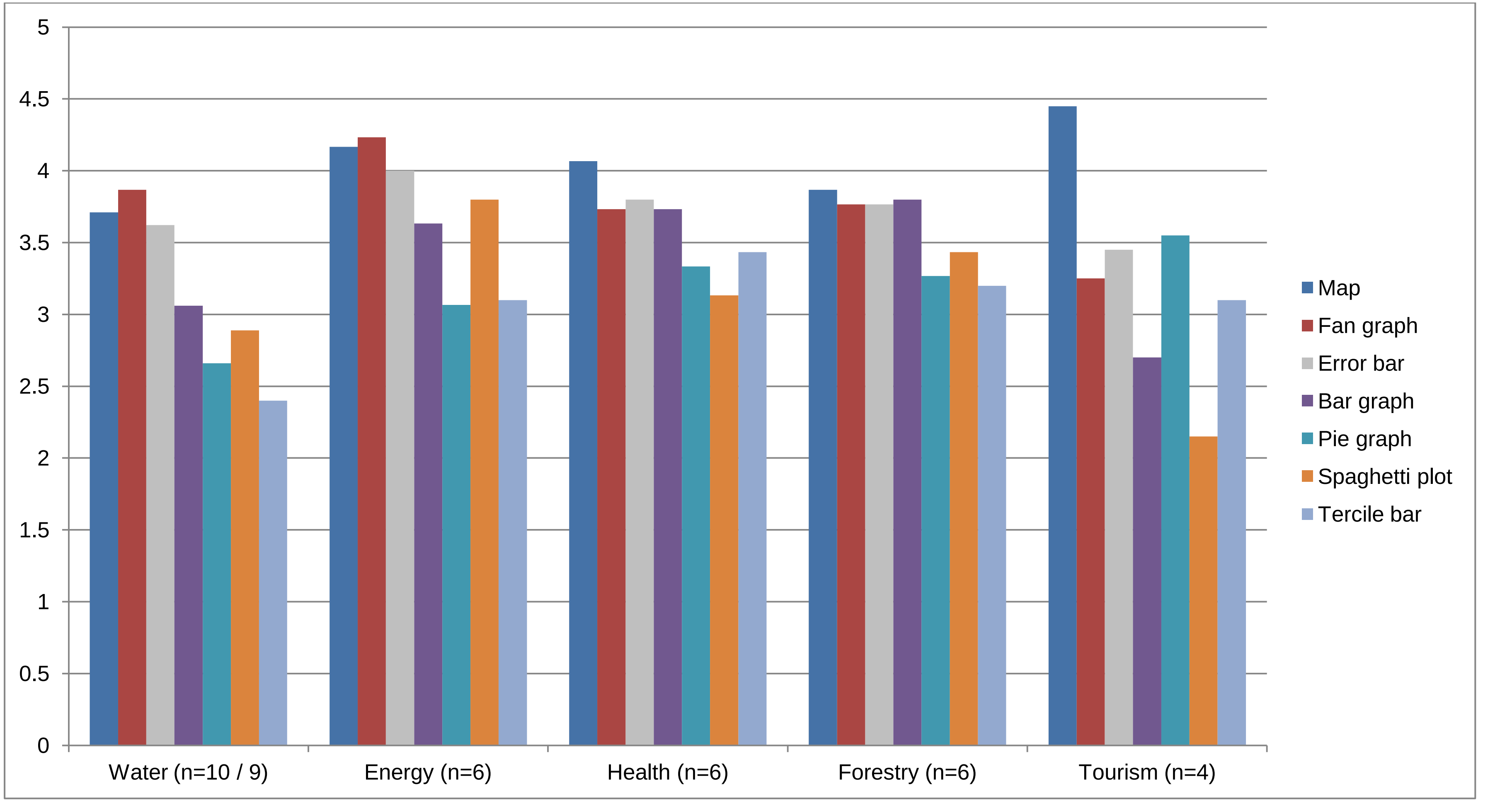
> *"Useful for seasonal temperature/precip forecasts. Means might not be useful for river flow risk management (flows exceeding given thresholds)."*

Map

Of the comments made with respect to the map, most mentioned the use of colour. One respondent indicated that the use of blue may be interpreted to mean that temperatures are predicted to be cooler than normal (rather than 'low likelihood of temperatures being within the upper tercile'). Two respondents commented on the use of the colour 'white': one, stating that they felt that the middle 50% should be contained within the white banding; another, that they did not like the use of white in this manner as they associated it use with missing data. It was also remarked that it was *"impossible to see the difference in colour between the 24-33 bracket and the 33-42 bracket."* While the map was the most popular of the visualisations, these comments indicate that the use of colour can easily be perceived as 'counterintuitive', likely depending on how colours are typically used in one's own field/specialism.

With respect to other characteristics of the visualisation, one respondent felt that it was a "Good idea to represent smaller values/greater values with smaller/bigger boxes" on the legend. Another stated that *"a 3-category map is much simpler"*, suggesting that some may feel that this style of map has too much detail.

3.9.3.2 Visualisation preference and familiarity by sector



.Figure 18 Overall **favourability rating** by sector. Rating represents mean agreement with five statements regarding visualisation preference. Level of agreement was rated on a scale of 1 (strongly disagree) to 5 (strongly agree) with 3 representing indifference level (neither agree nor disagree). Higher ratings denote stronger preference for visualisation.

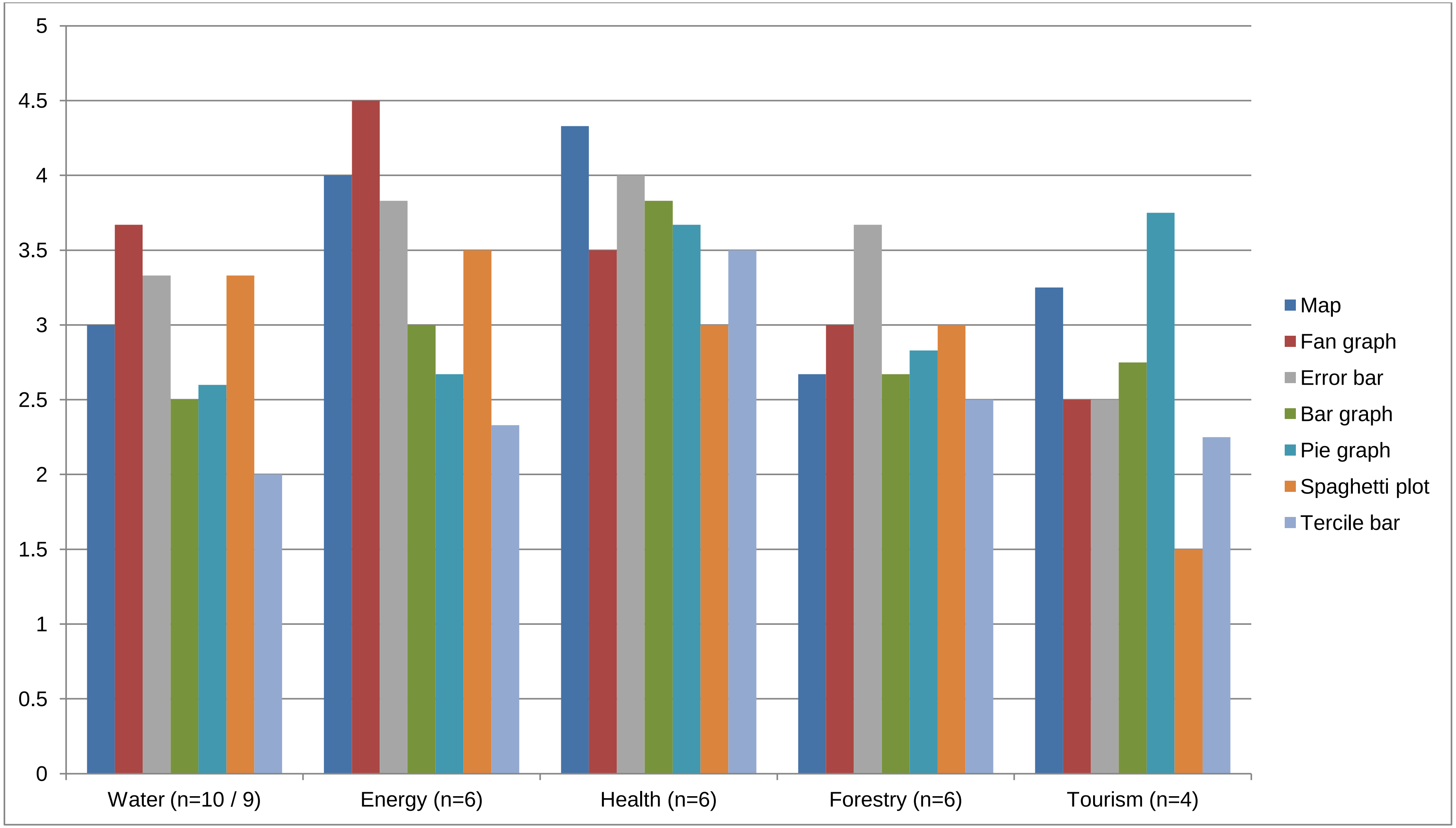


Figure 19 Average rating of **current use** by sector. Ratings represent level of agreement with the statement "I use graphs/maps like this in my work". .Level of agreement was rated on a scale of 1 (strongly disagree) to 5 (strongly agree) with 3 representing indifference level (neither agree nor disagree)

As one can see from Figure 18 above, of all the visualisations presented, the map received the highest average favourability rating by those in three out of five sectors (health, forestry and tourism); with those in the tourism sector rating it most highly. Amongst those in the water and energy sector the fan graph was rated most highly. Error bars were also highly favoured. Interestingly, while the water and energy sector demonstrated an almost identical order of preference, those in the water sector gave a much lower mean favourability rating

Amongst respondents from the tourism sector, the pie graph, fan graph and error bars all received a similar favourability rating. However, all were rated considerably less favourably than the map

The tercile bar received the lowest average favourability rating amongst those in the water, energy, and forestry sectors, followed by the pie graph. Amongst those in the health and tourism sectors however the spaghetti plot received the lowest rating. Of all of the visualisations the spaghetti plot was the most polarising, receiving a relatively high rating amongst those in the energy sector and the lowest rating of all in the tourism sector.

If one compares respondents ratings of current use (i.e. respondents indication of whether they presently use the types of visualisation presented in their work) in Figure 19 to overall favourability rating, one can see those visualisations rated most favourably tend to be those that respondents report themselves to be using. Of course, when comparing sectors in this manner it should be kept in mind that a) the overall number of respondents in each group is relatively low; and b) some sectors had more respondents than others. Hence, the greater difference between average ratings of visualisations in the tourism sector may be the result of their being fewest respondents in this sector. However, it is worth noting that when mean statistical comfort was examined on a sector-by-sector basis those in the tourism sector had a far lower average rating (M = 1.3, sd =.5) than those in other sectors (*Water*: M = 2.1, sd = .7; *Energy*: M = 2.0, sd = .6; *Health*: M = 2.2, sd = .4; *Forestry*: M = 2.0, sd = 0). As a rating of 2 corresponds with comfort using measures of spread and/or basic inferential statistics this may account for the fact that the fan graph and error bars were less favoured by respondents in this sector.

3.9.4. Use of other likelihood representations

After rating the seven visualisations, respondents were asked to indicate whether or not they had ever used various ways of representing likelihood in their work. Responses are detailed in .Figure 20. Numeric tables, maps, bar graphs and histograms were those most widely used, with 80% of respondents indicating that they had used them at some point. More complex forms of representation such as spaghetti graphs, probability density functions and cumulative probability density functions were the least widely used. However, only cumulative probability density functions were reported to have been used by less than 50% of respondents.

Table 10 below details mean rating of statistical comfort for those respondents who responded “Yes” or “No” when asked if they had ever used each of the information formats listed. For error bars, probability density functions and spaghetti plots statistical comfort was significantly lower amongst those who had not used these forms of representation in their work than those who had. As a rating of 2 on the statistical comfort scale denotes comfort with using measures of spread and probability density this is perhaps unsurprising. However,

it underscores the point that those with lower familiarity with such measures may be less inclined to utilise them.

Table 10: Mean rating of statistical comfort for those who have and have not used the listed forms of communicating confidence and uncertainty in their work

	Yes		No	
	n	Mean (sd)	n	Mean (sd)
Numeric tables	43	1.9 (.6)	2	1.5 (.7)
Bar graphs	39	2.0 (.6)#	6	1.5 (.5)#
Pie graphs	34	1.9 (.6)	11	2.0 (.7)
Histograms	38	1.9 (.6)	7	1.9 (.7)
Maps	41	2.0 (.6)	4	2.0 (.8)
Error bars	33	2.1 (.6)*	12	1.6 (.5)*
Probability density functions	26	2.1 (.6)*	19	1.7 (.7)*
Cumulative density functions	20	2.1 (.6)	25	1.8 (.6)
Spaghetti graphs	25	2.1 (.6)*	20	1.8 (.6)*

Difference significant at .1 (Mann-Whitney U test) *Significant at .05

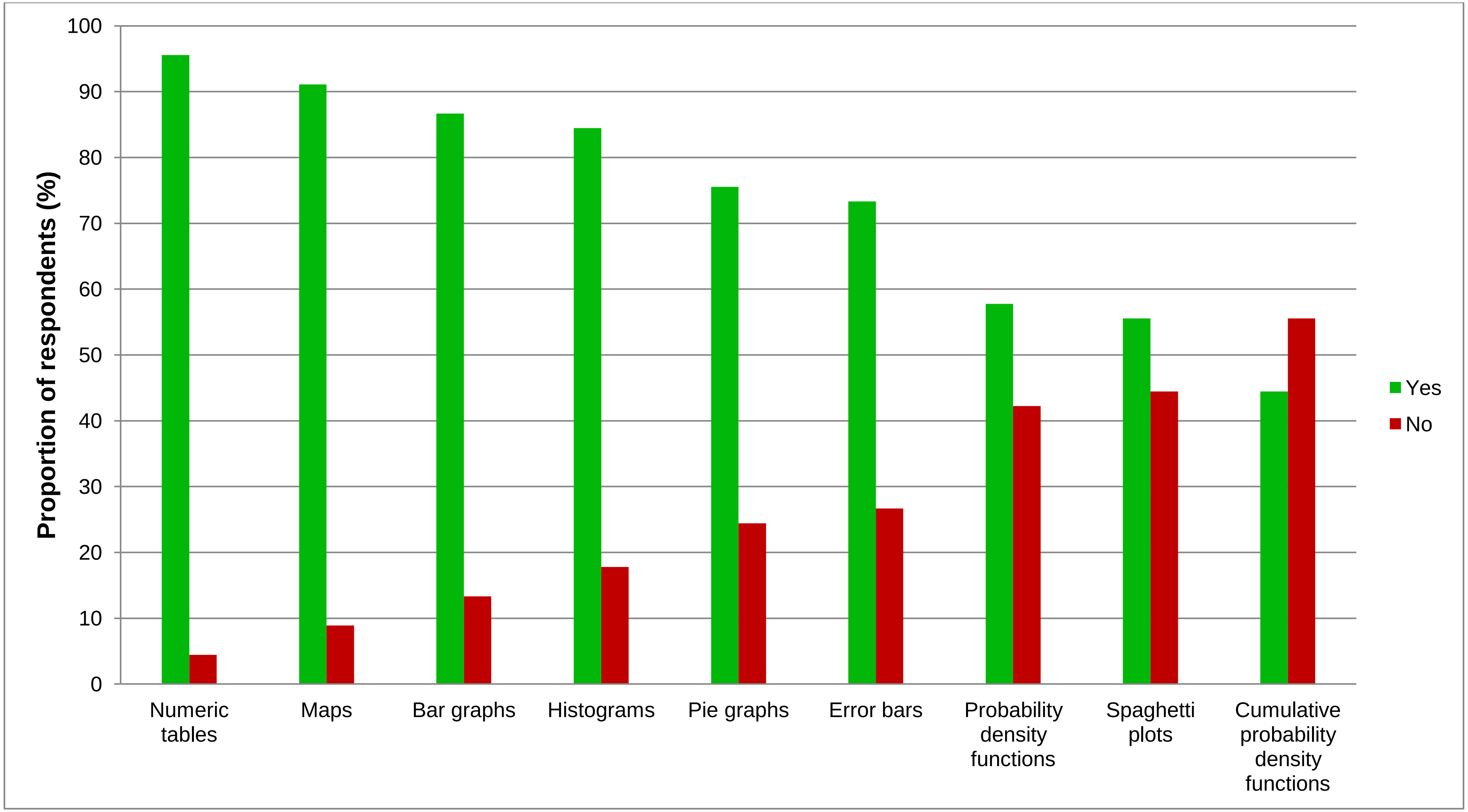


Figure 20: Proportion of respondents (n = 45) who report having made use of each of the listed methods of representing information about likelihoods in their work at some point.

3.9.5 Ideal information format

At the end of the section on information preferences respondents were presented with the following optional question:

"If you were completely free to choose how you received information about uncertainty in the climate or climate impacts your organisation is interested in what would you choose?"

In total 13 members of the sample opted to respond to this question. The detail provided varied, with some respondents listing information types and others describing them in more detail. Of the 13 respondents who opted to respond to this question 7 indicated that they wished to receive information in multiple formats.

The frequency with which specific forms of information presentation were mentioned are summarised in Table 11 below. As one can see maps were mentioned most frequently; while probability density functions/cumulative density functions, measures of spread (confidence levels or standard deviations), numeric tables and raw data were mentioned by two or more respondents. Two respondents simply stated that they felt that multiple information formats were useful, while another two emphasised the importance of simplicity. Other forms of information mentioned included past/future trajectories for parameters (with the respondent stating a preference for this to be accompanied by PDF where possible), and ensemble means and standard deviations

Of the 5 respondents who mentioned maps, 4 also mentioned other forms of representation, suggesting that while maps are generally well liked, they tend not to be the only format needed/wanted. Two respondents described the type(s) of map preferred. One wanted maps to show *"both average and extreme values"*. The other mentioned maps illustrating probabilities of temperature threshold exceedance or *"upper terciles, quintiles, etc."*

Table 11 Frequency with which types of information format were referenced in response to prompt to describe ideal way of receiving information about uncertainty with respect to climate or climate impacts

Format	n
Maps	5
Error bars	3
Probability density functions/cumulative density functions	3
Numeric tables	2
Raw data	2
Percentages	1
Past/future trajectories	1
Multiple formats (unspecified)	2
Simplicity (unspecified)	2

3.9.6 Discussion

As previously mentioned, the majority of respondents taking part in the survey indicated that they had a technical role and/or background. Hence it is unsurprising that a clear majority indicated that they had used measures/visualisations of spread (e.g. confidence levels, standard deviations) in their work at some point (though fewer reported using probability density functions and cumulative density functions). Of the hypothetical streamflow graphs presented, those visually depicting measures of spread via confidence levels (i.e. the fan graph and error bars) were rated most favourably overall. The fact that these types of graphs tended to be rated less favourably by those reporting lower levels of comfort with statistical information may however suggest that information recipients without a statistical background may find them more difficult to interpret and utilise.

When it came to visualisations in general, maps emerged as the most frequently used and favourably rated form of representation. However, while the seasonal temperature map was favourably rated on the whole, critical comments were made about the use of colour. These indicated that some found their use confusing (e.g. blue being use to denote lower probability of temperature being in the upper tercile rather than ‘coolness’) or different to common usage within their own field (e.g. white being used to indicated a moderate likelihood rather than missing data). When considering the development of methods of communicating uncertainty this highlights the importance of trying to avoid counterintuitive uses of colour. Although, of course, it may be impossible to produce a coding scheme consistent with the use of colour across all specialisms.

As well as receiving the joint-highest favourability rating, maps were also the most frequently referenced format when respondents were asked to detail their ideal representation. It should be kept in mind however that the majority of those who opted to respond who responded to this question listed multiple forms of representation (or mentioned that they would like multiple forms of representation without detailing specific formats), indicating that one single format is unlikely to good enough for many users.

The pie graph and tercile bar, both of which represented likelihoods with area covered, were the least favoured representations overall. Comments on these graphs indicated that such representations may not be useful for those requiring thresholds to be demarcated, and that the use of colour on the pie chart was not intuitive (i.e. did not indicate a clear progression). It is though notable that there was a strong positive correlation between the favourability ratings for these two visualisations. Those who favoured one format tended to favour the other and vice versa. This could reflect a preference for the use of proportion/area to represent likelihood. Alternatively, it may reflect familiarity (those who use one form more frequently use the other). It is worth noting that, on the whole, there was a high degree of correspondence between how much respondents favoured particular visualisations and whether they currently utilised them in their work. This could indicate that people tend to seek out those visualisations that they find most useful. However, it may also suggest that people tend to like those representations that are most familiar.

With regard to sectoral differences, the results detailed in 3.9.3.2 indicated a similar (though not identical) preference order across water, energy, health and forestry. Overall, water sector respondents tended to assign visualisations lower ratings than those in other sectors. Due to the small sample size firm conclusions cannot be drawn on this point. However, it is possible that lower ratings on the part of respondents in this sector may reflect unfavourable comparisons with visualisations currently in use with respect to streamflow. It is also possible that the lower preference for measures of spread (i.e. error bars and fan graph) amongst those in the tourism sector is a result of lower average comfort with more complex statistical information.

Key Points: Data preferences

- When it comes to numeric representations of likelihood percentages are widely preferred to frequencies and standardised probabilities.
- Of the seven visualisations presented the map was the most highly favoured, followed by representations of spread (i.e. the error bar and fan graph).
- Respondents tended to like those visualisations with which they were most familiar.
- Preference for representations of spread was associated with greater comfort with statistical information, indicating that – while generally favoured – such representations may be more difficult for less statistically experienced users to utilise. This was reflected in respondents' current information use.
- While the map was generally well liked some respondents critiqued the use of colour; thus highlighting the importance of ensuring that colour-schemes are not counterintuitive.

3.10. General discussion

This survey was undertaken to address the following questions:

How do current users of seasonal-to-decadal climate information perceive the accessibility, understandability and usefulness of this information, and how does this differ from perceptions of other types of climate information (and uncertain information more generally)

What forms of information about confidence and uncertainty in seasonal-to-decadal climate forecasts do present users currently obtain, and what forms of information would they like to receive that they currently do not?

How do respondent organisations approach uncertainty?

When it comes to receiving information about uncertainty, what formats do respondents prefer. Is this associated with format familiarity and comfort with statistics?

Accessibility, understandability and usefulness

Our results indicate that all forecasts were rated as being more useful than they were accessible or understandable. However, this is especially pronounced for information at a seasonal-to-decadal timescale. Across all forecasts ratings of accessibility and understandability were strongly correlated, demonstrating that those who found forecasts easier to obtain also tended to find them easier to understand. This may reflect level of expertise (those who find information easier to interpret know where to obtain it) and/or greater familiarity. Interestingly however the association between ratings of accessibility and understandability and perceived usefulness was – while positive - far weaker. This suggests that there may be a mismatch between respondents' desire to use information and the ease with which they are able to do so.

With respect to potential differences between sectors, users in the forestry sector rated seasonal climate information as substantially less accessible than those in other areas (though not less understandable or useful). However, as there were only a very small number of current users in this sector, this difference should not be overstated.

Information received and utilised by current users

Amongst respondents currently receiving seasonal-to-decadal climate information, land temperature and rainfall were the climate variables for which information was most commonly obtained. Frequency of use was greatest for forecasts with the shortest lead time (1 – 3 months), and diminished as lead time increased, until the final timescale of 6-10 years, where there was a small upsurge in reported use. This may reflect a switch from short term operational decision making to longer term strategic planning.

With respect to information about uncertainty, the formats most commonly obtained were confidence levels, verbal descriptions of likelihoods, and raw data. In terms of raw data, only one respondent indicated that their organisation did not receive this but would like to; thus suggesting that most of the organisations who wish to receive information in this form already do so. Comparatively few respondents reported that they received information about how well forecasts performed relative to observed climate. However, several whose organisation did not receive this information indicated that they would like to.

Hence, it would seem that a notable proportion of respondents wish for more information about forecast robustness (i.e. skill, accuracy, reliability).

Approach to uncertainty

Most respondents agreed that their organisation planned for rare yet severe events and considered "worst case scenarios", while few indicated that their organisation did not tend to focus on low likelihood events (although a majority prioritised those risks that were most likely to occur). This indicates that most (though not all) respondent organisations are concerned with unlikely but dangerous events and do not focus exclusively on central tendencies and high likelihood events. This underscores the importance of presenting information to these organisations in a form that permits the detection of outliers.

From an information provision perspective, the fact that the vast majority of respondents agreed that time pressure meant that decisions had to be made before they had all the information they would like, highlights the need to present information in a form that can be easily utilised and understood. In some cases this may mean constructing formats that enable fast Yes/No decision making. However, desire to receive information in this form varied between sectors, with a high proportion of respondents from the water and energy sectors favouring this format, and those in the health sector tending to reject it. This is likely to reflect the different types of decision made by organisations in different sectors. Preference for formats that facilitate Yes/No decision making was also associated with low tolerance for ambiguity (as indicated by agreement with the statement: *"We need to know what will happen not what might happen"*). It is perhaps understandable that those with a greater desire for certainty have a preference for taking clear Act/Don't Act decisions. However, this does raise the concern that presenting climate information in a format that facilitates Yes/No decision may create a false sense of certainty.

While the majority of respondents indicated some acceptance of uncertainty (as indicated by level of disagreement with the statement tolerance for the false alarms varied amongst organisations). Around half of respondents agreed that their organisation would be willing to accept more false alarms if it meant a greater number of extreme weather events being detected in advance. This lack of consensus points to a need to incorporate variations in tolerance for false alarms into communications.

Information preference

When asked to describe how they would ideally like to receive information about uncertainty in climate information, most respondents who chose to respond listed more than one format, indicating that multiple methods of communications are desired. When it came to the seven visualisations of uncertainty created or adapted for use in this survey, maps were the most highly favoured. Graphs that represented spread using confidence intervals (error bars and fan graphs) were also popular. On the whole, those forms of information most favoured by respondents were those that they most frequently used; with a strong correlation existing between favourability and frequency of use for all formats. This could suggest either that respondents are better able to use their preferred formats, or that preference results (at least partially) from familiarity.

It is notable that while error bars and fan graphs were the most popular type of graph, preference for the former was correlated with comfort with statistics: meaning that those

comfortable with more complex statistical information tended to rate this format more favourably than those comfortable with less complex statistical information. As previously noted, a majority of this survey's respondents reported having an explicitly technical role and/or a scientific academic background. Hence, if considering how information should be communicated to a broad range of organisations, it should be kept in mind that these information formats may be less highly favoured by those with less statistical experience and/or technical expertise.

While the map was the most highly favoured representation overall, comments made by respondents highlight the need to carefully consider the use of colour. When it comes to the use of colour it may be impossible a representation that is congruent with the colour-schemes and codes used across all fields. However, steps to identify and minimise counterintuitive uses of colour can and should be adopted.

3.11. Implications

The findings of this survey have key implications for Tasks 33.3 (formulation of strategies for communicating uncertainty and confidence levels) and 33.4 (decision lab) of this Work Package:

- The mismatch between perceived usefulness and perceived ease of understanding when it comes to seasonal and interannual/decadal forecasts highlights the need to present information in a manner that better facilitates understanding.
- Amongst those currently receiving climate information at a seasonal-to-decadal timescale a large minority indicated that they did not currently receive information about how well earlier forecasts matched observed climate, but would like to. This – along with certain comments made by respondents in this section of the survey– indicates that the provision of information about robustness needs to be examined. While such information is generally provided with forecasts, our findings indicate that end-users may not always recognise and understand it as such.
- If designing communications for a specific organisation, institutional tolerance for false alarms should ideally be gauged and incorporated into the design. The results of this study indicates that, even within sectors, willingness to trade a greater number of false alarms for a greater number of correct detections tended to vary.
- Formats that facilitate Yes/No decision making appear to be more favoured amongst those in utility sectors (energy and water) than health.
- Amongst those EUPORIAS stakeholders (and other interested organisations) who responded to the survey, maps and measures of spread (i.e. confidence levels) were the most highly favoured form of visualisation. This should be taken into account in Task 33.3. However, it should be noted that those less comfortable with complex statistical information may have more difficulty interpreting measures of spread. While the majority of respondents reported having a technical background and/or high comfort with statistics, a minority did not. Those in the tourism sector, for example, reported lower comfort with statistics than those in the other sectors examined and indicated a lower preference for measures of spread than those in other areas.

- As familiarity with a particular form of visualisation tended to correspond with a preference for it, adapting existing formats to convey information may lead to users to respond more favourably to them. By the same token however, it should be kept in mind that unfamiliarity may lead users to rate new forms of communication less favourably. It would thus seem important for Task 33.4 to examine whether those formats that are most familiar and well liked, are also those that are best understood.
- While maps are a highly favoured form of visualisation, care should be taken to ensure that the colour scheme used is not misleading, especially when it comes to red and blue. This is something that should be considered in both the development and testing of visualisations.

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Appendix I: Approach to uncertainty by sector

All respondents were asked to rate their agreement with the statements below on a scale of 1 (“strongly disagree”) to 5 (“strongly agree”). This appendix provides a full sectoral breakdown for those sectors where n ≥ 4.

1. "Time pressure means that we sometimes have to make decisions before we have as much information as we would like" **(Time pressure)**
2. "We plan for rare yet severe events" (**Plan for rare events)**
3. "We like to receive information in a form that helps us to make Yes/No decisions" **(Yes/No decisions)**
4. "When it comes to risk management, we mainly focus on those risks that are most likely to occur" **(Focus on most likely risks)**
5. "My organisation has clear guidelines for how much statistical confidence is required before we take action**" (Guidelines for statistical confidence)**
6. "We do our own risk modelling" **(Own risk modelling)**
7. "We don't tend to focus on events that have a very low chance of occurring**" (Don’t focus on low likelihood events)**
8. "We need to know what will happen, not what might happen**." (Need to know what will happen)**
9. "It is important for us to consider what might happen in a 'worst case scenario' as well as what is most likely to happen" **(Concerned with worst case scenario)**
10. "When it comes to predicting extreme weather events we are willing to accept more false alarms if it means that a greater number of real extreme events are detected in advance." **(W to accept false alarms)**
11. "We really just need raw model data so that we can do our own analysis." **(Just need raw model data)**

I. i Water

As can be seen in Figure i.i overleaf, a strong majority of respondents indicated that their organisation planned for rare yet severe events, and that – when it came to climate and weather – they believed it important to considered worst case scenarios. Consistent with this, only a small minority of respondents agreed that their organisation did not focus on low likelihood events. Although 40% agreed that they focussed on those risks most likely occur (with an additional 30% neither agreeing nor disagreeing with this statement).

Of the 10 respondents representing this sector 7 (70%) disagreed or strongly disagreed that their organisation needed *"…to know what will happen, not what might happen"* indicating that most had some acceptance of uncertainty. Of the five sectors who provided enough responses for a sectoral breakdown, those in the water sector were the most likely to indicate that their organisations did their own risk modelling (60%) and agree that when it came to weather and climate information they *"…really just need raw data so that we can run our own analysis"* (40%).

With respect to information and decision making, 90% of water sector respondents agreed that time pressure meant that they sometimes had to make decisions before they had all the information that they would like; while 70% agreed that they would like to receive information in a manner that facilitated yes/no decisions. Only 30% however indicated that their organisation had clear guidelines for how much statistical confidence was required for action to be taken; although a further 30% responded as Don't know/Not applicable.

When it came to potential trade-offs between false alarms and failure to detect, 50% of water sector respondents agreed that when it came to extreme weather their organisation would be willing to accept more false alarms if it meant that a greater number of real extreme weather events were to be detected in advance. Only 20% outright disagreed with the statement, with the remainder neither agreeing nor disagreeing or selecting "Don't know/not applicable".

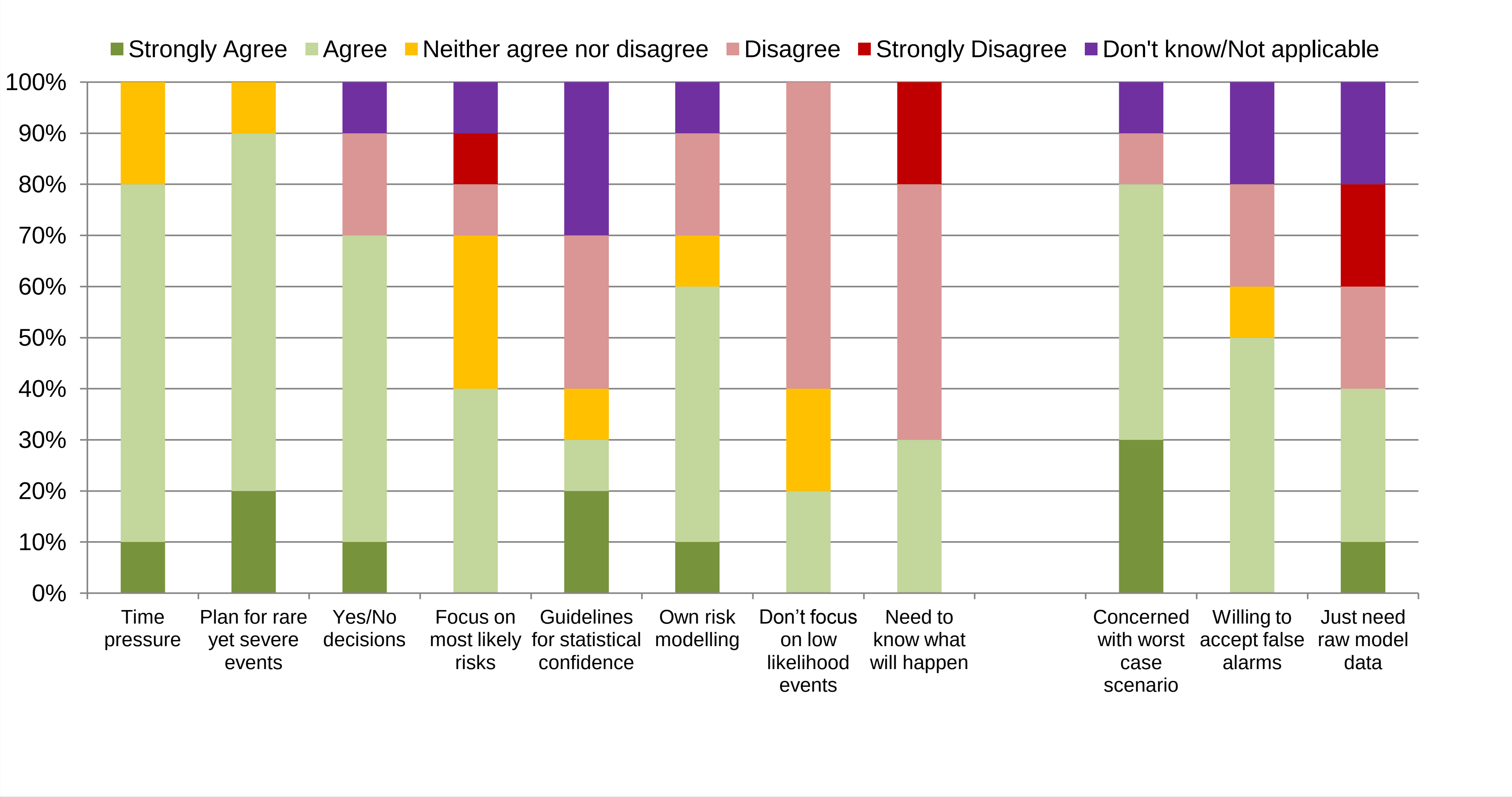


Figure I.i Agreement with statements regarding uncertainty amongst respondents from the water sector (n=10)

I.ii Energy

As was the case for the water sector, the majority of energy sector respondents, indicated that they planned for rare yet severe events (67%); with all respondents from this sector agreeing or strongly agreeing that when it came to weather and climate their organisation believed that it was important to considered worst case scenarios (see Figure 3.4 overleaf). While all but one respondent (83%) agreed that their organisation focussed on those risks that were most likely, none agreed that their organisation didn't tend to focus on low likelihood events (with 67% disagreeing or strongly disagreeing with this statement). Although 3 out of the 6 respondents from this sector (50%) agreed with the statement that their organisations needed to "know what will happen, not what might happen". When it came to tradeoffs between false alarms and failure to detect 50% agreed that their organisation was willing to accept a higher rate of false alarms, if it meant a greater number of extreme weather events were detected in advance.

With regard to the use of uncertain information within their organisation, all respondents from this sector agreed that their organisation did its own risk modelling, and preferred information in a form that facilitated Yes/No decision making. Of the sectors examined those in the energy sector were most likely to agree that their organisation had "clear guidelines for how much statistical confidence is required before we take action" (67%). A majority of respondents from this sector (67%) also indicated that time pressure sometimes meant that their organisation had to make choices before they had as much information as they might wish to.

While all respondents indicated that their organisation did its own risk modelling, only 1 out of the 6 (17%) agreed that they just needed raw data.

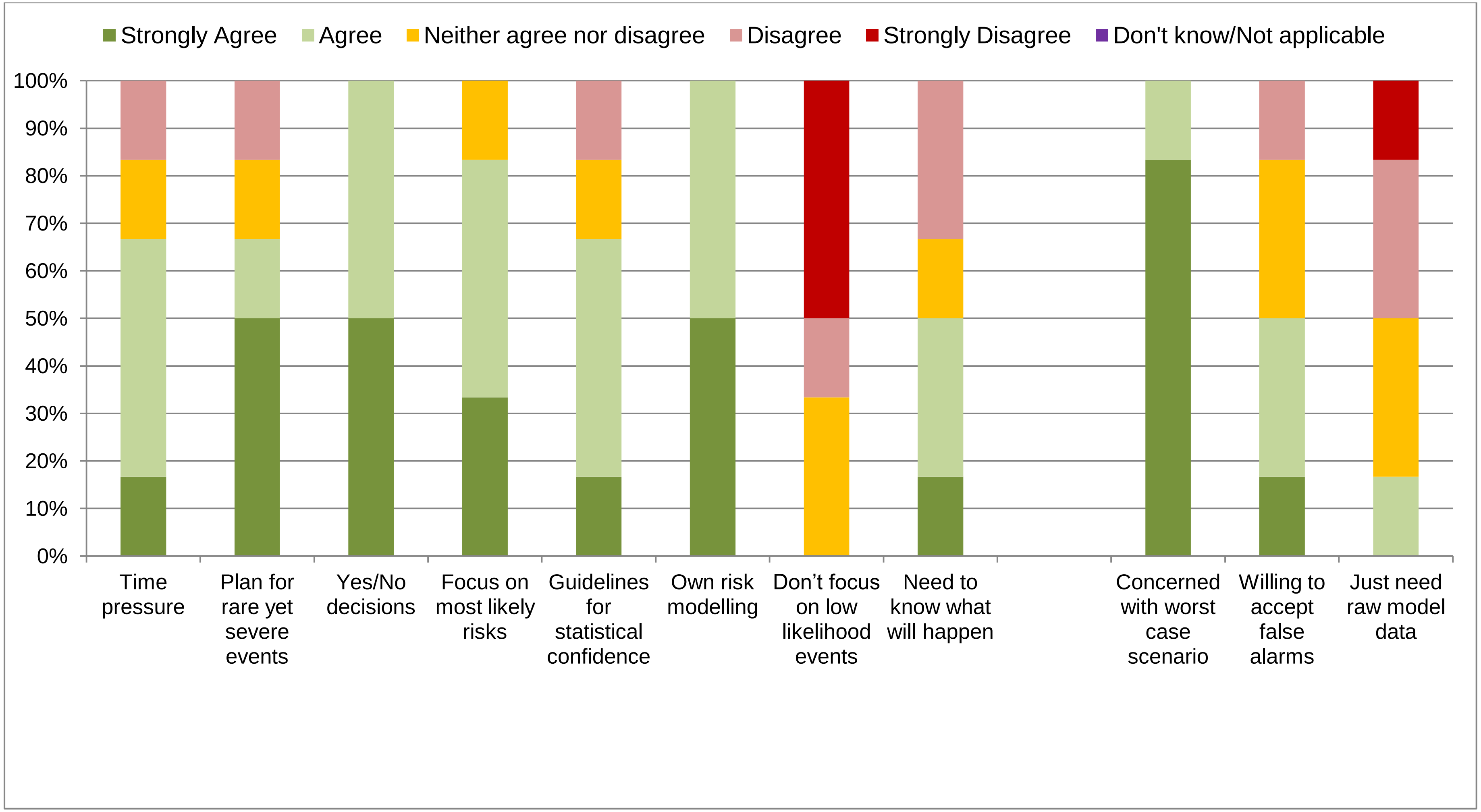


Figure I.ii Agreement with statements regarding uncertainty amongst respondents from the energy sector (n=6)

I.iii Health

Of the 6 respondents representing the health sector 4 (67%) indicated that their organisations planned for rare yet severe events (with the remainder neither agreeing nor disagreeing) although all agreed that it was important for them to consider worst case climate and weather scenarios (see Figure 3.6 overleaf). While 3 out of 6 (50%) agreed that their organisation tended to focus on those risks that were most likely to occur, only 1 out of the 6 (17%) indicated that their organisation did not focus on low likelihood events, or that they needed to know: *"what will happen, not what might happen".* This would seem to be consistent with a precautionary approach towards risk. As is the fact that respondents from sector demonstrated the highest willingness to accept a greater number of false alarms if it means a greater number of real extreme weather events being detected in advance; with 67% agreeing that this was the case for their organisation, and the remainder neither agreeing nor disagreeing.

With respect to in house risk modelling, 50% of the respondents from this sector indicated that their organisation did their own risk modelling, though only 1 (17%) agreed that – when it came to information about climate and weather – they just wanted raw data.

All respondents from this sector indicated that time pressure sometimes meant that they had to make decisions before they had as much information as they would like. Only 1 respondent however agreed that their organisation would wish to receive information in a manner that facilitated Yes/No decision making. Although 50% indicated that their organisation had clear guidelines for how much statistical confidence was required for decision making to take place.

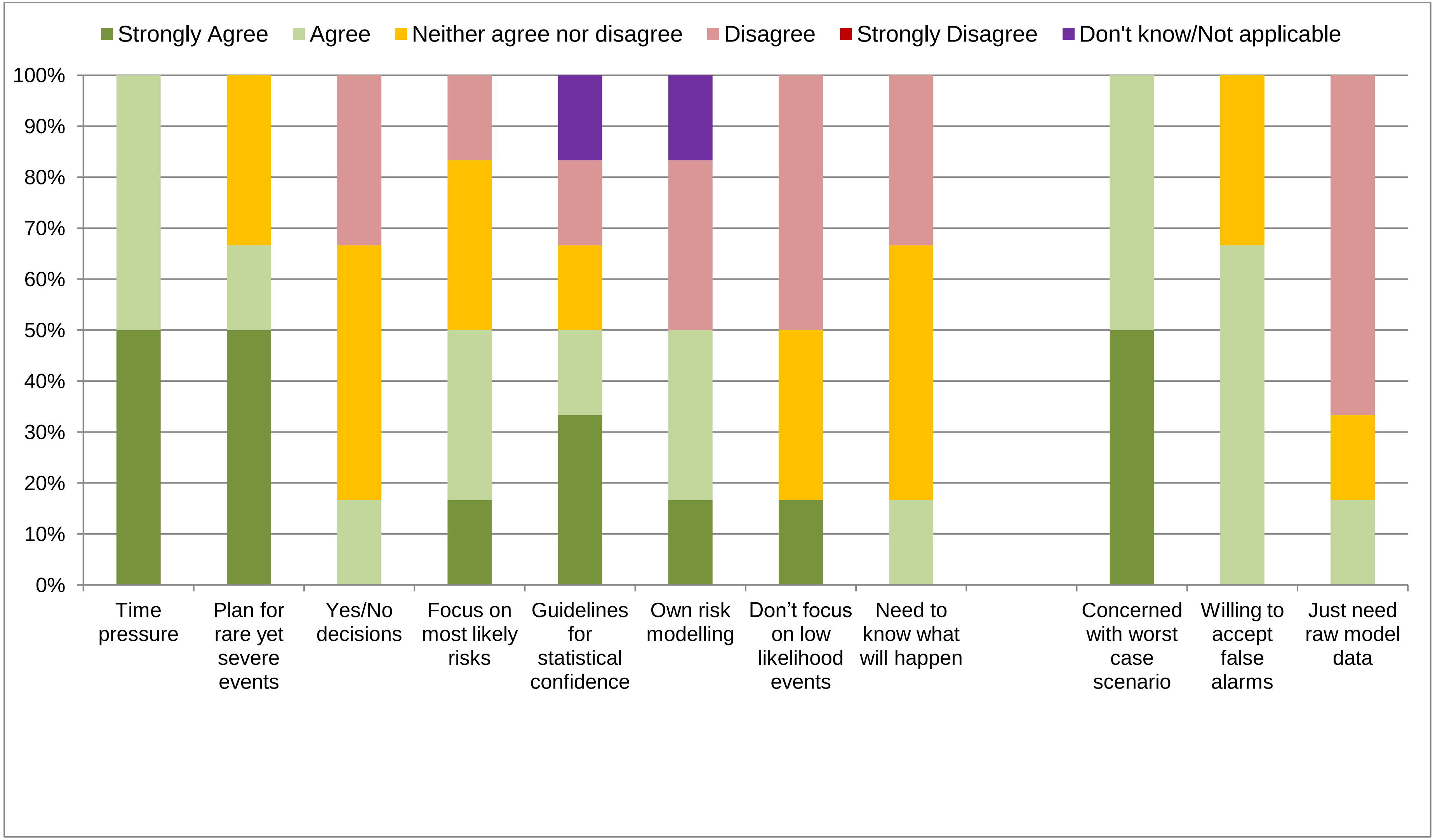


Figure I.iii Agreement with statements regarding uncertainty amongst respondents from the health sector (n=6)

I.iv Forestry

Of those sectors examined on an individual basis those in the forestry sector were least likely to agree that their organisation planned for rare yet severe events, with only 1 in 6 respondents agreeing with this statement (17%) and 3 in 6 (50%) disagreeing (see Figure 3.6 overleaf). A majority also indicated that they focussed on those risks most likely to occur (83%) and that they did not tend to focus on events with a very low likelihood of occurring (67%). However, a majority (67%) indicated that when it came to climate and weather their organisation felt that it was important to consider worst case scenarios, while 83% disagreed that they needed to *"know what will happen not what might happen"*. This would seem to indicate that while those in this sector do not tend to focus on very low probability events, there is some acceptance of uncertainty. Responses to the statement regarding tradeoffs between false alarms and failure to detect with 2 respondents (33%) agreeing, 1 disagreeing (17%), and the remaining 3 (50%) responding as "Don't know/not applicable".

With respect to information usage and preference, only one respondent agreed that their organisation did its own risk modelling while 4 (67%) disagreed. Similarly, only one respondent agreed with the statement that *"We really just need raw model data so that we can do our own analysis"*. In terms of having clear guidelines as to how much statistical confidence was required for decision making, all respondents from this sector disagreed these were in place. Hence, it seems that in house data modelling is relatively uncommon amongst responding organisations in this sector.

A majority (67%) of respondents indicated that time pressure meant that their organisation sometimes had to make decisions before they had as much information as they would like. The same proportion (67%) also indicated that they preferred to receive information in a form that facilitated Yes/No decisions.

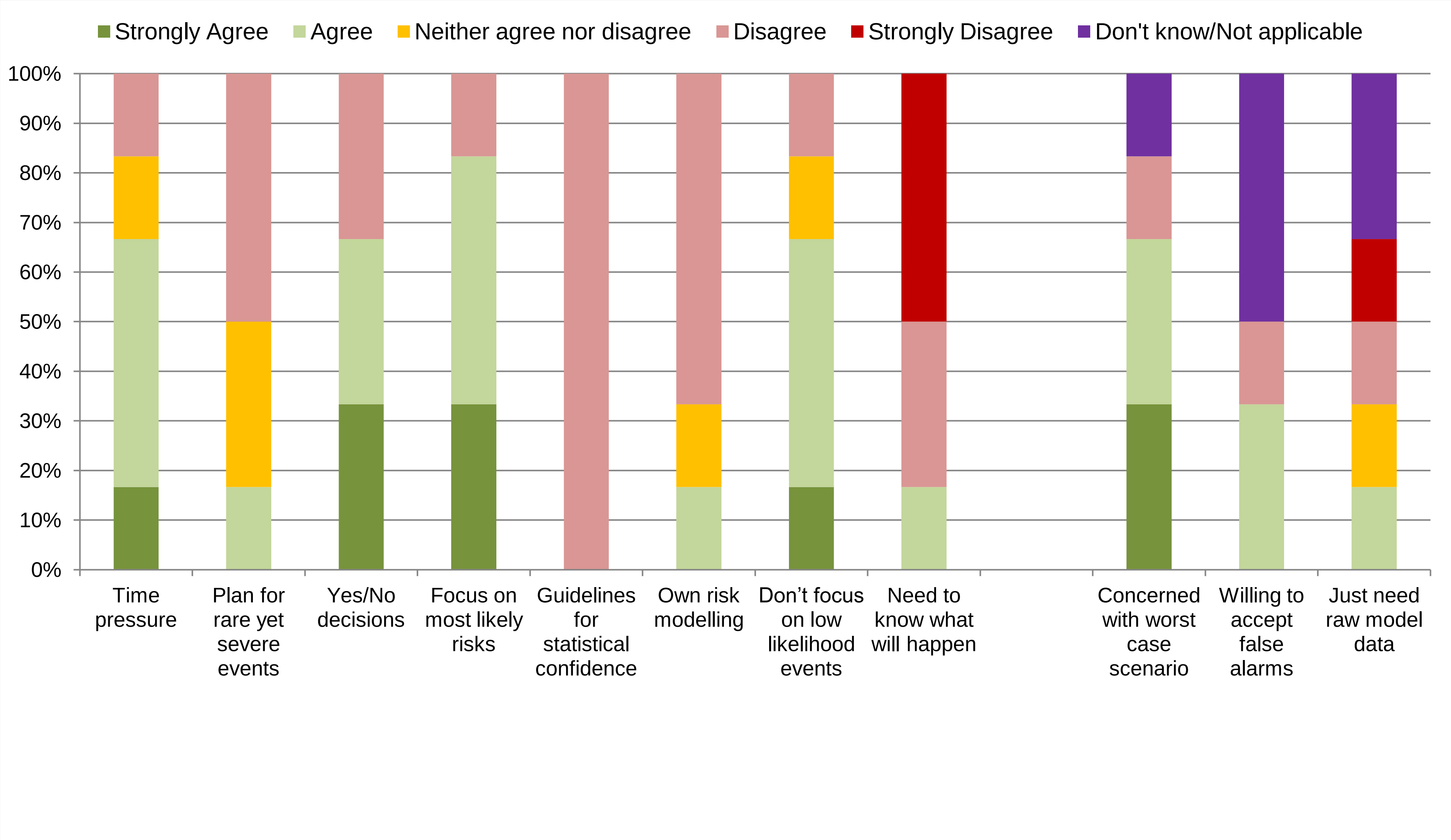


Figure I.iv Agreement with statements regarding uncertainty amongst respondents from the forestry sector (n=6)

I.v Tourism

With just four respondents representing this sector few clear patterns emerge. Of the respondents from this sector 3 out of 4 (75%) agreed that their organisation planned for rare yet severe events and felt that it was important to consider worst case scenarios when it came to weather and climate (see Figure 3.7 overleaf). The same proportion also indicated that they tended to focus on those risk most likely to occur.

None of the respondents from this sector indicated that their organisation did its own risk modelling. However, as only 1 respondent actively disagreed with this, while the others selected “Don’t know/Not applicable” or “Neither agree nor disagree” this may indicate that respondents were not

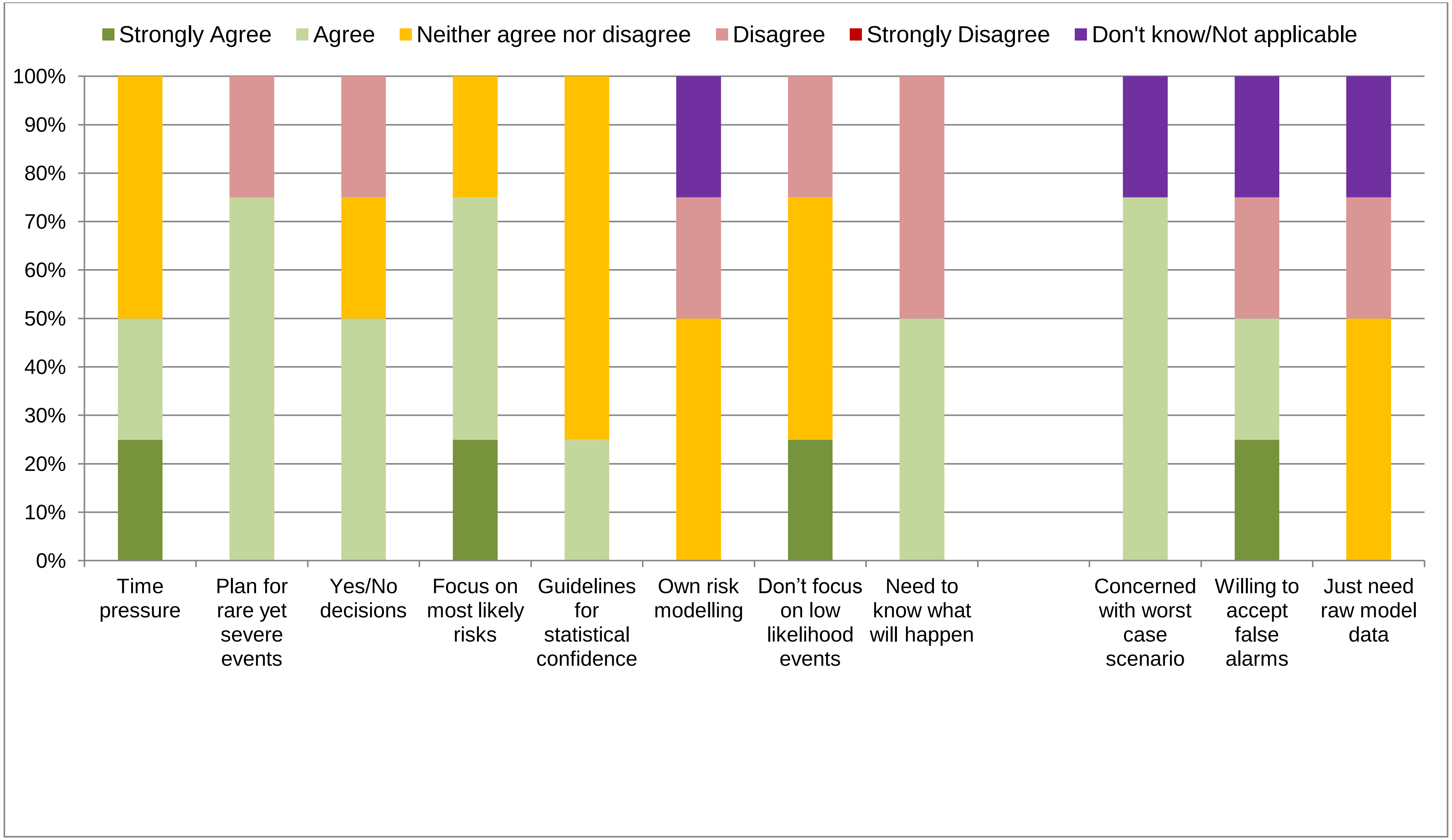
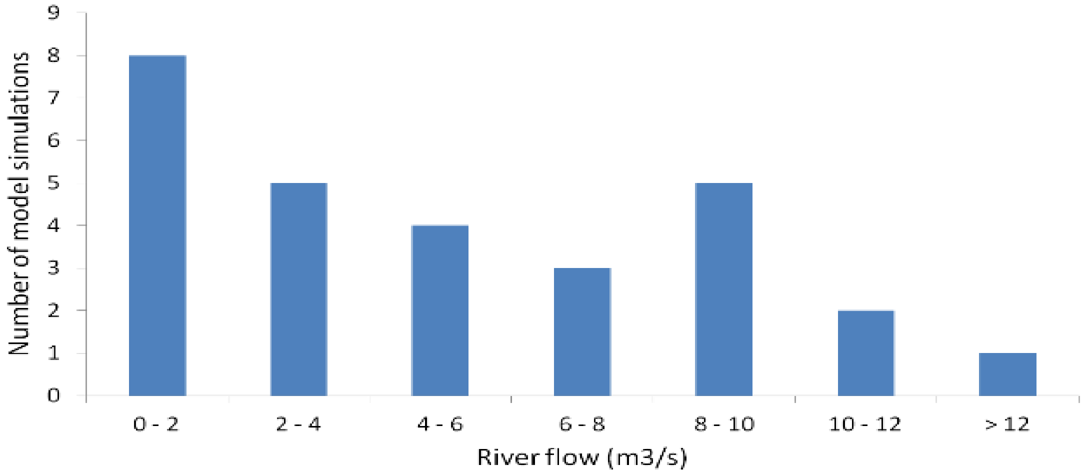


Figure I.v Agreement with statements regarding uncertainty amongst respondents from the tourism sector (n=4)

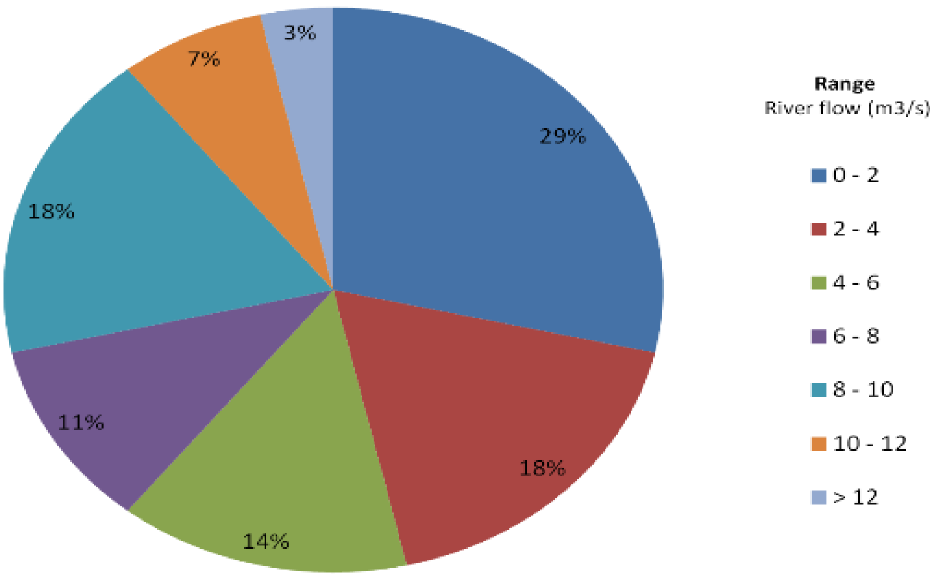
Appendix II: Visualisations

Bar graph



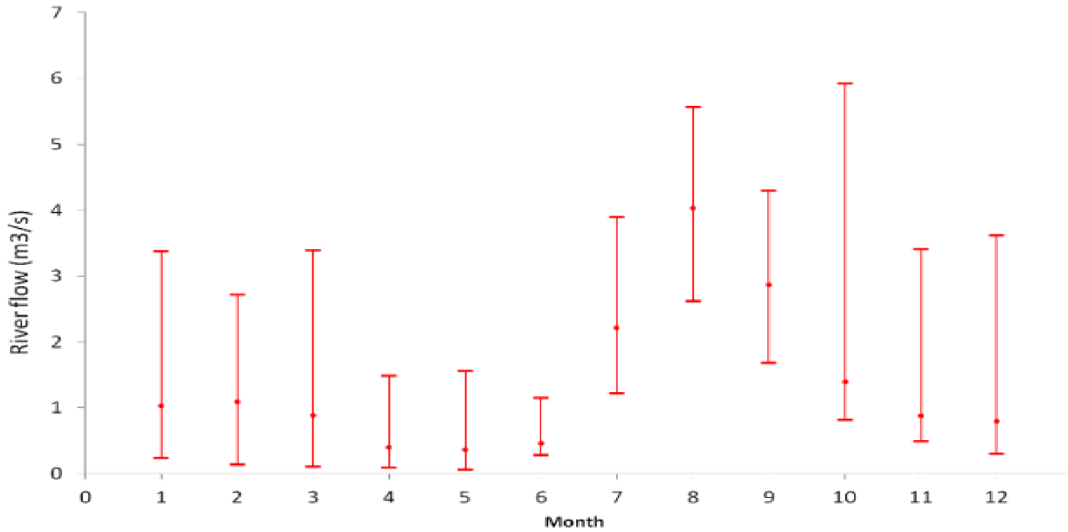
A frequency graph of the number of model simulations (out of 28) that predict that river flow will be within specific ranges of m3/s (cubic metres per second) over the next 12 months.

Pie graph



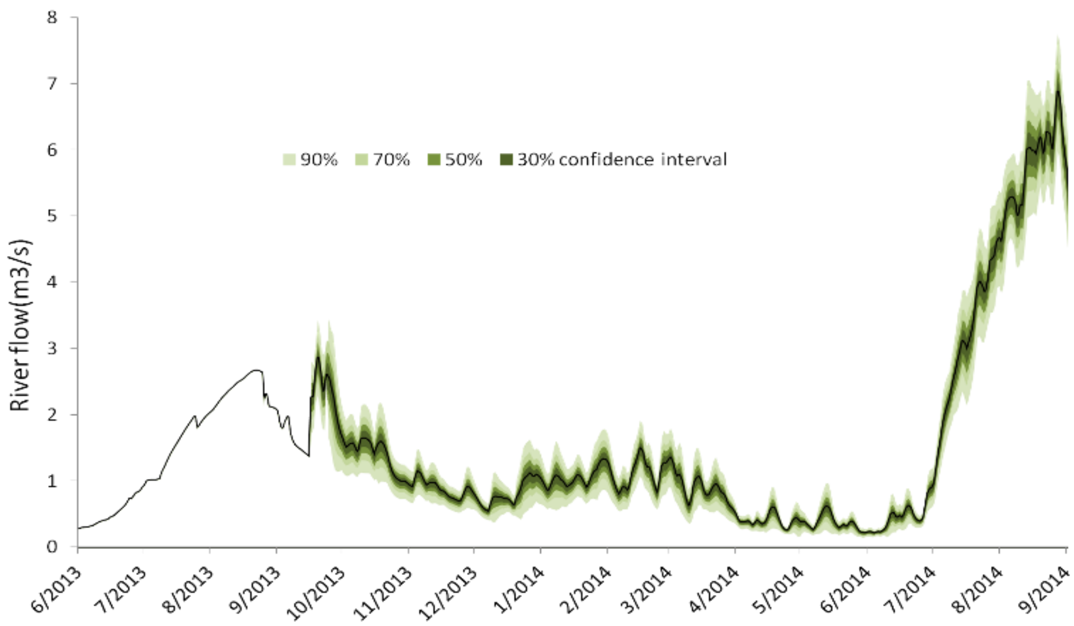
A pie graph showing the proportion of simulations (out of 28) that predict that average river flow will be within specific ranges of m3/s (cubic metres per second) over the next 12 months.

Error bars



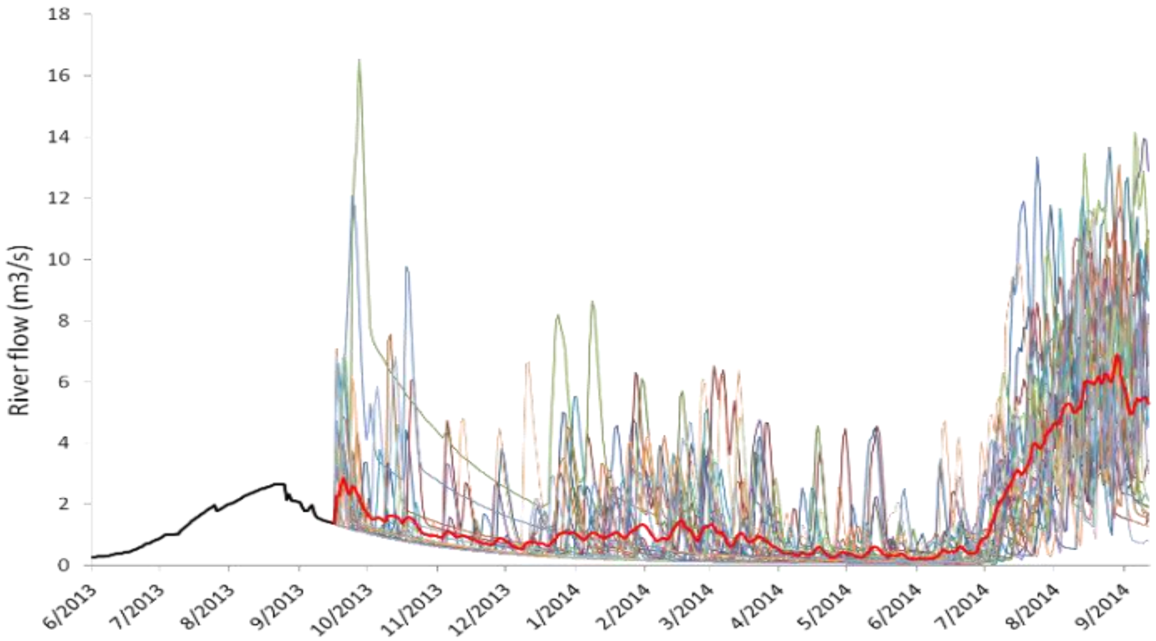
Error bars showing average predicted river flow by month for twelve months. These are based on 28 daily model simulations. The upper and lower limits of the line represent the minimum and maximum value generated by the simulations. The dot represents the mean.

Fan graph



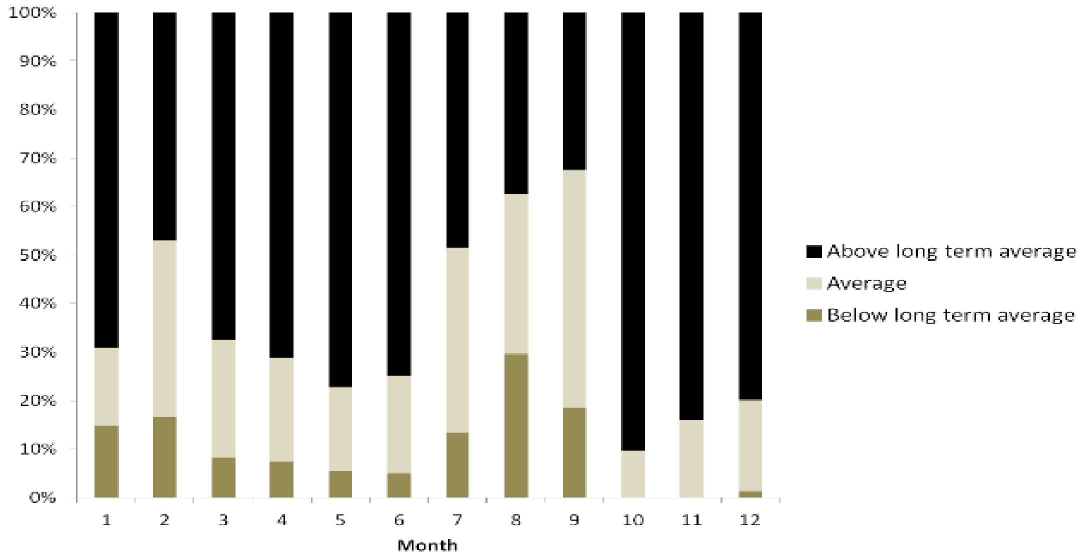
A fan graph showing predicted change in river flow over time. The thin black line at the start represents recent observations (i.e. actual river flow in the recent past). The coloured areas represent confidence levels around the mean. These confidence levels are based on 28 daily model simulations.

Spaghetti graph



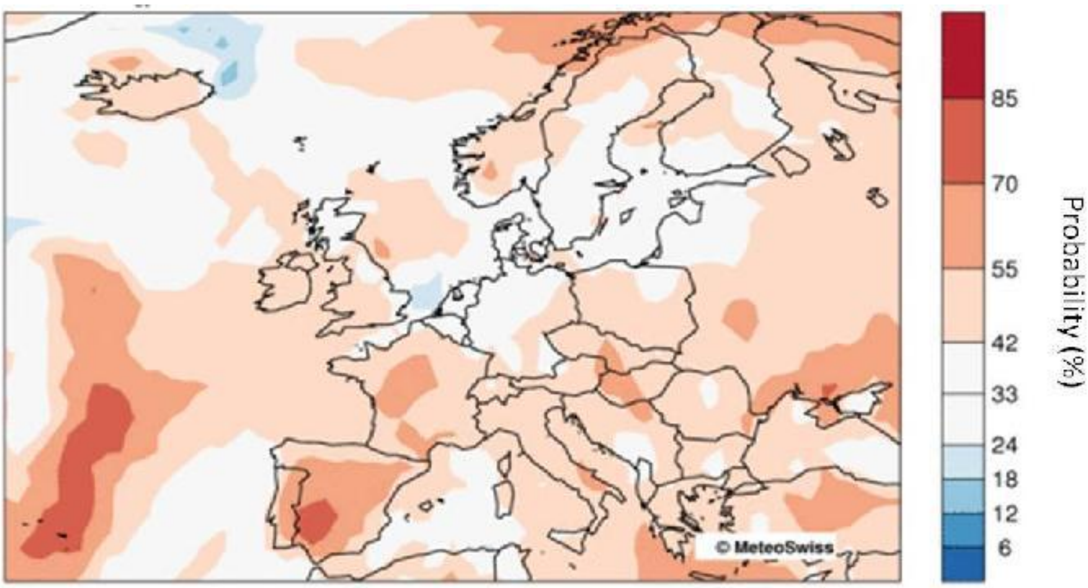
A spaghetti graph showing predicted change in river flow over time. The black line at the start represents recent observations (i.e. actual river flow in the recent past), the thin coloured lines represent 28 daily model simulations and the thick red line represents the mean of the simulations.

Tercile bar



Graph indicating the likelihood that river flow will be above the long term average, around the long term average, or below the long term average for each month.

Map



A map showing the predicted likelihood that average temperature over a three month period will be greater than the long term average.

Appendix III: Intercorrelation between items on visualisation rating scale

Table II.i Correlation between level of agreement with statements regarding **bar graph** format (Pearson's r)

	I would use this type of graph in my decision making	I would share this type of graph with a colleague...	This graph is easy to understand	I like this graph	I use graphs like this in my work
This graph is useful	.75	.57	.65	.70	.57
I would use this type of graph in my decision making		.70	.51	.47	.62
I would share this type of graph with a colleague...			.55	.43	.46
This graph is easy to understand				.54	.40
I like this graph					.47

Table II.ii Correlation between level of agreement with statements regarding **pie graph** format (Pearson's r)

	I would use this type of graph in my decision making	I would share this type of graph with a colleague...	This graph is easy to understand	I like this graph	I use graphs like this in my work
This graph is useful	.76	.75	.65	.68	.51
I would use this type of graph in my decision making		.85	.64	.73	.66
I would share this type of graph with a colleague...			.77	.82	.73
This graph is easy to understand				.85	.57
I like this graph					.72

Table II.iii Correlation between level of agreement with statements regarding **error bar** format (Pearson's r)

	I would use this type of graph in my decision making	I would share this type of graph with a colleague...	This graph is easy to understand	I like this graph	I use graphs like this in my work
This graph is useful	.82	.66	.37	.67	.64
I would use this type of graph in my decision making		.74	.33	.69	.70
I would share this type of graph with a colleague...			.49	.49	.59
This graph is easy to understand				.37	.45
I like this graph					.70

Table II.iv Correlation between level of agreement with statements regarding **fan graph** format (Pearson's r)

	I would use this type of graph in my decision making	I would share this type of graph with a colleague...	This graph is easy to understand	I like this graph	I use graphs like this in my work
This graph is useful	.86	.72	.61	.79	.54
I would use this type of graph in my decision making		.77	.62	.76	.52
I would share this type of graph with a colleague...			.81	.77	.39
This graph is easy to understand				.73	.42
I like this graph					.42

Table II.v Correlation between level of agreement with statements regarding **spaghetti graph** format (Pearson's r)

	I would use this type of graph in my decision making	I would share this type of graph with a colleague...	This graph is easy to understand	I like this graph	I use graphs like this in my work
This graph is useful	.77	.75	.51	.64	.57
I would use this type of graph in my decision making		.82	.48	.76	.81
I would share this type of graph with a colleague...			.62	.73	.61
This graph is easy to understand				.44	.36
I like this graph					.67

Table II.vi Correlation between level of agreement with statements regarding **tercile bar** format (Pearson's r)

	I would use this type of graph in my decision making	I would share this type of graph with a colleague...	This graph is easy to understand	I like this graph	I use graphs like this in my work
This graph is useful	.93	.83	.46	.82	.67
I would use this type of graph in my decision making		.89	.47	.82	.70
I would share this type of graph with a colleague...			.64	.84	.68
This graph is easy to understand				.62	.51
I like this graph					.73

Table II.vii Correlation between level of agreement with statements regarding the map format (Pearson's r)

	I would use this type of map in my decision making	I would share this type of map with a colleague...	This map is easy to understand	I like this map	I use maps like this in my work
This map is useful	.75	.57	.65	.70	.57
I would use this type of map in my decision making		.70	.51	.47	.62
I would share this type of map with a colleague...			.55	.43	.46
This map is easy to understand				.54	.40
I like this map					.47

Appendix IV: Task 33.1 User needs survey (all questions)

Section 1

Q1. Is your organisation involved in the EUPORIAS project?

Yes No
Don't Know

Q2 Name (Optional)

Q3 Organisation (Optional)

Q4 Email (Optional)

Q5 What is your role within your organisation?

Q6 Which sector(s) does your organisation belong to?

Water
Energy
Health
Forestry
Tourism
Agriculture
Insurance/finance
Emergency planning
Other (please provide details) ____________________

Q7 Does your organisation make use of any of the following types of weather and climate information?

Forecasts for up to four weeks in the future
Forecasts for between one month and one year in the future
Forecasts for between one year and ten years in the future
Forecasts for a decade or more in the future

Responses given on a scale of a scale of:

Yes
No
Don't Know

Q8 Are there any other types of forecast or projection about the future that are important to your organisation (e.g. economic growth forecasts, consumer demand forecasts)? (List up to 3)

1____________________
2____________________
3____________________

Q9 On a scale of 1 to 5 how easy to find (or access) do you think the following are? [NOTE: ONLY THOSE ITEMS RESPONDENTS HAD PREVIOUSLY INDICATED THAT THEY USED WERE DISPLAYED – IF RESPONDENTS INDICATED THAT THEY DIDN'T USE ANY THEY AUTOMATICALLY FORWARDED TO SECTION 2]

Forecasts for up to four weeks in the future
Forecasts for between one month and one year in the future
Forecasts for between one year and ten years in the future
Forecasts for a decade or more in the future
Respondent listed forecast 1
Respondent listed forecast 2
Respondent listed forecast 3

Responses given on a scale of a scale of:

1 Not at all easy to find
2
3
4
5 Very easy to find
Don't Know

Q9.a Are there any comments about this question that you would like to make? (Optional)

Q10 On a scale of 1 to 5, how easy to understand do you think the following are?

Forecasts for up to four weeks in the future
Forecasts for between one month and one year in the future
Forecasts for between one year and ten years in the future
Forecasts for a decade or more in the future
Respondent listed forecast 1
Respondent listed forecast 2
Respondent listed forecast 3

Responses given on a scale of a scale of:
1 Not at all easy to understand
2
3
4
5 Very easy to understand
Don't Know

Q10.a Are there any comments about this question that you would like to make? (Optional)

Q11 On a scale of 1 to 5, how useful do you think the following are?

Forecasts for up to four weeks in the future
Forecasts for between one month and one year in the future
Forecasts for between one year and ten years in the future
Forecasts for a decade or more in the future
Respondent listed forecast 1
Respondent listed forecast 2
Respondent listed forecast 3

Responses given on a scale of a scale of:

1 Not at all useful
2
3
4
5 Very useful
Don't Know

Q11.a Are there any comments about this question that you would like to make? (Optional)

Section 2

Q12 Thinking about your organisation's approach to dealing with confidence and uncertainty in general, please rate your level of agreement with the statements below.

> “We plan for rare but severe events."
>
> “My organisation has clear guidelines as to how much statistical confidence is required before we can take action.”
>
> "When it comes to risk management, we mainly focus on those risks that are most likely to occur."
>
> "We do our own risk modelling."

Responses given on a scale of a scale of:

1 Strongly disagree
2 Disagree
3 Neither agree nor disagree
4 Agree
5 Strongly agree
Don’t Know/Not applicable

Q12.a Are there any comments about this question that you would like to make? (Optional)

Q13 Thinking about your organisation's approach to dealing with confidence and uncertainty in general, please rate your level of agreement with the statements below.

> "Time pressure means that we sometimes have to make decisions before we have as much information as we would like."
> “We need to know what will happen, not what might happen.”
> "We don’t tend to focus on events that have a very low chance of occurring.”
> "We like to receive information in a form that helps us to make Yes/No decisions."

Responses given on a scale of a scale of:

1 Strongly disagree
2 Disagree
3 Neither agree nor disagree
4 Agree
5 Strongly agree
Don’t Know/Not applicable

Q13.a Are there any comments about this question that you would like to make? (Optional)

Q14 Thinking about your organisation's use of climate information specifically, please rate your level of agreement with the following statements. If your organisation doesn't presently use any form of weather or climate information select 'Don't know/Not applicable'.

> “It is important for us to consider what might happen in a 'worst case scenario' as well as what is most likely to happen"
>
> “When it comes to predicting extreme weather events we are willing to accept more false alarms if it means that a greater number of real extreme events are detected in advance.”
>
> “We really just need raw model data so that we can do our own analysis.”

Responses given on a scale of a scale of:

1 Strongly disagree
2 Disagree
3 Neither agree nor disagree
4 Agree
5 Strongly agree
Don’t Know/Not applicable

Q14.a Are there any comments about this question that you would like to make? (Optional)

Section 3

Q15 Which of the following best describes your feelings about working with statistics and numerical information, such as means, percentages, confidence levels, and more advanced forms of analysis?

1. “I am not comfortable using statistics or numerical information”
2. “I am comfortable using basic statistics and numerical information” (e.g. means, percentages, frequency counts)
3. “I am comfortable using more complex statistics and numerical information” (e.g. confidence levels, probability distributions)
4. “I am comfortable using standard statistical tests” (e.g. correlations, t-tests)
5. “I am comfortable using more advanced statistical techniques” (e.g. Monte Carlo simulations, mathematical modelling)
6. Other (Please give details) ____________________

Q16 Do you use statistics or numerical information in your day to day work?

Yes
No

Q16.a What kind of statistics or numerical information do you use? (Select all that apply) [PRESENTED ONLY IF RESPONDENT SELECTED YES TO Q16]

Frequency counts
Percentages
Measures of averages (e.g. mean, median, mode)
Exceedance thresholds (e.g. as might be represented by return periods)
Measures of spread (e.g. variance, standard deviation, confidence levels)
Probability distributions
Other (please provide details) ____________________

Q17 Below are three different ways of describing the likelihood of it raining tomorrow. Which of these do you prefer? (Required)

There is a 30% chance of rain tomorrow
There is a .3 chance of rain tomorrow
There is a 3 in 10 chance of rain tomorrow
I would prefer another format (please provide details)
____

Q18 – 23

[INSTRUCTIONS]

On the next few screens you will be presented with graphs representing uncertainty in a hypothetical river flow forecast. All graphs are based on the same underlying data. We would like you to look at them and rate what you think of each type of graph on the scales provided.

You and your organisation may not be interested in river flow itself, but these types of graphs can also be used to show information about confidence and uncertainty in forecasts for other climate and climate impact variables such as temperature and rainfall. Therefore, we ask that you base your ratings on your thoughts about the style of the graphs rather than whether you would be interested in using information about river flow itself.

Note: some images may take a few seconds to load. When you are ready to see the graphs click "Next"

[Respondents were presented with a series six hypothetical streamflow forecast visualisations (see Appendix II for illustrations)]

Bar graph
Pie graph
Error bar
Fan graph
Spaghetti graph
Tercile bar

[Respondents rated their opinion of each on a set of six scales]

"This type of graph is useful"
"I would use this type of graph in my decision making"
"I would share this type graph with a colleague, for them to use in their own decision making."
"This graph is easy to understand"
"I like this graph."
"I use graphs like this in my work."

Responses given on a scale of a scale of:

1 Strongly disagree
2 Disagree
3 Neither agree nor disagree
4 Agree
5 Strongly agree

Q18.a – 23.a Are there any comments about this type of graph that you would like to make? (Optional)

Q19 On the next screen you will be shown a map representing a hypothetical seasonal temperature forecast for Europe (please note this does not represent a current forecast). We would like you to look at the map and rate what you think on the scales provided.

Temperature might not interest your organisation, but this style of map can be used to present information about a range of different climate and climate impact variables. We therefore ask that you base your ratings on what you think of the type of graph rather than your interest in temperature.

[Respondents rated their opinion of the map (see Appendix II) on a set of six scales]

"This type of map is useful"
"I would use this type of map in my decision making"
"I would share this type of map with a colleague, for them to use in their own decision making."
"This map is easy to understand"
"I like this map."
"I use maps like this in my work."

Responses given on a scale of a scale of:

1 Strongly disagree
2 Disagree
3 Neither agree nor disagree
4 Agree
5 Strongly agree

Q19.a Are there any comments about this type of map that you would like to make? (Optional)

Q20. Below is a list of ways in which information about probabilities and quantities can be shown. Have you ever used them in your work? (Please select Yes if you have and No if you have not)

Numeric tables
Bar graphs
Pie graphs
Histograms
Maps
Error bars
Probability density functions
Cumulative probability density functions
Spaghetti graphs
Other (please provide details) ____________________

Responses given as:
Yes
No

Q21 If you were completely free to choose how you received information about uncertainty in the climate or climate impacts your organisation is interested in what would you choose? (Optional)

Section 4 [CURRENT USERS OF SEASONAL OR DECADAL INFORMATION ONLY]

Q22. Your answers to previous questions indicate that you currently use climate forecasts at a seasonal to decadal timescale.That is to say climate forecasts for between one month and ten years in the future. Which climate variables and impacts does your organisation get these forecasts for (tick all that apply)

Temperature (land)
Rainfall
Cloud cover
Wind
Temperature (sea)
River flow
Crop yields
Extreme indices (e.g. heat, cold)
Other (please provide details) ____________________

Q23 How often does your organisation use climate forecasts for the following timescales?

1 - 3 months in the future
4 - 6 months in the future
7 -12 months in the future
1 - 2 years in the future
3 - 5 years in the future
6 - 10 years in the future

Responses given on a scale of:
1 Never
2 Not often
3 Often
4 Very often
Don't know

Q24Does your organisation get any of the following types of information about uncertainty in its seasonal to decadal climate forecasts? (Please note: the things listed here may not be available for all types of variables and indices)

Ranges of values (e.g. 'temperature projected to be between 18C and 23C')
Confidence levels
Probability distributions
Indicators of signal strength
Raw data
Verbal descriptions of likelihoods (e.g. descriptions such as 'likely' or 'unlikely')
Information about possible sources of error in the models used
Information about how well earlier forecasts have matched observed climate variables and impacts.

Responses given on a scale of:
1 Yes
2 No
3 Often
4 No, but we would like to
Don't know

Q25 Do you receive information about uncertainties in any other form?

Yes (Please provide details) (1) ____________________

No (2)

Q26 Are there any comments about any of these questions that you would like to make? (Optional) [REFERRING TO Q22 - Q25]

Q27 On the last screen you indicated that you get the following types of information about uncertainty in climate forecasts. How often would you say that you use this information in your decision making? [NOTE: ONLY ITEMS RESPONDENTS INDICATED THAT THEY RECEIVED WERE DISPLAYED – IF RESPONDENTS DIDN'T RECEIVE ANY OF THE LISTED FORMS OF INFORMATION THEY DID NOT SEE THIS QUESTION]

Ranges of values (e.g. 'temperature projected to be between 18C and 23C')
Confidence levels
Probability distributions
Indicators of signal strength
Raw data
Verbal descriptions of likelihoods (e.g. descriptions such as 'likely' or 'unlikely')
Information about possible sources of error in the models used
Information about how well earlier forecasts have matched observed climate variables and impacts.

Responses given on a scale of:

1 Never
2 Not often
3 Often
4 Very often
Don't know

Q28 Do you feel that the information you currently receive regarding climate forecasts at a seasonal to decadal timescale fully meets your needs?

Responses given as:

Yes
No

Q28.a How could this be changed so that your needs are met? [IF “NO” SELECTED FOR Q28]

Section 4 [NON-USERS OF SEASONAL OR DECADAL INFORMATION ONLY]

Q30 Why don't you use currently forecasts at a seasonal to decadal timescale? (tick all that apply)

- The matter has never been discussed in our organisation
- There is too much uncertainty in these forecasts for them to be useful in our decision making
- The information available isn't precise enough for us to use in our decision making
- No forecasts are available for the events or indices that we are interested
- We have not been able to find a suitable provider
- The information is not provided in a way that we can use
- Other (please provide details) ____________________

Q30a How precise would seasonal to decadal forecasts have to be to be useful to you? [IF RESPONDENT CHECKED “THE INFORMATION AVAILABLE ISN'T PRECISE ENOUGH FOR US TO USE IN OUR DECISION MAKING”]

Q30b Why isn't the information usable? (tick all that apply) [IF RESPONDENT CHECKED “THE INFORMATION IS NOT PROVIDED IN A WAY THAT WE CAN USE”]

- The information available is not provided in a way that is easy to understand
- The information available does not contain enough detail about uncertainty
- The information available does not contain enough detail in general
- Other (please provide details) ____________________

Q31Are there any comments about any of these questions that you would like to make? (Optional) [REFERRING TO Q29 - Q30]

Section 4 [NON-USERS OF SEASONAL OR DECADAL INFORMATION ONLY]

Q30 Why don't you use currently forecasts at a seasonal to decadal timescale? (tick all that apply)

The matter has never been discussed in our organisation
There is too much uncertainty in these forecasts for them to be useful in our decision making
The information available isn't precise enough for us to use in our decision making
No forecasts are available for the events or indices that we are interested
We have not been able to find a suitable provider
The information is not provided in a way that we can use
Other (please provide details) ____________________

Q30a How precise would seasonal to decadal forecasts have to be to be useful to you? [IF RESPONDENT CHECKED "THE INFORMATION AVAILABLE ISN'T PRECISE ENOUGH FOR US TO USE IN OUR DECISION MAKING"]

Q30b Why isn't the information usable? (tick all that apply) [IF RESPONDENT CHECKED "THE INFORMATION IS NOT PROVIDED IN A WAY THAT WE CAN USE"]

The information available is not provided in a way that is easy to understand
The information available does not contain enough detail about uncertainty
The information available does not contain enough detail in general
Other (please provide details) ____________________

Q31Are there any comments about any of these questions that you would like to make? (Optional) [REFERRING TO Q29 - Q30]

Section 5 [OPTIONAL]

Q32 Gender (Optional)

Male
Female

Q33 Age (Optional)

Q34 How long have you worked in your current field? (Optional)

Q35 What is your highest level of formal education? (Optional)

High School
Undergraduate degree
Postgraduate degree
Other (please provide details) ____________________

Q35.a What was your degree subject? (If you have more than one degree list all of them) (Optional) [DISPLAYED ONLY IF RESPONDENT SELECTED UNDERGRADUATE DEGREE OR POSTGRADUATE DEGREE FOR Q35]

Q29 Your answers to previous questions indicate that you do not currently use climate forecasts at a seasonal to decadal timescale. That is to say climate forecasts for between one month and ten years in the future. If you were to receive forecasts at this timescale, which climate and climate impact variables would you be interested in receiving forecasts for? (tick all that apply)

Temperature (land)
Rainfall
Cloud cover
Wind
Temperature (sea)
River flow
Crop yields
Extreme indices (e.g. heat, cold)
Other (Please provide details) ____________________