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Chinese water managers' long-term climate information needs

Abstract

Decision-makers can use climate information to adapt to the risks of climate variability and change. The adequate provision of climate information is critical for adaptation planning in climate-sensitive sectors. However, for climate products to be appropriately tailored for these sectors, it is necessary to identify and understand users' specific information needs. The aim of this research was to assess the use of and need for climate information by water managers in China, with a focus on long-term climate information in the Yellow and Yangtze River basins. Data was collected from regional water managers, and climate information providers using a workshop (n=15), and semi-structured interviews (n=27). It was found that water manages in China required climate data with different timescales and variables. The findings show that water managers receive historical, weather and seasonal forecasts data from the China Meteorological Administration (CMA) mainly because there is a close dialogue between data providers and users in terms of historical, weather, and seasonal climate data that does not exist with regard to climate change projections. The use of external sources of climate change projections by users in China allows critical evaluation of climate services provided by the CMA; from that, an understanding of the limitations of current services such as limited variables and timescales was established.

Keywords: Climate information, User needs, Water resources, Decision-making, Climate change projections, China.

1. Introduction

Global water scarcity has been ranked as a major crisis of the 21st century (Srinivasan et al., 2012; Khosravi, 2019). Climate change is leading to greater water scarcity and more frequent flooding (Anderson, 2008; Zhang et al., 2018). Climate mitigation, through the reduction of greenhouse gas emissions, is needed to counterbalance the impact of climate change on water resources. However, adapting to changes in precipitation, as well as the distribution of water and extreme weather events is even more important for water managers (He, 2013). Shresta et al., (2014) argue that applying climate change projections to water resources planning is the primary requirement needed to enable climate change adaptation in the water sector.

However, it has been noted that water managers traditionally use historical observations and that their expectations of future problems are closely linked with past experiences (O'Connor et al., 2005; Rayner, 2019). Climate information ranges from historical climate data to climate change projections (Figure 1) (Bruno Soares et al., 2018). Access to useful climate information allows decision makers to increase system and societal resilience to current and future climate conditions (Golding et al., 2017; Bruno Soares et al., 2018; Goddard, 2016). In this context, climate services provide climate information to support users' decision-making pertaining to increasing resilience to the impacts of climate change through tools, websites, and tailored products (Vaughan and Dessai, 2014; Hewitt et al., 2012; Bruno Soares et al., 2018). The development of climate services as a research and operational field has increased in recent years (Golding et al., 2019; Bruno Soares and Buontemtempo, 2019). Its rapid development is due to scientific advances (Rummukainen, 2016; Flato et al., 2013; Nyamwanza et al., 2017; White et al., 2017; Golding et al., 2019), and the increased recognition amongst governments of the need to implement greater climate resilience measures (Stakhiv and Stewart, 2010; Tostensen et al., 2016; Edwards et al., 2016; Golding et al., 2019). The support of international funding efforts such as the Global Framework for Climate Services (Hewitt et al., 2012; Golding et al., 2019; Bruno Soares and Buontempo, 2019) has also had a vital role in the recent development of climate services.

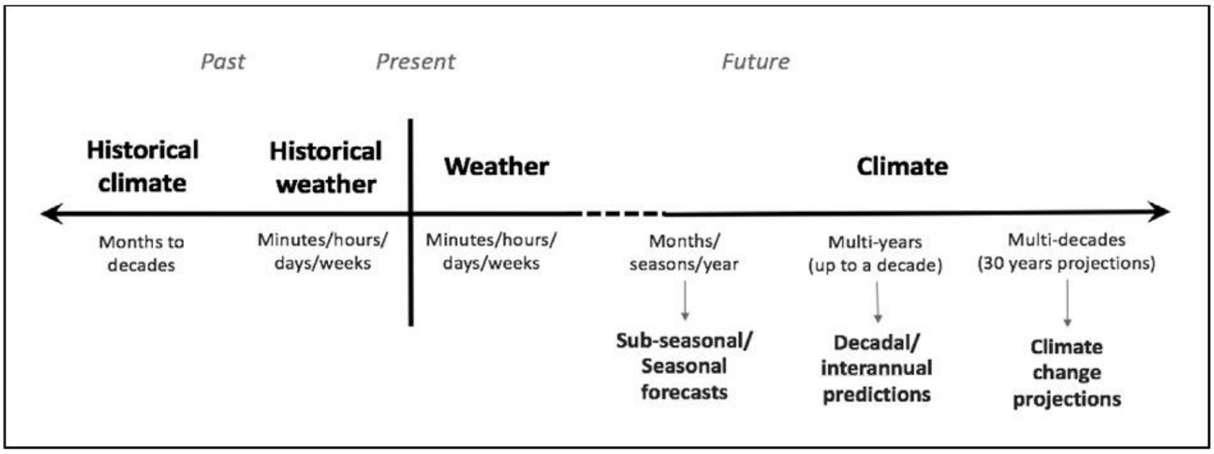

Fig 1. Main typologies of weather and climate information (Bruno Soares et al., 2018)

Water managers make a variety of decisions, and each requires a distinct set of weather and climate information (Table 1). For example, operational decisions such as flood warnings require weather forecasts, whilst decisions such as the size of reservoirs need long-term information such as climate change projections. As illustrated in Table 1, decadal climate predictions are not used in decision making at present due to limited skill (Bruno Soares et al., 2018). Several technical challenges need to be resolved before this timescale is ready to be used at an operational level (Towler et al., 2018). Therefore, seasonal forecasts and climate change projections are used for shorter-term and longer-term planning in some countries (Raucher et al., 2015; Towler et al., 2018). In some countries the need to consider climate change projections in water resource planning is mandated at policy and basin level. For instance, climate change has to be considered in the river basin management plans in Europe (Kaspersen et al., 2016). In the United Kingdom (UK), climate projections are used as inputs into water resource planning processes to prepare for future droughts, floods and sea level rise (Counsell et al., 2018).

Table 1. Water management decisions defined by timescale of application (adapted from WMO, 2012)

Operation	Planning	
Weather forecasts (1-10 days) Day-to-day operational activities	**Seasonal forecasts (1-12 months) Short-term planning**	**Climate change projections (10-50 years) Long-term planning**
• Flood warnings • Storage management (Irrigation, hydropower, peak municipal water demands) • Irrigation scheduling • Demand management	• Drought contingency planning • Flood contingency planning • Seasonal forecasts • Risk mapping • Irrigated crop planning • Water allocations • Demand management	• Revisit design standards based on historic information, design flow estimation under nonstationary conditions • Development of adaptation strategies • Regulation of water abstractions • Spatial planning • Water allocation schemes • Reservoir sizing • Risk mapping (floods, droughts) • Supply demand

Providing robust climate information alone is insufficient to ensure the production of useful climate information for decision making (Hewitt et al., 2012; Buontempo et al., 2018). This is because there are barriers to integrating climate information into planning processes such as the mismatch of temporal or spatial qualities of data with user needs, lack of awareness of the data and the inaccessibility of desired data (Rayner et al., 2005, Lemos et al., 2012, Bolson et al., 2013). Assessment of user needs is an important requirement when seeking to provide useful climate information (Buontempo, 2018). In this research, we assess water managers' use of and need for climate information, with a focus on long-term climate information in the Yellow and Yangtze River basins. To do this, Section 2 describes the study area and the methods adopted; Section 3 presents our findings. This is followed by a discussion of the research findings in Section 4. Finally, Section 5 provides concluding remarks.

2. Context and methods

2.1. Study area

South China generally has greater water resources than the northern regions due to complex topology and diverse climates (Zhang and Anadon, 2014; Zhao et al., 2015). Moreover, this country is experiencing recent climate change challenges including more intense and frequent droughts in the north (Qian and Zhou, 2014; Qian et al., 2014; Hu 2003; Amato et al., 2019), and flooding in the south and the Yangtze River Basin (Yu et al., 2004; Yu and Zhou 2007; Zhou et al., 2009; Li et al., 2010; Amato et al., 2019). A drying trend in the Yellow River Basin and significant wetting in the Yangtze River Basin were detectable over the last 50 years (Wang et al., 2011). Flooding in the Yangtze River is a major concern for Chinese water authorities (Wang and Zhang, 2008). The South-North Water Transfer Project is the world's largest inter-basin transfer scheme, and has been designed to move abundant water in the Yangtze River in the south to the north of China through three routes – Eastern, Middle and Western routes (Rogers et al., 2019). The Yellow River Basin and the Yangtze River Basin have been chosen as the study area for this research, with a primary focus on the South-North Water Transfer Project (Figure 2).

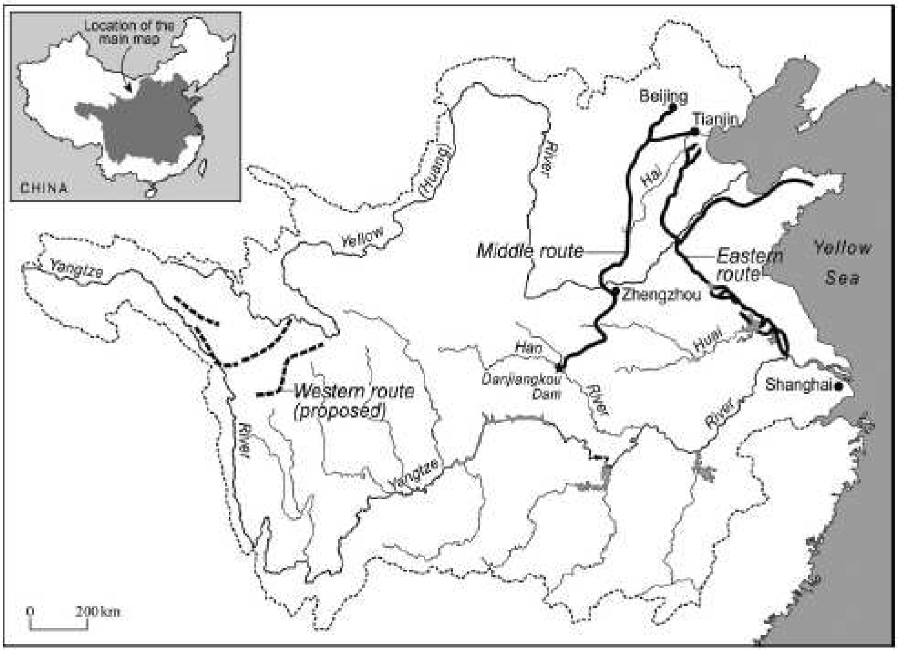

Fig 2. Yellow and Yangtze River basins and the South-North Water Transfer Project in China (from Rogers et al. 2016)

2.2. Relevant Chinese Institutions

The Ministry of Water Resources (MWR) is the main organisation at the national level responsible for water management in China (Boekhorst et al., 2010). The MWR has some departments at provincial level (Turner and Otsuka 2006, MWR 2009) and River Basin Commissions (RBCs) at basin level (Yan et al., 2006; MWR, 2009). These RBCs were established in the 1950s to mitigate flood damage along the country's major rivers through the construction of reservoirs, flood control infrastructure, water use planning, and the protection of water resources (Boekhorst et al., 2010).

The China Meteorological Administration (CMA) has overall responsibility for climate services in China such as climate research and development, and the maintenance and development of observations and monitoring programmes in China (Golding et al., 2017). The CMA provides climate services to a range of users in different sectors such as the water sector at three administrative levels: national, provincial and prefectural levels (Opitz-Stapleton et al., 2016). Literature shows that Chinese climate services have a strong focus on seasonal forecasts and that the seasonal forecasting system developed by the Beijing Climate Centre (BCC) is now interpreted appropriately by regional climate centres (Golding et al., 2019). This demonstrates that China's climate services have close interactions with their seasonal forecast users through regional climate centres (Golding et al., 2017).

2.3. Methods

Due to the dearth of literature on climate services and users' climate information needs in China, a qualitative approach was chosen to enable an in-depth understanding of climate information needs in the water sector in China to be obtained. Qualitative studies tend to be more exploratory in nature, particularly where existing literature and underpinning theory are limited (Yilmaz, 2013).

Initially, an interactive discussion was held in August 2019 with CMA scientists to obtain a preliminary overview of the long-term data that was available in China, such as climate predictions and projections. This discussion provided insights and a list of climate information products that were used in subsequent workshops with water managers in China. A workshop with fifteen water managers from the Yellow River Basin Commission, the Yangtze River Basin Commission and the Nanjing Hydraulic Research Institute was then held in Nanjing in August 2019. The objective of the workshop was to better understand the regional water sector's need for and use of climate information. The workshop also helped the development of a protocol for subsequent semi-structured interviews with users of climate information in the water sector in China (Appendix 1). Three preliminary interviews were completed in August 2019 to test the protocol. These initial interviews and the interactive workshop suggested that there is little uptake of climate change projections amongst water managers who traditionally rely more on historical climate data for long-term planning. Hence, the decision was made to expand our subsequent sample of interviewees to include hydrological researchers, who are the main users of climate change projections in the water sector, in addition to water managers.

In total, 27 semi-structured interviews were conducted with water managers and researchers. Interviewees were recruited using snowball sampling, commencing with referrals from known contacts in the Chinese water sector. Preference was given to participants from the study areas of the Yellow River Basin Commission and the Yangtze River Basin Commission. Interviewee distribution by organisation is shown in Figure 3. Eighteen interviewees were water managers, eight interviewees were researchers from institutes such as China's Institute of Water Resources and Hydropower Research (IWHR) and the Nanjing Hydraulic Research Institute, and one intermediary was from the hydrometric department of the Yellow River Basin Commission.

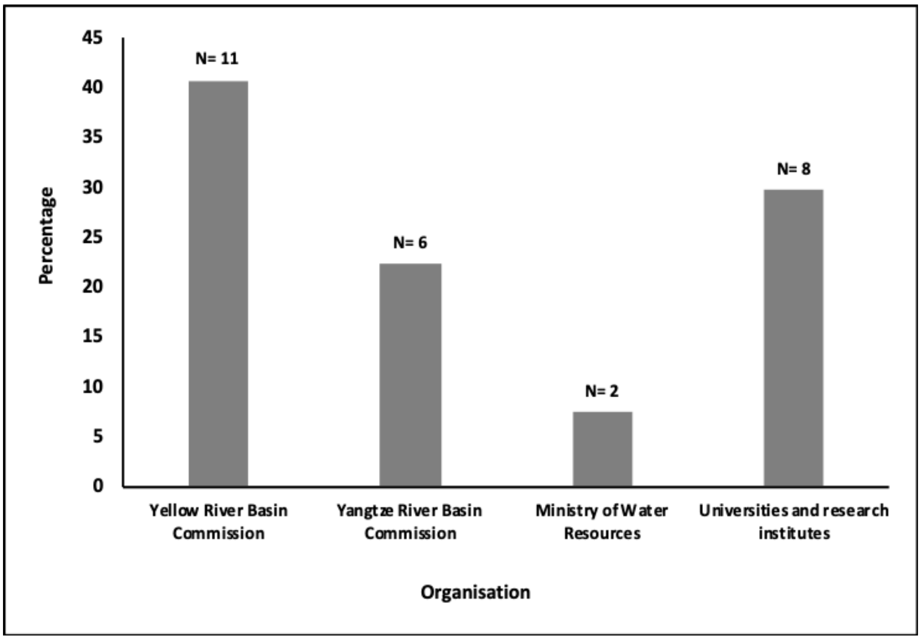

Fig 3. Interviewees by organisation (N=27)

The interview protocol was adapted from relevant studies on climate services (Bruno Soares, 2018; Dessai and Bruno Soares, 2015), focussing on long-term climate information. This protocol addressed the following two interview themes:

1) The climate information currently used to support water resource decision-making, particularly long-term climate information;

2) Long-term climate information that interviewees would like to access if available.

A total of ten interviews were conducted in English, whilst seventeen were conducted in Mandarin and then translated into English. Transcriptions were prepared for qualitative thematic analysis in line with the interview themes above. Coding was principally deductive, with themes having been identified through the preceding workshop and a review of existing literature and previous studies. However, where new themes emerged, an inductive approach was taken.

3. Findings

3.1. Current use of climate information

- **Water managers' timescales of interest**

The interviewees in our sample held responsibility for different types of water management decisions such as issuing flood warnings, forecasting floods, designing dams and planning water allocation. Interview data showed that weather forecasts are used for day-to-day operational activities and for emergency responses such as flood emergency plans and flood warnings. Seasonal forecasts are used to support longer planning of up to 12 months, such as annual flood forecasting, annual water allocation plans, and operation plans for dams. Historical hydrological and climate data are used by water managers for strategic planning purposes such as dam design. Decadal climate predictions and climate change projections are only used by hydrologists and water-related researchers in universities and research institutes. This finding is supported by the outcomes of 26 interviews (Figure 4). In this context one expert from a flood and drought disaster prevention department, said: *"We need rainfall (1 day to 2 days- up to 3 days) to forecast rain up 1 to 3 days to support flood emergency plan and flood warning. We are also concern about seasonal forecasts to know whether we have drought in the following year. However, longer than one year is not used in our department and maybe it is used in research".*

Another expert, a hydrology forecaster from the Hydrology Bureau of the Yellow River Basin Commission, said: *"We are responsible for mid-term (7-10 days) and long term (3 months to max 1 year) forecasting. Therefore, seasonal climate forecasts are used to support short term planning like annual flood control and annual water allocation plans".* A water manager from the Hydrology Bureau of the Yangtze River Basin Commission stated: *"We use seasonal forecasts to provide flood forecast for one year and this forecast is used by the flood and drought prevention department to control flood during following rainy season.*

Moreover, it is used by the water resource management department to support annual water allocation plan".

A water manager of the South-North Water Transfer Project from the China Institute of Water resources and Hydropower Research (IWHR) said that: *"Weather, seasonal and historical climate data are used by water managers in China. We use hourly data (next 6 hours) to forecast precipitation to change the speed of our pumps and release the water. We would prefer to use maximum next year data (from November to next October) to decide on releasing water and more than one year is uncertain for making these kinds of decisions.*

Seven out of eighteen water managers were from the Yellow River Basin Engineering Company, one was from the Hydropower Planning and Operation Department. All eight water managers were responsible for water reservoir design and water allocation planning, and all these interviewees confirmed that historical climate data is used for these purposes. The Yellow River Basin Engineering Company provides technical support for the Department of Planning in the Yellow River Basin Commission which is responsible for water infrastructure design. A manager from this company mentioned that: *"Our main responsibilities is providing technical support for dam designing and water allocation plans in the Yellow River Basin Commission. We have designed some parts of middle line of the South to North Water Transfer Project. We use historical data (last 30 years) as the input to our water allocation model (in-house developed model). Runoff and sediment are our input for the water allocation model and it is provided by Hydrology Bureau of the Yellow River Basin Commission".*

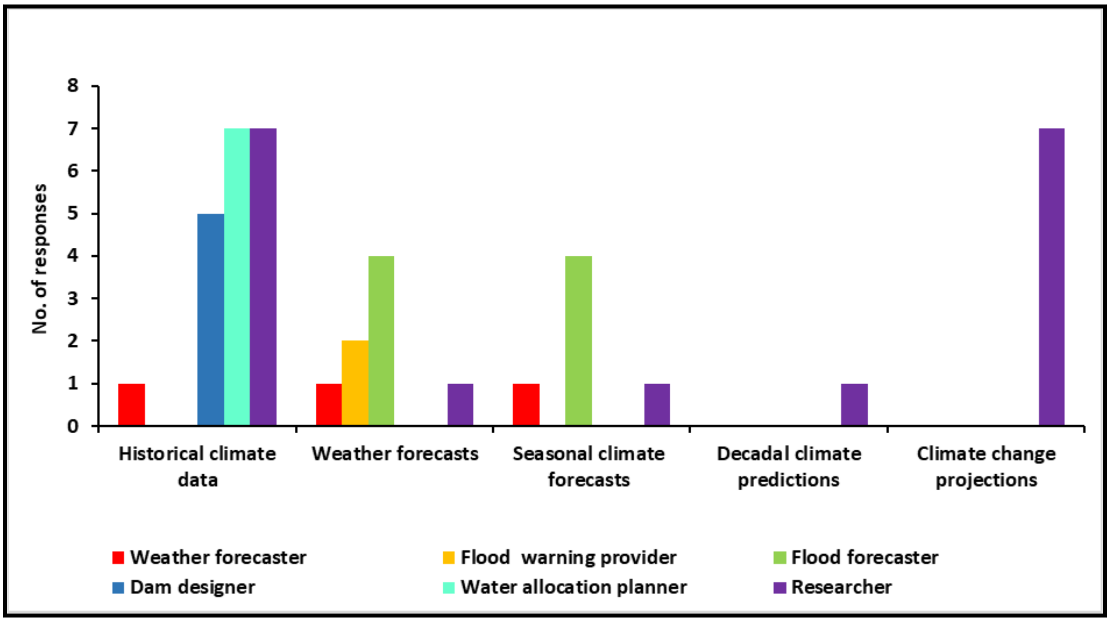

Fig 4. Various types of climate data used in the water sector in China (N=26)

The interviewees were further questioned about their reasons for not including climate change projections in their water resource decisions. The main reasons given by interviewees are: lack of legal framework, gap between research and practise, uncertainty of climate change projections (Figure 5). These results are fairly consistent with other studies such as Rayner (2019), O' Connor et al (2005) and Dow et al., (2007).

Four interviewees stated that historical data is used for decision making at the basin level due to existing laws and river basin planning guidance (National standard for water resource planning). One interviewee confirmed this by saying that *"We use historical data based on the Code for river basin planning (SL201-2015) for all kind of planning in the basin like water infrastructure designing. We use data from 1956 to 2016 for our models and we think these real data is more reliable"*.

Six interviewees, mostly from research institutes and universities, stated that there is a gap between research and practice. One interviewee from the Yellow River Basin Engineering Company with a research background (who used climate change projections in writing the PhD thesis) added: *"In practice we use data which is simple and we can combine it with our own experience. Historical data is easier to use and more accurate because it is what has happened. Moreover, our water managers are not familiar with climate change projections"*.

Ten interviewees stated that more than one-year climate data is not reliable to use in water management decision-making. One interviewee mentioning that: *"We provide forecast for one year and deliver it to the water resource management department for water allocation planning but they say this one-year forecast is not certain and reliable, therefore, more than one year is not applicable for our purpose."*

Three interviewees who were hydrologists and researchers, perceived that water managers do not believe in climate change, and this could be another reason that they do not trust climate projections and rely on historical observed data instead. We also found a blurred understanding and confusion regarding the meaning of climate change projections (cf. Bruno Soares et al. 2018). There appeared to be a misconception amongst water managers that climate projections can produce future climate conditions accurately and at precise spatial and temporal scales. This is consistent with literature such as that by Lackstrom et al., (2016) and Mehta et al., (2012) which confirmed that the differences between climate scenarios and forecasts should be clarified through raising awareness.

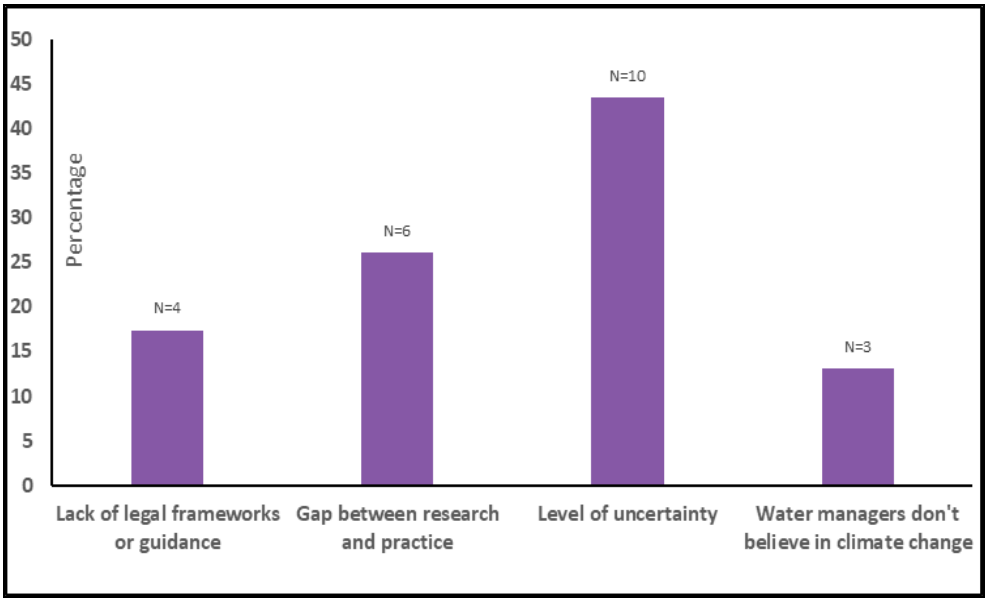

Fig 5: Reasons for not using climate projections in decision making in the water sector in China

- **Climate and hydrological variables**

Use of variables differs by application as well as between decision-making and research. Interviewees indicated that runoff, sediment and rainfall are the most frequently used climate and hydrological variables in China's water sector. Humidity, wind, and radiation are mainly used in research. This distribution is shown in Figure 6.

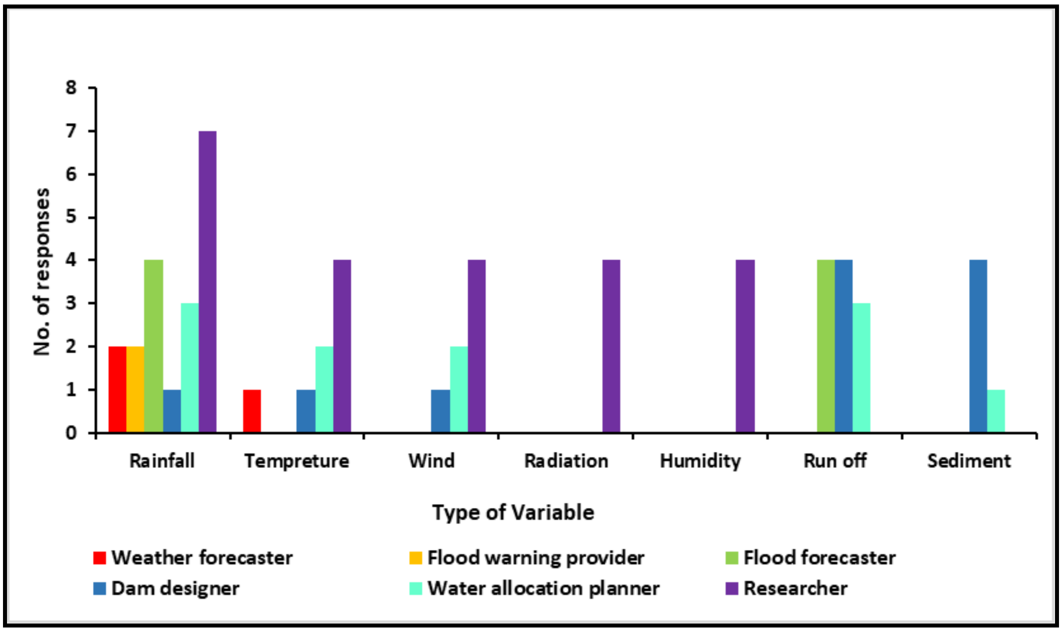

Fig 6. Type of climate and hydrological variables used by the water sector in China

- **Source of data**

Water managers and researchers rely on different sources of information. Water managers receive most of their meteorological data from the CMA, and their hydrological data from the Hydrology Bureau of the Ministry of Water Resources (MWR). This hydrological data is observed by hydrometric stations across the basin, and one interviewee mentioned that these hydrometric stations are the responsibility of the MWR. The CMA appears to be the main provider of weather and seasonal climate forecasts for water resource decision-making in China. However, they are not the only provider of climate data as rainfall and temperature data are also provided by the MWR. An interviewee from the Hydrology Bureau said: *"We get part of our temperature and rainfall from the CMA and part of them from our organisation. These two organisations' climate data complement each other as the CMA has more stations in some areas and for some areas, the MWR has more stations."*

Researchers using climate change projections indicated that their data was sourced from multiple organisations including; the European Centre for Medium-Range Weather Forecasts (ECMWF), and the National Aeronautics and Space Administration (NASA) (Figure 7). As ECMWF is principally a provider of climate information at seasonal and sub-seasonal timescales, it is curious that that this organisation was named as a source of climate projection data. This could indicate either a conflation of ECMWF with the related but distinct Copernicus Climate Change Service platform, or that some interviewees perceived long-term to refer to seasonal timescales. Foreign sources appear to be preferred by researchers for climate projections, whilst national sources are preferred by water managers in China.

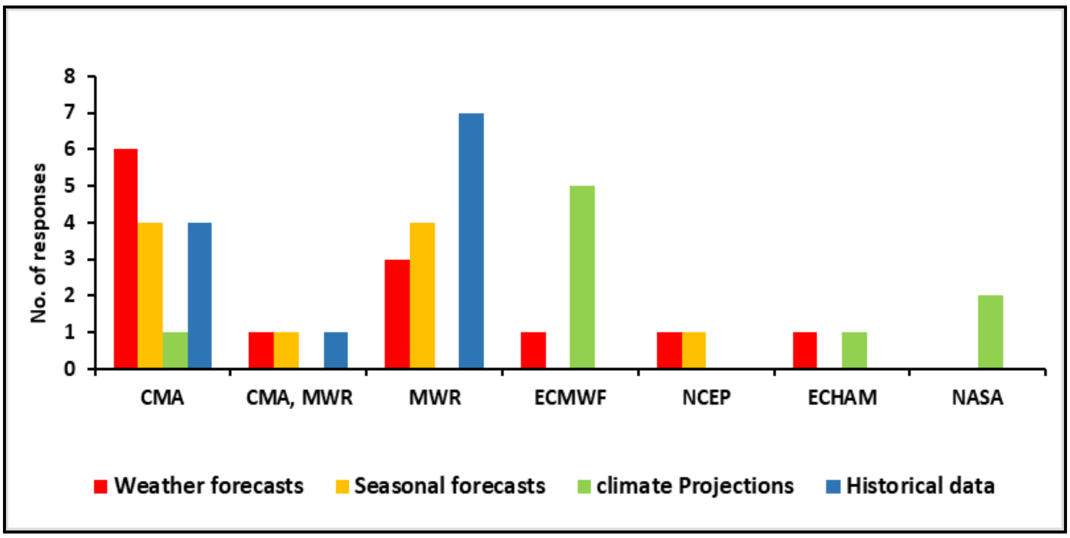

Fig 7. Source of weather and climate information per type of data/information across respondents (N=26)

3.2. Long-term climate information needs

Interviewees were asked whether they were aware of the climate change projections provided by the CMA, and whether they had reasons for not using it. Only two of the eight researchers interviewed were aware that the CMA provided regional climate projections as the data is not online available. One explained why they knew of these projections, saying: *"As we have some collaborative projects with the department of climate change in the CMA, therefore, we are aware of the RCM (Regional Climate Model) data which are produced by CMA."*. Three reasons were given for not using these projections, namely accessibility, detail provided, and robustness.

- **Demand for more accessible data:**

The lack of online availability and requirement to request projections added to perceptions of accessibility. One researcher from the IWHR indicated that: *"We use open source data like NASA which is easy to access. Moreover, NASA introduce their data but the CMA doesn't introduce their data and we don't know these data downscaled by the CMA."*

- **Preference for climate change projections with different timescales and more variables**

Three researchers mentioned that the CMA's climate change projections were limited to precipitation, minimum temperature, mean temperature and maximum temperature. These researchers expressed a need for additional variables such as humidity, wind speed and radiation. They also mentioned that only monthly data was available, but their research projects required different timescales such as hourly or daily. As expressed by one researcher: *"These monthly simulation data (The CMA's projections products) are only suitable for exploring long term change or for projecting water availability (quantity of water), however, my research is about extreme events in China and I need daily data."*. Another interviewee clarified that: *"The current focus of water issue in China is on the water quantity and evaluation of water availability."*

It is worth noting that while researchers indicated a demand for projections concerning humidity and wind speed, these variables were not of interest to water resource managers. This is shown in Figure 7. Whilst the water managers in our sample did not currently consider climate projections, raising awareness of the value of this data was seen to be important in developing climate services for this group.

- **Improvements in robustness of data**

Three researchers were concerned that CMA data may not have received the same level of scrutiny for robustness as other sources. With regard to this specific concern, one researcher stated: *"I don't know to what extent the CMA's projections are reliable, as I have not seen it has been used in any research. NASA produces a lot of publications and introduce their data. I do care about availability and reliability of data, however, the CMA projections are not open access and have not been introduced to the researchers by publications."*

4. Discussion

Results of the interviews show weather forecasts are the most used climate data for operational day-to-day activities, a finding that is consistent with previous studies in Europe such as that by Bruno Soares et al. (2018), whilst seasonal forecasts and historical climate data are used for shorter-term and longer-term planning in the basins. Weather, seasonal forecasts and historical data are, therefore, the most used climate data by the water sector in China. The availability of climate data and forecasting can play an important role in water resource decision making such as flood control and disaster relief. For example, flood control in China relies mainly on flood warnings and annual flood forecasting, and this requirement is serviced by the CMA. This finding is consistent with Golding et al., (2017) who found that seasonal data is more available and accessible for users in China's Climate Services than other longer timescales because the CMA has a strong focus on seasonal forecasting with a wide range of operational services.

Rainfall, temperature, runoff and sediment are the most frequent variables used in water resource decision making. While sediment and runoff data are applied to long-term planning, such as dam design and water allocation, rainfall and temperature are used for operational activities and flood forecasts. Humidity, wind and radiation on the other hand are mainly used in research. One conclusion that arises from this is that water managers use hydrological variables more than climate forecasts due to their greater familiarity with that data; this conclusion is consistent with those of previous studies such as Knopman (2006), Vandersypen et al., (2007) and Feldman and Ingram (2009).

In terms of data sources, the CMA and MWR are the primary sources for weather and seasonal climate information. Consequently, the CMA is not the sole provider of climate information to the water sector (Opitz-Stapleton et al., 2016) as the MWR provides hydrological variables such as sediments, run off and water levels in addition to some climatological data such as air temperatures and rainfall from their gauging stations. This daily collected data is published by the Hydrological Bureau of the MWR in a Hydrological Annual Book. The interviews showed that, in China, there is close communication between users in the water sector and one data provider (CMA) about weather and seasonal climate information. This has also been confirmed by Golding et al., (2019) who evaluated seasonal forecast climate services in the Yangtze River Basin and found out that many users are engaged and regularly attend consultation meetings to receive forecast information.

A key theme that emerged in this study was the gap between research and decision making. The findings show that researchers are the main users of climate change projections in the Chinese water sector. This confirms the work of other scholars who showed that historical data rather than climate change projections are the basis for most water resource planning in China (He, 2013). This may be explained by water resource managers' expectations of future problems being closely linked with past experiences (O'Connor et al., 2005, Rayner, 2019). Despite the potential benefits that climate change projections offer to the water sector, previous research shows that most water managers in China are not familiar with climate change projections. The different types of information used by water managers and researchers would be a factor to consider when designing a platform to bring them together to understand each other's requirements. Such a platform would also help water managers to become familiar with the benefits of integrating climate change projections in water sector planning.

The gap between research and decision-making has also been experienced in other regions and countries such as South Africa (Waagsaether and Ziervogel, 2011) and South Australia (Rayner, 2019). The latter study focused on the use of climate information by South Australian water managers and concluded that extensive efforts have been made to downscale long-term climate models, but that these had fewer impacts on day-to-day water resource management due to institutional pressures that make it difficult to incorporate such information into existing organisational routines. This means, *ceteris paribus*, that even when useful knowledge and tools exist, there is poor adoption of adaptation strategies (Marshall et al., 2011). A program was set up under the South Australian Climate Change Adaptation Framework to promote climate change awareness amongst policy makers, and encourage adaptation planning to timescales on which adaptation decisions would have to be (Rayner 2019). Similar efforts to raise awareness have also been undertaken in South Africa (Waagsaether and Ziervogel, 2011). Given such international programmes, it follows that an exercise to raise awareness amongst China's water sector could influence their adoption of long-term climate information.

Researchers were asked about the sources of the climate change projections they used. Foreign sources appear to be preferred for climate projections, whilst national sources are preferred for other types of climate data. The use of external sources of climate information is not necessarily a problem, but it points to a critical evaluation of the service (Golding et al., 2019). In addition, most researchers were not aware that the CMA works on climate change projections, and were more aware of the weather and seasonal forecasts that the CMA produces. Interviews confirmed that there is no communication between users and providers in terms of climate change projections. In terms of data reliability, one researcher claimed not to know how reliable the CMA's projections were. Golding et al., (2019) assessed the use of seasonal forecasts in the Yangtze River Basin and highlighted that close cooperation, good communication, and open dialogue could raise trust and understanding of data as well as improve confidence in making use of the forecasts. Other scholars similarly confirmed that high levels of interaction among producers and users can facilitate adoption (Kirchhoff, 2013; Rayner, 2019). Therefore, an open dialogue and communication between users and providers can, *ceteris paribus,* enhance confidence and reduce objections to using climate change projections in China.

Researchers as the main users of climate change projections expressed a desire for accessible climate change projections, particularly those that contained different time scales such as daily and hourly, or more variables such as humidity, wind speed and radiation. The feasibility of producing these timescales and variables should be investigated jointly by users and providers through a model of 'co-production' of climate services. Under this model, users and climate scientists would need to work collaboratively to produce suitable information (Lemos and Morehouse, 2005; Finnessey et al., 2016; Buontempo et al., 2018; Vincent et al., 2018). In this model, users clearly voice their needs and providers develop information specifically targeted to meet those needs (Lemos and Morehouse, 2005; Dilling and Lemos, 2011). Research on climate service co-production emerged for the first time in the USA about 15 years ago in response to a policy imperative for more useable climate information by decision-makers (Bremer et al., 2019). Use of the co-production model between users and providers can be found elsewhere such as in South Carolina (Carbone and Dow, 2005), and the United Kingdom (DEFRA, 2018) where climate scientists meet regularly with stakeholders from various government bodies.

5. Conclusion

A qualitative methodology was used to investigate and understand the use of and need for climate information by the Chinese water sector. A broad range of decisions are made by the sector, and these decisions require data from different sources with different timescales and variables. Differences in data sources, timescales of interest and use were particularly apparent between researchers and water managers. The results show that weather forecasts, seasonal forecasts, and historical data are more frequently used by water managers in China, whilst climate change projections and decadal climate predictions are only used by researchers. An important implication of this is that longer-term planning decisions are being informed by historical climate data, which by definition cannot capture future – and potentially unprecedented - climate change impacts. However, amongst water sector researchers there did appear to be a growing demand for climate projections that were more accessible and robust, with more variables and more timescales. Together, this highlights the need to work with water sector managers to explore the potential added value that climate change projections could provide to water resource planning in China, alongside historical data.

To achieve greater uptake of climate projections it may be necessary to strengthen the dialogue between climate projection providers, hydrological researchers and water managers Indeed we find that while there is a close dialogue between data providers and users in the water sector in terms of weather and seasonal climate data, and that this data is sourced from the CMA, this is not as apparent for climate change projections. Amongst hydrological researchers climate change projections are currently sourced from multiple external (international) sources due to limitations in accessibility and variables available. A co-productive exercise between data users and the CMA (as provider) could enhance the CMA's climate change projections services. It may also help familiarise water managers with the benefits of climate change projections in their planning, and might also acquaint them with the growing body of hydrological research which has been produced by researchers in China. Raising awareness of climate change and adaptation planning under the Climate Change

Adaptation plan will have to be made in the future. In addition, it encourages the further integration of climate change considerations into the long-term planning. While these findings are China specific, they do highlight broader challenges in the uptake of climate change projections.

Credit authorship contribution statement

Fatemeh Khosravi: Investigation, Analysis, Writing - original draft. **Andrea Tylor:** Methodology, Supervision, Review & editing. **Yim Ling Siu:** Project administration, Funding acquisition, Review & editing.

Declaration of competing interest

The authors declare no conflict of interest.

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