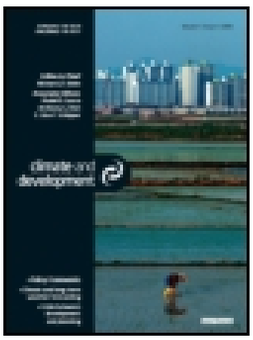
Event attribution science in adaptation decision-making: the context of extreme rainfall in urban Senegal



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Event Attribution science in adaptation decision-making: the context of extreme rainfall in urban Senegal

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ABSTRACT

Event attribution assesses the effect of climate change on individual extreme events. While scientists have suggested that results could be relevant for climate adaptation policy, this has had little empirical investigation, particularly in developing regions. Taking the case of Senegal, the national adaptation policy context regarding extreme precipitation and flooding in urban areas, and the scientific information needed to support this policy is investigated using key informant interviews, a workshop and document analysis. Flooding in Senegal was found to be viewed primarily as an urban planning concern rather than a climate change issue, with actions to address the impacts focussing on current vulnerabilities of urban communities without considering changing climate risks. While stakeholders thought event attribution might be useful to inform about climate change impacts and future risks of extreme events, it is unclear whether there would be an opportunity for this at present, due to the limited role climate information has in adaptation decision-making. While addressing vulnerability to extremes is necessary whether or not the risk is climate change-related, if long-term planning is to be resilient then knowledge about future changes in risks of extremes will need to be considered, even if individual events are not attributed to climate change.

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1. Introduction

In developing countries, people's lives and livelihoods are particularly vulnerable to extreme weather and climate events (Cardona et al., 2012). Alongside factors such as poorly planned development, poverty and environmental degradation, climate change can increase the risk of a weather event becoming a disaster (World Bank, 2013). Understanding the influence of anthropogenic climate change on extremes is therefore vital for the management of climate risks (Lavell et al., 2012), especially as such events may help motivate adaptation decision-making to address climate change (Berrang-Ford, Ford, & Paterson, 2010). However, extremes will only be a useful guide if they signal the underlying climate trend (Travis, 2014). Otherwise, decisions could be made leading to maladaptation and greater vulnerability in the future (Barnett & O'Neill, 2010) if, for example, adaptation plans erroneously assumed an event would increase in frequency or intensity.

Event attribution science aims to quantify the impact of drivers such as anthropogenic climate change on individual extreme events, and therefore may be able to provide useful information for those making adaptation decisions focussing on the impacts of extremes (e.g. Stott et al., 2013). However, there has been little consideration of application in national level adaptation policy-making beyond academic debate, particularly in developing country contexts. Sippel, Walton, and Otto (2015) found some interest in event attribution results among a small sample of adaptation stakeholders across Europe. Schwab, Meinke, Vanderlinden, and von Storch (2017) carried out a more in-depth study with regional decision-makers addressing storm surges along the German Baltic Sea coast and heatwaves in the Greater Paris area, and found interest in event attribution for raising awareness of climate change impacts to motivate mitigation, for political leverage and to inform public climate change discourse. This paper carries out an in-depth investigation into perceptions of the relevance of this scientific technique in a developing country context, focussing on national adaptation decision-making addressing flooding in urban Senegal.

While climate information may inform adaptation decisions, many other considerations including resource management, involvement of different stakeholders, and long-term economic development may be taken into account (Dilling & Lemos, 2011; Pegasys, 2015). Therefore this paper also looks to understand more generally the adaptation policy context in Senegal, including the structures in place and stakeholders involved, to establish where event attribution information could play a role if deemed relevant by those involved.

1.1. Event attribution and adaptation policy

Probabilistic event attribution (Allen, 2003) looks to assess how the probability of an event has been affected by climate change. This can be done using climate model simulations to compare the probability of the event occurring in models of the actual world and a world without anthropogenic greenhouse gas

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emissions (e.g. Bellprat et al., 2015; King et al., 2013; Stott, Stone, & Allen, 2004). Any change in probability can be attributed to emissions, helping generate understanding of how climate change is currently influencing extremes. Suggested uses for event attribution results include informing loss and damage policy (e.g. James et al., 2014), liability (e.g. Allen, 2003), to raise awareness of the impacts of climate change (e.g. Stott et al., 2013), improve climate change understanding (Stott et al., 2013), encourage mitigation (Janković & Schultz, 2017) and for insurance (Sippel et al., 2015). However, studies have yet to substantially contribute to any of the areas where its relevance has been promoted (Lusk, 2017).

The relevance of results for adaptation policy has been suggested by both scientists developing event attribution methodologies and stakeholders associated with international loss and damage negotiations (Parker et al., 2017). Specifically, results could inform about whether events are likely to increase or decrease in frequency in the future (Otto et al., 2015). This could help reduce the risk of maladaptation by guarding against adapting to events where anthropogenic climate change has decreased their probability and which are therefore likely to decrease in occurrence in the future (e.g. Otto, Jones, Halladay, & Allen, 2013; Stott et al., 2013; Stott & Trenberth, 2009; Stott & Walton, 2013). Climate policy stakeholders have also suggested results could be relevant for adaptation in highlighting the impacts of climate change on current risks as well as in the future (Sippel et al., 2015). Furthermore, results could help guide and prioritise resource allocation for adaptation actions (Hoegh-Guldberg et al., 2011; Huggel, Stone, Eicken, & Hansen, 2015), or be used within a risk-pooling and climate risk insurance framework (Boran & Heath, 2016).

In contrast, Hulme, O'Neill, and Dessai (2011) argue that event attribution would not be relevant for adaptation policy. They claim it may lead to a focus on global climate funds being allocated as compensation for attributable events, considering only the climate change aspect, rather than the overall risk including the vulnerability of those affected. Other scientists support this view, along with stakeholders addressing the impacts of extremes, who argue that addressing drivers of vulnerability is more important than establishing causes of events (Parker et al., 2017; Surminski & Lopez, 2015). Thompson and Otto (2015) emphasize that event attribution studies consider the impact of climate change on the probability of the event only at the time it occurred, so may not be appropriate for decision-making on longer timescales.

Schwab et al. (2017) found that among regional decision-makers in Germany and France who focussed on climate change adaptation, mitigation and risk management, while there was a general interest in extreme event attribution they did not think it directly relevant to their own fields. Reasons included needing to address the impacts of events regardless of the causes, or already knowing humans are partly responsible and not requiring exact numbers to quantify the contribution.

1.2 A case study of Senegal

Senegal is one of the UNFCCC's 48 least developed countries (UNFCCC, 2014). Along with many other countries in sub-Saharan Africa, it is vulnerable to climate change due to its weak state capacity, financial constraints and reliance on rainfed agriculture (Castells-Quintana, del Pilar Lopez-Uribe, & McDermott, 2015). Senegal's climate is characterized by a rainy season driven by the West African monsoon bringing the country's rainfall during June to September (Fall, Niyogi, & Semazzi, 2006; Funk et al., 2012; Rust, Vrac, Sultan, & Lengaigne, 2013). Senegal experienced a decrease in total precipitation in the 1960s and 1970s, followed by a slight increase (Fall et al., 2006; Funk et al., 2012) and New et al. (2006) suggest that rainfall intensity has also increased across West Africa in recent decades. There is some uncertainty around the causes of this increase in precipitation: Dong and Sutton (2015) found that increased greenhouse gas (GHG) concentrations had likely been the main cause of the recovery in rainfall across the Sahel since the 1980s, although other studies suggest warming sea surface temperatures in some regions due to GHGs may decrease Sahelian precipitation (e.g. Bader & Latif, 2003). Giannini et al. (2013) explained the partial recovery in precipitation by the reversal to warming of the subtropical North Atlantic, which is now out-pacing warming of the global tropical oceans. They found this recovery to result from increases in daily rainfall intensity, rather than in frequency, most evidently in Senegal.

There is also much uncertainty around how rainfall will change in this region in the future, with little model agreement in terms of both mean precipitation (Christensen et al., 2013) and extreme events (Seneviratne et al., 2012). Furthermore, there have been few attribution studies of specific events in Africa and this region presents challenges for studies through observational and modelling uncertainties (Otto et al., 2015). However, a study has investigated seasonal rainfall over West Africa in 2012, showing that the probability of high precipitation in that year was likely decreased due to anthropogenic climate change (Parker et al., 2017).

Extreme rainfall in Senegal often results in flooding, which particularly impacts low-lying urban areas and can occur frequently during the rainy season. Senegal's National Adaptation Programme of Action highlights this risk. It can result in damage to infrastructure and homes, health problems, and people relocating (Ministère de l'Environnement et de la Protection de la Nature, 2006). From 1980 to 2009, floods in Senegal impacted more than 900,000 people, caused 45 deaths and led to property damage estimated at more than US$142 million (Ministère de l'Environnement et du Developpement Durable, 2015). In 2012, heavy rainfall led to flooding across the country affecting more than 280,000 people, with 19 deaths reported, over 10,000 houses destroyed or damaged, 5000 families displaced, and drinking water sources contaminated, and the national emergency plan, ORSEC (d'Organisation des Secours, Organisation of Relief), was launched (OCHA, 2012).

While rainfall and topography are key drivers of flooding, complex human factors also have roles in Senegal and many other sub-Saharan cities. These include rapid urbanization, in part increased by decreasing rainfall trends, leading to reduced infiltration, uncontrolled settlements in flood-prone areas which obstruct natural drainage channels, and inadequate and poorly maintained rainwater drainage infrastructure in suburbs (Barrios, Bertinelli, & Strobl, 2006; Diagne, 2007; Government of Senegal et al., 2010; Government of Senegal and

World Bank, 2013; Mbow, Diop, Diaw, & Niang, 2008; UNISDR, 2013; World Bank and GFDRR, 2011). These areas make up around 30–40% of the cities (Government of Senegal, 2014). Residents are often poor and particularly vulnerable as flooding can have large impacts on their housing, economic activities which are often low-income, education and health (Government of Senegal et al., 2010; Sané, Gaye, Diakhaté, & Aziadekey, 2015).

In Senegal, while land use remains the responsibility of the government, urban development governance has been decentralized (Mbow et al., 2008). Vedeld, Coly, Ndour, and Hellevik (2015) found a lack of support from higher to lower-level government for climate adaptation, a lack of political guidance from the national level and a shortage of financial resources. In Mumbai, India, despite lacking national support for addressing flooding there is adaptive capacity among local groups (Boyd & Ghosh, 2013), however, Schaer (2015) described how local adaptation strategies employed in urban Senegal can often be maladaptive, and do not compensate for a lack of infrastructure.

1.3. Research questions

This paper considers whether event attribution could inform national adaptation decision-making regarding extreme precipitation and flooding in urban Senegal. The following sub-questions will be addressed:

Q1. What are the perceptions of the drivers of vulnerability to flooding events?

Q2. How are flooding events perceived in the context of climate change?

Q3. Who are the important and influential stakeholders working on adaptation and related issues?

Q4. What information is relevant to these stakeholders regarding extreme precipitation and flooding?

Q5. What are the barriers and opportunities to event attribution informing adaptation decisions?

2. Methods

Three research methods (interviews, a participatory workshop and document analysis) were selected to elicit specific information and triangulate findings. As the case study focusses on national adaptation policy, key informants included national-level decision-makers, researchers and civil society representatives.

2.1. Interviews

Interviews were carried out with stakeholders involved in, and associated with, national adaptation decision-making, and relevant researchers. Interviews investigated how stakeholders perceived the 2012 floods, including both the drivers of vulnerability and the event in the context of climate change (Q1 and Q2). They were also used to map out the important stakeholders (Q3), to gain in-depth understandings of national adaptation policies and the scientific information used and required for these (Q4), and to investigate whether event attribution could play a role in future decision-making in this context (Q5).

Interviews were semi-structured and identified through existing contacts and a snowball-sampling technique (Atkinson & Flint, 2004). Twenty-three people were interviewed between February and August 2016. Stakeholders included government ministries ($n = 10$), government research organizations ($n = 4$), non-governmental research organizations ($n = 6$) and civil society ($n = 3$). Transcripts were coded using NVivo version 11 software (QSR, 2015), with a thematic analysis (Braun & Clarke, 2006) used to identify key themes.

2.2. Stakeholder workshop

To complement the interviews, a workshop was held in Dakar, Senegal in February 2016 on the theme of event attribution science and its relevance for national adaptation policy in Senegal (see Appendix A for workshop agenda). It brought together 40 participants from government ministries, non-governmental organizations (NGOs) and research institutes in Senegal alongside researchers from the UK. Senegalese participants were identified by gatekeepers hosting the workshop and included 11 representatives from the Direction of Environment and Classified Establishments (including 6 from the Department of Climate Change) and 8 from other government ministries responsible for water and flood management and urban development. There were also 13 climate researchers present and 3 NGO participants working specifically on climate change issues and 2 on development.

The workshop was participatory, involving the sharing and co-production of knowledge to enhance engagement (Jones, Roux, Scott, & Tanner, 2014). At the start, delegates filled in a short questionnaire about their understanding of the links between climate change and extreme events ($n = 23$). Next, results from an event attribution study of 2012 West African rainfall (Parker et al., 2017) were presented and discussed. CAULDRON, a participatory game designed to communicate the science of event attribution, was then played (see Parker et al., 2016 for more details and www.walker.ac.uk/projects/the-cauldron-game for materials), with the aim that reflections on the game might lead to more in-depth discussions about the science and policy. Discussions then took place in randomly assigned groups, each adding responses to large pieces of paper (see Appendix B for photos). This gave each group, and each member, a chance to provide their answers in an attempt to include the concerns of all voices (Barbour, 2007) and also helped engage all members of the group (Krueger & Casey, 2009). Groups identified key actors involved in putting adaptation policies in place and using scientific information (Q3) and discussed whether and how extreme events and attribution results could be integrated into adaptation policy (Q5).

2.3. Document analysis

Policy documents, reports and media articles were analysed. Government and NGO documents on national adaptation strategies provided information on the adaptation decision-making background in Senegal and on particular policies and

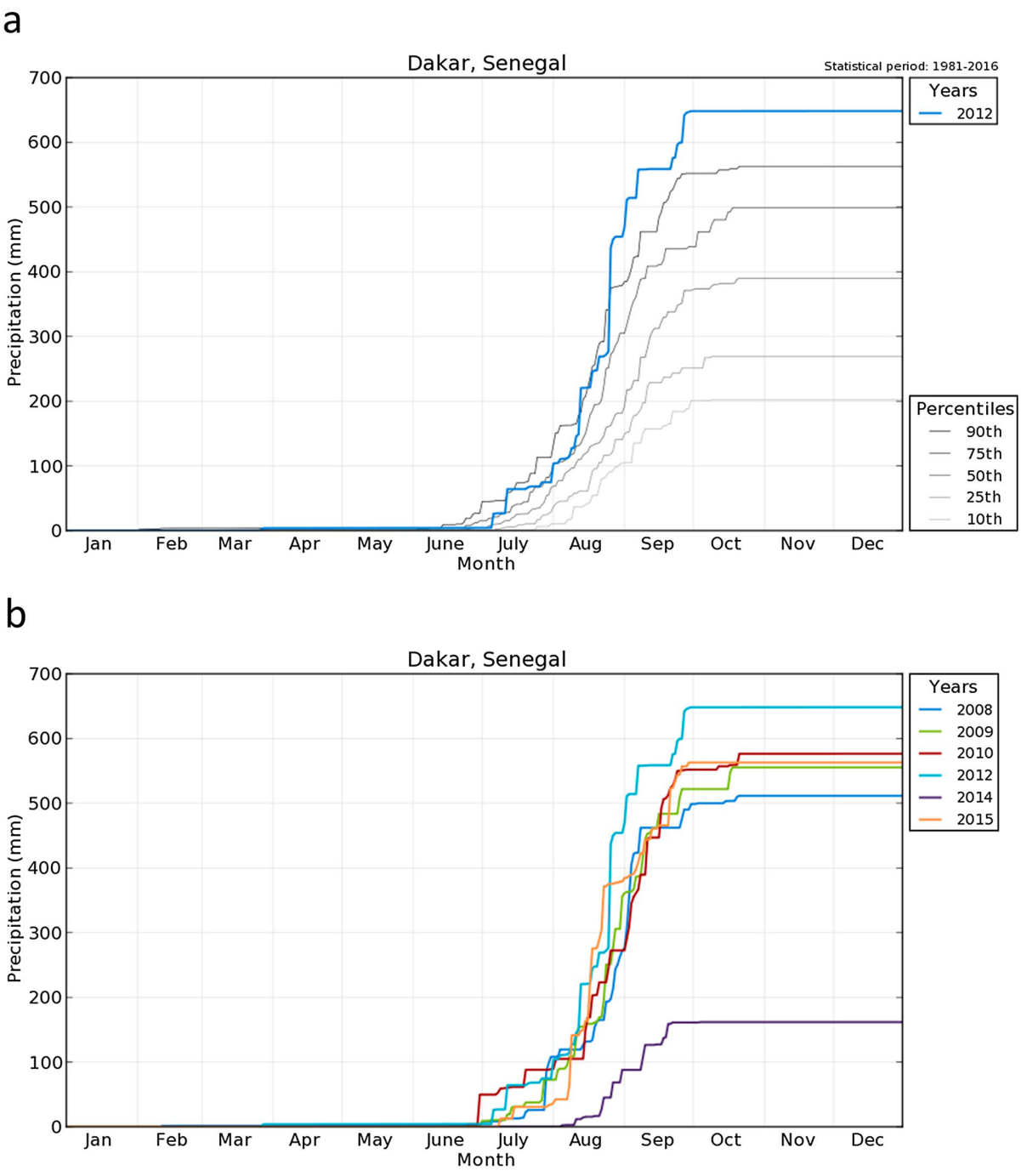

Figure 1. Cumulative precipitation in Dakar, Senegal in 2012 compared to (a) percentiles from 1981–2016 period and (b) other recent years for which all data was available. From RAINWATCH (Boyd et al., 2013; Tarhule, Saley-Bana, & Lamb, 2009), operational across West Africa (http://www.rainwatch-africa.org/rainwatch/, accessed 9 January 2017) and operated by ANACIM (National Agency of Civil Aviation and Meteorology) in Senegal.

projects. Online news articles from five of the major Senegalese online news sites (Agence de Presse Sénégalaise, Le Quotidien, Le Soleil, Sud Quotidien and Wal Fadjri) were also analysed. These were used to further investigate narratives around how extreme rainfall events were related to climate (Q2) and the adaptation strategies regarding flood events reported on. Articles were selected by searching, in French, 'climate' AND 'rain OR precipitation OR flood' or 'flood management', narrowed down to 'climate change' AND 'flood risk management plan' where necessary. The articles were translated into English and irrelevant ones discarded, leaving 91 articles for analysis. These were coded using NVivo software (QSR, 2015) and a thematic analysis (Braun & Clarke, 2006).

3. Results

3.1. How extreme rainfall events are perceived in Senegal (Q1 and Q2)

What stakeholders perceive the drivers of extreme rainfall events to be could influence how the impacts are addressed and the relevance of climate information to support such

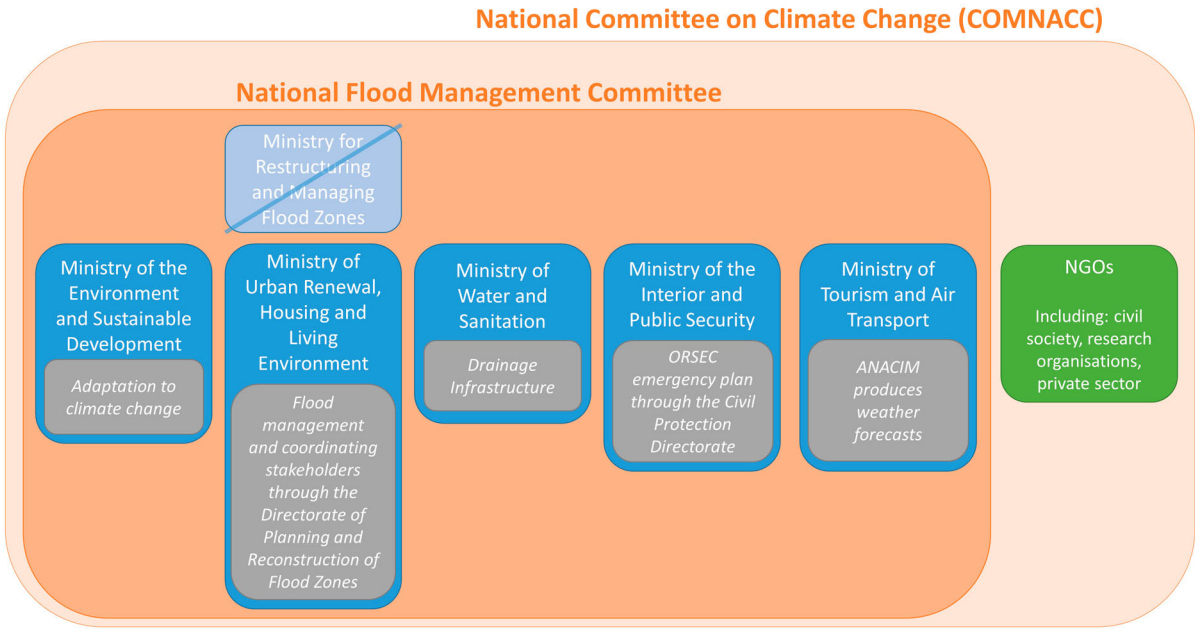

Figure 2. Stakeholders involved in climate change and the management of flooding events in urban Senegal. Blue boxes represent the key government ministries (pale blue no longer exists) and grey their primary roles.

decisions. The majority of stakeholders believed climate change was affecting precipitation in Senegal, in ways such as changes in the timing of the rainy season, more heavy rainfall events and floods, and also more droughts. The questionnaire revealed that many thought rainfall such as that in 2012 was more intense than normal for Senegal's climate, but was 'becoming normal' for urban areas over the past few years. This is reflected in precipitation data for Dakar (Figure 1), which shows that cumulatively 2012 was above the 90th percentile following a particularly heavy event in mid-August. The rainfall total was highest in 2012 compared to other recent years, although others also reached levels around the 90th percentile.

The questionnaire also revealed that 78% of participants believed the 2012 rainfall event was, at least in part, affected by climate change due to there being higher rainfall intensity or totals than normal. While the majority of workshop participants had not heard of probabilistic event attribution previously, they did think that it might be possible to attribute specific extreme events to climate change. In interviews, stakeholders were more uncertain. They highlighted the need for more studies and that climate change is not always the cause of an event, despite reporting a general view in Senegal that all extremes are attributable to climate change.

Stakeholders also emphasized that human actions can have substantial contributions to the impacts of flooding events. They particularly highlighted the building of houses in flood-prone areas and the 'drainage problem, with the city [Dakar] growing and with burgeoning settlement and no real network for run-off' (Researcher, 3/3/16, Dakar). It was noted that even a relatively small amount of rain can lead to flooding in parts of Dakar.

Media articles did not widely report on links between floods and climate change, with less than 20% of articles making comments, including that climate change may lead to more floods, or that natural climate variation is the cause. Other factors affecting flooding impacts were reported on much more, including uncontrolled building in low-lying areas due to a lack of governance, rapid urbanization, and lacking or outdated rainwater drainage infrastructure.

There is recognition of flooding as an impact of climate change in both Senegal's Intended Nationally Determined Contribution (INDC) and the Senegal Emergence Plan (Government of Senegal, 2014; Ministère de l'Environnement et du Developpement Durable, 2015). However the World Bank and GFDRR (2011) claim that while there has been unusually high rainfall over recent years, there is no consistent trend and projections for precipitation are uncertain. The NAPA and the Senegal Emergence Plan (PSE) note that impacts have highlighted and been aggravated by urbanization reducing infiltration, a lack of urban planning and management and weak sanitation networks (Government of Senegal, 2014; Ministère de l'Environnement et de la Protection de la Nature, 2006).

3.2. Adaptation stakeholders (Q3)

Figure 2 highlights key stakeholders involved in adaptation decision-making regarding extreme precipitation and flooding in urban Senegal as identified by interviewees. Other government ministries and NGOs also have some involvement in urban flood management in Senegal, such as the Ministry of Health and United Nations organizations (Schaer, Thiam, & Nygaard, 2018). The Ministry of the Environment and Sustainable Development is 'the focal point for adaptation strategies for the whole country … which coordinates all the activities relating to the climate change issues' (government representative, 3/3/16, Dakar). They do not currently have any mechanisms addressing flooding, and are limited by a relatively small budget (Pegasys, 2015).

The Ministry of Urban Renewal, Housing and Living Environment (MRUHCV) is in charge of flood management policies. The Ministry for Water and Sanitation also has a role through responsibility for drainage infrastructure in urban areas. In 2012, a Ministry for Restructuring and Managing Flood Zones (MRAZI) was put in place (GFDRR, 2014). However in 2014, this was dissolved when the government changed, and responsibility for flood areas transferred to the MRUHCV. Within the MRUHCV, the Directorate of Planning and Reconstruction of Flood Zones (DARZI) office is in place to 'coordinate all the activities about flood issues' (government representative, 29/2/16, Dakar). When an extreme event occurs, the Civil Protection Directorate within the Ministry of the Interior and Public Security are responsible for coordinating emergency actions using the ORSEC emergency plan (Government of Senegal, 1999).

In order to coordinate the actions of different ministries addressing flooding there is a National Flood Management Committee, established in 2009 (GFDRR, 2014) and currently chaired by the MRUHCV. Interviewees explained that managing flooding is a decentralized process and that 'decisions come from the ministry, through the technicians, and are shared with the local government and NGOs to give information, and the local stakeholders are those in charge to appropriate the decision and take action' (Government representative, 3/3/16, Dakar). However, there was concern that local governments do not have the competency or financial means to carry out projects themselves (Government of Senegal et al., 2010). There is also a National Committee on Climate Change (COMNACC), comprising directors of all the ministries, including representatives from ANACIM (National Agency of Civil Aviation and Meteorology) and NGOs including civil society, research and the private sector, which coordinates climate-change-related activities in the country and advises ministries on climate change.

NGOs, including civil society and the private sector, may not be well-represented or have significant influence at the national level. Interviewees from both government and civil society suggested the main roles for civil society were to implement projects at local levels based on government decisions. However, civil society actions even at local levels may not be significant, as 'rainwater needs very heavy investment and those organizations don't have the economical means to support all the costs related to rainwater management' (Government representative, 3/3/16, Dakar).

Many interviewees and media articles commented on a lack of communication and coordination between stakeholders involved in addressing the impacts of flooding. Different stakeholders sometimes intervene in the same issues, such as the installation of rainwater drainage infrastructure, and so 'if we don't have coherence and harmonization we will have duplication in giving responses' (Civil society representative, 2/3/16, Dakar). Interviewees also noted that ministries do not always ask others for advice before acting. For example, the MRUHCV may not consult the Ministry of the Environment and Sustainable Development when planning settlements and this 'day-by-day collaboration is missing' (Researcher, 4/7/16, Skype).

3.3. Addressing flooding impacts in Senegal: mechanisms and climate information used and needed (Q4)

3.3.1. Mechanisms to address flooding

Detail about the actions in place in Senegal to react to and anticipate flood events is in Table 1. As mentioned in Section 3.2, the ORSEC emergency plan can be launched to react to extreme flood events. Two principal actions to anticipate flooding were identified from interviews and documents. Firstly the improvement of drainage infrastructure, as 'there are a lack of channels in some areas and there are also a lack of monitoring of these channels and there is also an increase in people, in population.' (Government representative, 29/2/16, Dakar). Secondly, the relocation of residents from flood-prone areas, and regulation of those zones because 'previously the government didn't care about where the people were settling' (Government representative, 29/2/16, Dakar). It was also noted that relocating people would require their participation and incentives to move, and government should work with local populations to encourage awareness and ownership of adaptation strategies. Projects such as PROGEP (Table 1) and 'Vivre avec l'eau' do aim to involve communities, for example through increasing public participation in waste management to help flood prevention and education on resilience (Agence de Developpement Municipal, 2015; BRACED, 2014).

Some interviewees were critical about actions to address flooding, commenting that nothing, or not enough, was being done to address flooding in the long term. For example, only 4 of the 19 new urban centres planned to be developed between 1995 and 2000 have been so far (Government representative, 3/3/16, Dakar). Media articles also reported that drainage infrastructure work had not been completed.

3.3.2. Weather and climate information used

Interviewees mostly reported that climate information was not considered in policies to address flooding. However, some policy documents supporting these actions do include climate information, such as observed rainfall trends and projections, including the INDC (Ministère de l'Environnement et du Developpement Durable, 2015) and the NAPA (Ministère de l'Environnement et de la Protection de la Nature, 2006) and there is some evidence of observed trends being used in planning drainage infrastructure. Reports describe how it is not possible to determine future changes in extreme precipitation in Senegal due to modelling limitations (Government of Senegal and World Bank, 2013) and actions are taken without carrying out environmental impact or hydrological studies (Government of Senegal et al., 2010).

On shorter timescales, weather forecasts can inform the preparation of the ORSEC plan. ANACIM provide these on daily to seasonal scales. The OMVS (Senegal River Basin Development Organisation) and the CSE (Ecological Monitoring Centre) provide information on areas flooded or prone to flooding, if requested. Following a forecast, it is the government's responsibility to provide any necessary warnings, but while an early warning system for flooding has been planned (Ministère de l'Intérieur, 2015), implementation has been stalled by a lack of

Table 1 . Mechanisms to address the impacts of flooding in urban Senegal (Source: Authors).

	Emergency plan (ORSEC)	Drainage infrastructure (e.g. channels, basins, pumps)	Regulation of building areas and relocation of residents
Policy document background		• INDC: Strengthen sanitation infrastructure and storm water drainage systems in cities • PSE: Restructure flood-prone areas, put in place infrastructure including water drainage systems	• PSE: Relocate people living in low-lying areas and make sure no building takes place in these areas • NAPA: Define which areas should not be occupied and regulate these. • INDC: Plan urban ecosystems including watersheds
Stakeholders involved	• National ORSEC plan led by the Civil Protection Directorate (under the Ministry of the Interior) • Involves all government ministries, civil society and the private sector	• ONAS, Ministry of Water and Sanitation. • Minister of Local Governance, Development and Spatial Planning • ADM	• Ministry of Urban Renewal, Housing and Living Environment (MRUHCV) • ONAS, Ministry of Water and Sanitation • Minister of Local Governance, Development and Spatial Planning
Actions taken	• This is a contingency plan to react when particularly bad flood events occur • Actions include ◦ Pumping water ◦ Temporarily relocating residents (e.g. to school buildings) ◦ Providing food and other social assistance.	• Ten-Year Flood Management Programme, 2012–2022 ◦ identify potentially flooded areas and build infrastructure • PROGEP (Stormwater Management and Climate Change Adaptation Project), 2012–2022 ◦ put in place infrastructure in Dakar suburbs including drainage systems • "Jaxaay" plan (2006-2012) ◦ put in place water drainage systems using emergency pumps • UK aid BRACED project Vivre avec l'eau (Live with water) also working on infrastructure • ONAS constructing drainage systems	• "Jaxaay" plan (2006-2012) ◦ Built >3000 houses in Dakar and other regions for flood victims • Ten-Year Flood Management Programme, 2012–2022 ◦ Relocate populations from flood zones ◦ improve land-use planning policy and develop new urban centres • Put in place new urban centres with infrastructure
Weather/climate information used	• Weather forecasts from ANACIM (government may give flood warning)	• Historical precipitation data used in PROGEP and by ONAS	
Sources	Government of Senegal (1999) and Direction de la Protection Civile (2008); Interviews	Agence de Developpement Municipal (2011, 2015); BRACED (2014); GFDRR (2014); Government of Senegal (2014); and Ministère de l'Environnement et du Developpement Durable (2015); Interviews	GFDRR (2014); Ministère de l'environnement et de la protection de la nature (2006); and Ministère de l'Environnement et du Developpement Durable, 2015; Interviews
Policy needs suggested by interviewees	• Early Warning System for floods	• Restructure areas	• Stop settlements being built in flood-prone areas and relocate people from these • Urbanization plan
Research needs suggested by interviewees	• More accurate forecasts, earlier warnings of extremes • Improved understanding of the causes of extreme events, improved modelling techniques and observations of precipitation	• Map areas prone to flooding • Map the geography of the landscape, including the water table • Understand how extreme events affect the environment • Population data	

funds. A government representative explained that if heavy rain is forecast the Civil Protection Direction calculates their available resources and informs local governors to prepare, rather than actively preparing themselves, as sometimes an extreme event is forecast but does not occur. A civil society interviewee commented that the government does not use seasonal forecasts in the management of floods.

3.4. The relevance of event attribution (Q5)

At the workshop, stakeholders suggested event attribution could be useful for national adaptation policy by evaluating the drivers of events which have occurred, but such tools may need to be adapted for use in specific contexts. In interviews, all stakeholders thought event attribution results could have some use. The main application mentioned was to understand whether climate change had influenced the likelihood of an event in order to anticipate future events and inform policy decisions. As one interviewee said, 'for long-term planning you have to take into account all the parameters, including climate change' (Civil society representative, 1/3/16, Dakar). Others thought results could be useful to distinguish and communicate impacts of climate change, to ensure all events were not assumed attributable, and to encourage mitigation of greenhouse gases. A use was also suggested at international level for policymakers in negotiations, to 'know the causes, if it is related to climate change how we can have support from developed countries' (Government representative, 7/6/16, Skype). While stakeholders thought such information could be useful to advise policymakers, one interviewee also commented that knowing whether climate change had influenced an event or not might not be relevant for those affected by the impacts (Researcher, 4/7/16, Skype).

4. Discussion

4.1. Perceptions of drivers of flood vulnerability in the context of climate change

In general, although the stakeholders questioned, national adaptation documents and media articles recognized climate as a driver of urban flooding in Senegal, the impacts were perceived to be caused by issues around urban planning. These include a lack of governance leading to settlements in known flood-prone areas and lacking and outdated drainage infrastructure. These findings correspond with work by Mbow et al. (2008), who discussed the impact of rapid urbanization and informal settlements on flood risk in Dakar, and by Diagne (2007), who highlighted the need for improved rainwater drainage in Saint Louis.

The perception of flooding as an urban planning issue is somewhat reflected in the government ministries responsible for managing the impacts. This task is predominantly shared between the MRUHCV and the Ministry for Water and Sanitation, who are responsible for policy and infrastructure, and the Civil Protection Directorate in charge of emergency actions. Although the Ministry of the Environment and Sustainable Development is responsible for climate change adaptation, with the COMNACC also responsible for coordination of such issues, they have little to do with addressing flooding in practice. This may indicate that climate variability and change are not a prominent or well-communicated consideration when addressing flooding impacts.

Despite the stakeholders mainly attributing the impacts of flooding to ineffective urban planning, the majority of the workshop participants did think specific heavy rainfall events leading to flooding could be attributed to climate change. Their opinions may, however, have been sensitized by the workshop focus on event attribution. Interviewees showed more uncertainty about whether attributing individual extremes to climate change is possible. As some interviewees also attended the workshop, the interview context may have provided more opportunity for them to consider and explain their answers, which may explain the general reduced confidence. The range of perceptions regarding attributing extremes are consistent with findings with other climate policy stakeholders (Parker et al., 2017). Interviewees mentioned that many they worked with tended to attribute all extreme events to climate change. This could lead to maladaptation if decisions are made based on the assumption that flood events will increase in frequency in the future, which may not be the case in the region (Parker et al., 2017).

4.2. Addressing flooding and the information required

In urban Senegal, the main actions at the national level to anticipate future floods are the relocation of residents from flood-prone areas to new settlements, and the installation of drainage infrastructure. Correspondingly, the stakeholders in this study identified the main information required as population data and maps of flood-prone areas, rather than information about the future climate. This may imply that decisions are constructed around understanding current flood risks rather than anticipating future changes and the capacity to plan ahead. Although such decisions can help address immediate issues, actions may not necessarily be resilient in the long-term. However, this reflects that in sub-Saharan African countries, urban development challenges are often immediate rather than require longer-term climate projections relevant to decades ahead. In particular, addressing urbanization often focusses on information about current rather than future climate variability, as the immediacy of the issues can side-line long-term perspectives (Jones et al., 2015). As interviewees reported that even low levels of rainfall could lead to urban flooding, it may well be the case here that climate information, particularly with regards to the future, may not be the most relevant and useful. This may also be applicable in other developing country urban areas experiencing flooding due to poor drainage, such as Maputo, Mozambique (Broto, Boyd, & Ensor, 2015). However, the necessity of climate knowledge and planning appropriate infrastructure is highlighted by the fact that a new location to which people were relocated from Dakar also experienced flooding due to inadequate rainwater drainage (Schaer et al., 2018).

On shorter timescales, some stakeholders suggested more accurate and earlier forecasts of extreme events would be useful to be able to react accordingly, and correspondingly there is a need for an early warning system for urban flood events to disseminate alerts to vulnerable communities (Government of Senegal et al., 2010; Ministère du Tourisme et des Transport Aériens, 2016; World Bank and GFDRR, 2011). National level experts explained that currently if heavy precipitation is forecast, there are very few anticipatory actions taken, given the lack of trust the agencies have in the forecasts. The government recognizes that in order for improved forecasts to be beneficial, dialogue between the scientists and government stakeholders, and also local level stakeholders, would be required to build trust in this information (Ministère de l'Intérieur, 2015).

4.3. Perceptions of the relevance of event attribution

The main relevance for event attribution in Senegal according to the stakeholders engaged with here would be to understand the influence of climate change on events to guide adaptation to future similar events. However, it is important to note that the influence of climate change on a particular event, especially when estimated using climate simulations forced by observed sea surface temperatures, may not be the same on a similar event at a different time. Thompson and Otto (2015) discuss how using event attribution to inform adaptation to future events may have limitations as studies do not consider the probability of events in the future. However, Donhauser (2017) suggests the methodology could be used for forward-looking decision-making, by applying it to models of the future to analyse extremes and help assign probabilities to future scenarios for planning. Boran and Heath (2016) also suggest studies could help map areas with heightened risks of extreme events, to inform a forward-looking risk-pooling and climate risk insurance framework within adaptation policy. Furthermore, individual event attribution studies can help build understanding of climate change impacts in the region, and could be used

alongside other climate information such as projections and local knowledge of precipitation events to improve understanding of climate risks (Parker et al., 2017). This may be particularly helpful in a region such as West Africa where precipitation projections are uncertain. Knowledge about climate change impacts on individual events may also be useful as their occurrence can help the adaptation issues associated with them rise up the political agenda (Johnson, Tunstall, & Penning-Rowsell, 2005; Kingdon, 2003).

Another use suggested in interviews was to build awareness and communicate the impacts of climate change, as was also found by Schwab et al. (2017). This could ensure that policymakers do not assume all events are caused by climate change, which could lead to potential maladaptation (Travis, 2014). Some interviewees suggested attributing extreme events to climate change could also encourage mitigation, although Janković and Schultz (2017) highlight that this does not consider socioeconomic components of changing risks of extremes, and could undermine scientific credibility as extreme events will still occur in a world with mitigation.

Event attribution can provide information about meteorological hazards, but not overall risk (Hulme et al., 2011), and this could help explain why studies have not yet substantially contributed to adaptation planning (Lusk, 2017). Schwab et al. (2017) found European decision-makers were more interested in overall risk and the causes of impacts than the causes of the meteorological events. In Senegal, the stakeholders interviewed generally viewed flooding as an urbanization issue, as well as a climate impact, showing awareness that multiple drivers of flood risk need to be addressed. One interviewee commented that attributing events would not be relevant for those affected by the impacts. As relatively little rain can lead to flooding in urban Senegal, it can be argued that the impacts on communities need addressing regardless of whether or not they are climate-change-related. This fits with Hulme et al.'s argument that 'climate adaptation investment is most needed where vulnerability to meteorological hazard is high, not where meteorological hazards are most attributable to human influence' (2011, p. 765). However, contrary to the concerns of Hulme et al. (2011), it is the knowledge of the hydrometeorological events that needs incorporating into scenario planning and decision-making to buffer future shocks in a more anticipatory manner, as this does not appear to be happening. Further interdisciplinary research will be required if vulnerability is to be addressed alongside the climate hazards successfully (e.g. Daron, Sutherland, Jack, & Hewitson, 2015; Morss, Wilhelmi, Downton, & Gruntfest, 2005).

Other stakeholders thought event attribution results would be more relevant for international policymaking. Evidence of the impact of climate change on specific events could be used in negotiations to encourage support from developed countries. Studies have even begun to estimate the contributions of individual countries' emissions to changes in the likelihoods of particular extreme events (Otto, Skeie, Fuglestvedt, Berntsen, & Allen, 2017). This application has also been discussed by stakeholders associated with loss and damage negotiations (Parker et al., 2017), although reference to attribution in this context is contentious due to its association with compensation (James et al., 2014). Still, event attribution can serve as a mechanism to generate questions about how adaptation policy can better link global climate risk to local stakeholders affected by shock events, and merits further research.

4.4. Incorporating event attribution: current barriers and future needs

Stakeholders were optimistic in interviews that event attribution studies could have some application in adaptation decision-making. However, this could be challenging due to the current lack of climate information used in planning. This may partly be due to urbanization decisions not requiring climate information in the immediate term; furthermore, the climate information that is available may not be perceived as useable (Lemos, Kirchhoff, & Ramprasad, 2012). However, information about future changes in climate will be required if plans are to be resilient. An interviewee emphasized this, saying there are 'Too short, urgent plans. There are floods so let's see how we could respond but we do not plan by saying this is the scenario of five years or ten years or being informed by the science' (Civil society representative, 2/3/16, Dakar). How to use information about future scenarios will require collaboration between producers of the information and policymakers as one interviewee explained, 'the integration of climate change in the documents for development policies is quite complex. We have not yet settled the question of how [to integrate climate change information]' (Government research representative, 10/6/16, email).

As stakeholders in this study already view urbanization as one of the main causes of flooding impacts, whether events are related to climate change does not appear to currently affect decisions or be necessary to reduce impacts in the short-term. However, there could be challenges if stakeholders, and policies, do assume climate change is increasing the probability of flood events and then event attribution studies show particular events had become less likely due to climate change. For example, in Mozambique, climate policy narratives in the early 2000s were supported by the available climate science that risks of floods were increasing, leading to adaptation strategies and international financial support based on this. Higher spatial resolution results have since shown there is very little change in flood risk likely, but the policy narratives have not changed (Patt, 2012). If this were the case in Senegal it is likely that flood impacts would still need addressing, particularly as small amounts of rain can have devastating impacts in urban areas. However, it could affect how events are perceived, with even greater emphasis on urbanization issues.

Alongside incorporating climate information, there are more general governance challenges for addressing flooding from extreme precipitation in Senegal. These will need to be considered in order to address the policy needs identified by stakeholders, including strategies to react to forecasts, improve infrastructure, and develop more effective land use management. Issues around communication and coordination are key. While there is some effort to involve all the ministries in the management of flood events through the National Flood Management Committee, recognizing that flooding is a multisectoral issue, there is still a distinct lack of coordination and communication between ministries, and of NGO

representation at the national level. Schaer et al. (2018) also found limited integration between flooding policies and plans developed between the different sectors involved, and overlaps between ministries in charge of coordinating efforts in urban Senegal. In particular, weather and climate information from ANACIM does not appear to play a prominent role in government adaptation planning. If this is to be incorporated in the future, users will need to perceive it to be salient, credible, and legitimate (Cash et al., 2003) and accessible to them (Boyd et al., 2013; Southgate et al., 2013).

Another challenge is the financial resources required to manage the impacts of flooding. Media articles reported that the effect of spending for flood management had not been seen. An interviewee explained that 'there are all these anticipatory plans in the documents but the state don't have the means to put in place infrastructure for the anticipatory aspect.' (Government representative, 3/3/16, Dakar). In particular, local governments lack funding for infrastructure, technical capacity and skills to address complex climate risks, so local institutional capacity requires strengthening, alongside the involvement of local communities (Wang, Montoliu-Munoz, & Gueye, 2009).

The perceptions of whether events can be attributed to climate change and uses for this science found here clearly highlight the need to share what event attribution can provide with the relevant stakeholders. This could help policymakers consider whether results could be relevant for their decisions and ensure they do not assume all events are attributable to climate change, which could lead to maladaptation and other drivers of risk being neglected. As with any climate model studies, event attribution results are complex and have uncertainties (National Academies of Sciences, Engineering, and Medicine, 2016). Low confidence in the effect of climate change on a particular event could make applying this information more challenging, as decision-makers may require small uncertainties in the results (Schwab et al., 2017). However, practitioners are often experienced in making decisions about the future with uncertain information (Morss et al., 2005). Dialogue between scientists and policymakers can communicate the many dimensions to uncertainty (Patt, 2009) and, furthermore, could inform the application of the science so the events studied are relevant to policymakers and research questions are framed appropriately (Otto et al., 2015).

As there have been very few event attribution studies in Africa to date, it may not be surprising that there was limited knowledge of these techniques among the stakeholders engaged with in Senegal. This was also the case amongst decision-makers addressing storm surge in Germany, where no event attribution studies have been conducted (Schwab et al., 2017). The lack of studies also means that currently there is very little understanding of how climate change has influenced individual events in Africa. The study of rainfall in West Africa in 2012 (Parker et al., 2017) focussed on the high seasonal rainfall so may not be directly relevant when considering floods, which are caused by shorter-term heavy rainfall. Studies such as that by Bellprat et al. (2015) on southern African rainy seasons which considered both seasonal and extreme rainfall risks may be relevant here, particularly as influences can differ over timescales of events. There is still much uncertainty around how heavy rainfall in West Africa is being affected by climate change and may change in the future (Seneviratne et al., 2012), providing a challenge for policymakers to produce adaptation strategies that will be resilient into the future.

5. Conclusions

There is a scientific debate about whether event attribution science could inform adaptation policy, but this has had little consideration in specific national contexts, and before now no consideration in a developing country context. In this paper, we have investigated its perceived relevance at decision-making level using a case study of policy to address extreme precipitation and flooding in urban Senegal. We have shown that national adaptation decision-makers interviewed here recognize climate as a driver of increasing flood occurrence, but perceive the impacts to be primarily caused by issues around urban planning, including settlements in flood-prone areas and a lack of drainage infrastructure. The key stakeholders addressing these issues are the government ministries responsible for urban planning and water and sanitation.

Stakeholders in this study thought event attribution results could be relevant in order to plan for similar events in the future, understand which events are impacts of climate change, and encourage support in international climate negotiations. However, there are many barriers to integrating this science into planning in Senegal at this stage, which may be reflected in other developing countries. These include the limited climate information currently incorporated into planning and decision-making and a lack of coordination between the stakeholders addressing flooding. These barriers will need to be critically examined in line with current understanding and communication of science-policy in adaptation. There is a focus on addressing current rather than future risks, as the impacts of flooding in urban Senegal need to be addressed in order to protect the most vulnerable communities now. Decisions are prioritizing addressing current urbanization issues and do not focus on considering integration of longer-term climate information. Understanding whether events and impacts are caused by climate change may not be directly relevant for this. However, if such short-term planning is to be resilient in the long-term and protect vulnerable communities from flooding impacts in the decades ahead, decisions on urban planning, drainage infrastructure and other adaptation actions will need to incorporate relevant and accessible knowledge about how the risks of extreme events are likely to change in the future.

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