Guidelines for the adaptation to floods in changing climate

Joanna Doroszkiewicz¹ · Renata J. Romanowicz¹

Received: 5 February 2017 / Accepted: 29 May 2017 / Published online: 9 June 2017
© The Author(s) 2017. This article is an open access publication

Abstract A decrease of flood damages in the future requires not only adaptation to flood caused by present day climate, but also climate change effects on floods should be taken into account. The paper illustrates the need to take into account changing climate conditions in flood adaptation strategies and to apply in practice the concept of integrated water resource management (IWRM). IWRM is based on a number of policy instruments, economic instruments, political signals, and also, on the effects of climate change on floods and collaboration across national, regional and local administrative units. The guidelines for a country adaptation to floods in a changing climate are outlined. A comparison of the adaptive capacities in Poland and Norway is used to illustrate the need for the implementation of proposed guidelines to assure flood risk management under climate change in a sustainable way.

Keywords Flood risk management · Climate change · Norway · Poland · Adaptation scenarios

Introduction

Climate change may alter the physical characteristics of hazards and as a consequence, increase damages and loss of lives when climate change adaptation is not undertaken. Following the definition (IPCC 2003), adaptation is

understood as any modification in natural or social systems in response to actual or expected climatic stimuli or their effects. To adapt to climate change, the adaptive capacity of a country may need to be increased by modifications of existing policy instruments or by development of new instruments. In each European country the more or less complex systems of policy instruments already exist. Those policy instruments should assist in the development of consistent adaptation tools by both strengthening the coherence between different policy instruments and between different administrative levels—local, regional and national. However, for a sustainable development, i.e. without undermining the integrity and stability of the natural systems, it is not sufficient to modify the policy instruments but also it is necessary to take into account physical measures of each of the hazards.

Floods, as one of the common hazards in Europe pose a problem now, and according to IPCC (2013), (IPCC 2014a, b, c) will pose a problem in the future. Therefore, there is a need for consistent strategy for adaptation to floods in every water-related sector. It requires an application of the concept of integrated water resource management (IWRM). The framework of IWRM (Davis 2007) consists of development and management of water, land and related resources, to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of the environment. The basic idea behind the flood risk management, being a part of IWRM is to plan adaptation actions leading to the minimisation of flood risk in future climate conditions.

The aim and the novelty of this study are to outline a framework of a realistic strategy for adaptation to future floods that can be implemented in practice. The comparison of existing flood adaptation strategies in two countries, with different origins of adaptation approach, here Poland

✉ Joanna Doroszkiewicz
joador@igf.edu.pl

Renata J. Romanowicz
romanowicz@igf.edu.pl

¹ Hydrology and Hydrodynamics Department, Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland

and Norway, are used to identify the needs and shortcomings of adaptation strategies. These two particular countries were chosen following the requirements of the funding body of this study (Norway Grants).

In the following section a review of challenges for a strategy of adaptation to future floods is given. Section three focuses on the methodology of flood adaptation, including spatial planning in Poland and Norway. Attention is given to the multi-level approach. Section four presents a comparative case study of flood adaptation process in Poland and Norway. Finally, conclusions are drawn and general guidelines for the development of a flood adaptation strategy are given.

The challenges of flood adaptation strategy

There are several research questions closely related to flood adaptation strategy in changing climate conditions. Some of those vital questions are (Salas et al. 2012):

1. What is the climate change impact on floods?
2. How can water resources be managed under changing climate conditions?
3. How the spatial planning should be performed under changing climate conditions?
4. What is the climate change impact on society?
5. How to communicate both flood risk and uncertainty to raise the public awareness?

In what follows we discuss those questions in detail.

Regarding the first question, analysis of projections of future climate (CORDEX or ENSAMBLES GCMs and RCMs) (Jacob et al. 2013) has many shortcomings, but presently it is the most popular way to estimate future temperature and precipitation (IPCC 2013). Considering precipitation and temperature as main factors influencing river flows, another option is proposed by Prudhomme et al. (2010), who suggest “scenario-neutral” approach to climate change impact studies. “scenario-neutral” separate hazard coming from climate change and vulnerability of the catchment by combining knowledge about the probability of hazardous event with the sensitivity of a catchment. The results of this analysis are possible ranges of climate change.

The second question refers directly to the choice of the strategy of adaptation to floods. Facing the problem of adaptation to unknown, or better to say, to unsure future, brought—“bottom-up” and “top-down” approaches to climate change adaptation strategy. The bottom-up approach assumes the development of solutions in minor organisational units and implementing them in major organisational units. This approach is time consuming and would slow down the decision making process when

applied on its own. The bottom-up approach, for the management of floods in a changing climate (Merz et al. 2014) is not sufficient in a global context. On the other hand, a top-down approach assumes a top-down initiative, which involves the introduction of national provisions in the form of legislation, laws or national strategies for the regions and local organizational units. Therefore, the local expectations and needs might not be represented well enough.

For above mentioned reasons (Adger et al. 2005; IPCC 2014c) or (Arnell and Gosling 2016) state that flood risk management in the global climate change context needs not only “bottom-up” but also “top-down” approaches. Combined approach seems to be a contemporary response for water resources management needs and leads to the policy called Integrated Water Resources Management (IWRM). The complexity of the definition and policy itself is the reason why IWRM requires stable and consequent political conditions to be fully implemented. To come up with the integrated strategy of a country it is important to undertake the collaborative inter-governmental policy-making, taking into account all parties involved (Bruce and Madani 2015).

Urwin and Jordan (2008) encourage policy makers to change the policy in a way it facilitates the adaptive planning, which is crucial action for the improvement of local implementation of programmed strategy. Nevertheless, increasing flexibility of existing policy may lead to both positive and negative consequences. Overmuch flexible policy and also flexible legal solutions can lead to a decreased level of local units involvement in the implementation of adaptation to climate change (Amundsen 2012; NOU 2010). An acknowledgement of climate change should be the factor that encourages all organizations involved to treat flood adaptation as a long-term process (Venema and Drexhage 2009).

The third question deals with the spatial planning under climate change. Sustainable Urban Water Management SUWM is a part of IWRM. Dealing with risk in flood-prone areas in the case of existing buildings and infrastructure is impeded and implementation of the SUWM is more difficult (Werkheiser and Piso 2015).

SUWM a long time to be implemented. This time is usually much longer than the length of term of decision makers and administrative officers (Marlow et al. 2013; Brown and Farrelly 2009). However, decreasing vulnerability and increasing the capacity of riverside may bring not only less adverse consequences on local level but also social, economic and environmental benefits for the region, (Sivapalan et al. 2012; Bresch 2017).

Regarding the forth question, besides economic factors such as governmental compensation or insurance system, the reaction of the society to climate change

depends on cognition and culture factors (Kuruppu and Liverman 2011). They have done the research on the local societies of the Kiribatti islands where the awareness of climate change is high and the climate change is visible with a “bare eye” of the respondents. However, their awareness of risk influenced by climate change and risk itself in the society is low. Due to the high stress caused by sea level rise, the society would undertake the action related to adaptation to climate change without the full knowledge of these changes. Results from this bottom-up approach are completely reverse to the results of Burningham et al. (2007) who present top-down approach to flood adaptation in the future climate conditions in Britain. Burningham et al. (2007) show the results of flood risk assessment, stemming from a top-down initiative, are not treated by local users as a “real threat”. The latter was confirmed by the Norwegian study (Næss et al. 2005) where the county society was not prepared to take adaptation action to floods in advance. Keeping in mind that those examples come from societies of different cultural background, they suggest that unless the society does not experience the threat it does not undertake actions. Even though the mutual interactions between different types of factors are not well understood, they are still important. The research on interactions between sociological and hydrological processes has been proposed by Di Baldassarre et al. (2009) with the River Po (Italy) used as a case study. Di Baldassarre et al. (2013) presented a simplified model describing the relationship between socio-economic development and the hydrology of a river basin. The model allows for the comparison of different routes of economic development coupled with the scenarios of peoples’ reactions to floods (moving away or building water control structures).

The fifth question deals with communication of flood risk uncertainty to the society. Neither uncertainty nor probability and risk of flooding are not well communicated to local land users and decision makers. In many cases, poor risk and uncertainty communication are the main barriers against the creation of a unified and solid flood adaptation strategy (Haasnoot et al. 2014). Methods used to deal with the uncertainty of flood risk depend on the region of the world and the scale of the assessment.

The first of the questions considered in this section defines the range of the possible changes in flood hazard due to climate change. The second and third questions describe the adaptation strategy options and the fourth and fifth question deal with the problems of strategy implementation.

Following presented flood adaptation strategy requirements, we provide the guidelines for adaptation in the form of five stages listed in the next section.

Proposed framework of a country strategy for adaptation to floods

Figure 1 shows the proposed structure of strategy of adaptation to flood. Following this scheme flood risk assessment, driven by changing climate conditions and society changes, form the basis for building scenarios of adaptation to floods. The acquired set of adaptation scenarios is scrutinized using the bunch of criteria, among others cost-benefit criteria. The scenario with optimal results is checked for its legal feasibility. If the legal regulation instruments, including national budget, allow to follow the scenario the strategy on implementing the scenario is undertaken.

The proposed adaptation strategy involves the following steps:

Step 1: Flood risk assessment: analysis of flood hazard (inundation) maps and flood risk maps in the country of interest. A flood hazard map shows the land area that will be inundated by a flood of a given return period [e.g.

Fig. 1 Guideline for adaptation to floods under future climate conditions

the 100-year flood has a probability of 1/100 (1%) each year to occur]. Particular interest is given to flood hazard maps including the influence of future climate scenarios and generated losses for society it carries.

Step 2: Building the scenarios of adaptation: application of physical measures and spatial planning; development of possible adaptation scenarios which include how to treat the contemporary adaptation to the flood of existing or planned residential areas, infrastructure, hydraulic structures and fields. The description includes margins for the change of future climate. The latter is introduced through the simulations of precipitation-runoff and flow routing models for future climate projections and producing future flood hazard maps.

Step 3: Scenario choice: this step constitutes the choice of optimum scenario from the point of view of costs and benefits and gives recommendations for the risk managers broadly known as “decision-makers”.

Step 4: Analysis of legislative instruments being in force in the country of interest. They form the basis of the policy instruments in adaptation to floods, made and used by the decision makers. At this step all involved units from different levels give the feedback on the possibility of realisation of the scenario chosen. If the scenario chosen in step 3 is feasible, it passes to implementation (step 5).

If it is not feasible, another scenario has to be chosen (step 3).

Step 5: Implementation: analysis of the allocation of responsibility in the process of adaptation to floods in a country across the administrative structures. At this step all involved units from different levels discuss the strategies for the realisation of the chosen scenario.

In the following section, basic knowledge to flood adaptation and climate change is explained by a comparison of the present status of adaptation process and the future needs of two European countries, Poland and Norway, as case studies.

Case study: Norway and Poland

The proposed guidelines for the flood adaptation strategy are illustrated using two European countries, Poland and Norway, as case studies. Poland has followed the EU recommendations on adaptation to floods (European Parliament, Council of the European Union 2007). Norway does not belong to the EU, but has developed a flood adaptation strategy based on the knowledge of the expected effects of climate change on floods and national policy instruments already in place to reduce flood damages. The

current flood adaptation strategy in Norway includes guidelines on how to consider the climate change impact on floods. In Poland, according to the Strategic Plan for Adaptation to Climate Change (SPA 2020) created by Ministry of the Environment (IOŚ-PIB and KLIMADA 2013) the frequency, magnitude and extent of the extreme events will increase. However, until present, flood risk management plans do not take into account the impact of climate change on floods in Poland. Moreover, the adaptation policies and laws in Poland have never been assessed from the point of view of their role in a strategy of adaptation to floods in a changing climate.

Flood risk assessment: flood hazard and risk extent in present and future climate conditions (step 1)

The iterative nature, of the directives of European Union in case of flood risk management allows for the updating of flood hazard, flood risk assessment and flood risk management planning in Poland. In Poland, the preliminary flood risk assessment qualify the catchments to more detail analysis. Within this step, base of available at that time data, the choice of 253 catchment has been made. The further analysis result with hazard maps which include flood extent (the area of inundated land), water depth, the elevation of the top-point (crown) of embankments (Fig. 2) and where appropriate, the velocity in a separate map (Fig. 3). The upper and lower parts of presented maps have a different hue (Figs. 2, 3 and 4) which is caused by the difference in lightening of the scanned surface.

Flood hazard maps were prepared for three different flood return periods: short (≥ 10 years), medium (≥ 100 years), presented below and long (≥ 500 years). On the basis of flood hazard maps with addition of adverse consequences for society, economy and environment the flood risk maps were prepared for the same return periods.

Due to the large economic value of highly urbanized and densely populated areas, it was considered that velocity of flood water distribution should be included in separate hazard maps. Additionally, the Polish Water Law requires that areas where there is a danger of destruction or damage of the embankment, dams or protective structure of the technical zone should be included in the flood hazard map.

In Poland flood risk maps are divided into two groups. The first group presents the flood risk in terms of adverse consequences for the environment, cultural heritage and economic activity. The important content of the risk maps in Poland are nature conservation program areas. Nature conservation program areas became a problem for water management decision making bodies because some flood adaptation measures are prohibited in restricted areas. The second type of maps include adverse consequences for

Fig. 2 An example of a flood hazard map with probability of occurrence 1%, in Poland for the City of Tarnow (Source: KZGW (2014) geoportal.kzgw.gov.pl 30.04.2015 3:52 PM)

people and flood losses. The estimations of flood losses were only carried out in areas where data from the surveys were available. Other areas were classified according to the depth of flood on private residential buildings and buildings of social use.

Norway follows its own approach of flood risk management. Flood hazards and flood risk maps are replaced with a combination of flood hazard and flood risk maps called flood inundation maps (Fig. 5). Maps have been developed for approximately 130 river reaches with a high flood risk. Figure 5 presents an example of a flood inundation map prepared for Naustdal in Norway. The map contains the extent of flooded area with a certain probability of flood occurrence (in our example 0.5%, i.e. area that will be flooded by a 200-year flood), and the value of a depth of water on flooded area. The classes of water depth are classified for each 0.5 m, up to 2 m depth. Norwegian maps also include the buildings that only will have water in the basement and buildings prone to severe damages from floods.

However, calculations of the adverse consequences for the environment, cultural heritage, industrial business and private property of people are not evaluated directly in flood inundation maps, even though the existing buildings and infrastructure are included in the map.

The impact of future climate change is an issue that has not yet been considered on Polish hazard maps or risk maps, but is included in the Norwegian maps. Hydrological projections for floods in Norway under a future climate (Lawrence and Hisdal 2011) and (Hanssen-Bauer et al. 2015), are accomplished by ensemble modelling based on locally adjusted precipitation and temperature data from several regional climate models, in conjunction with multiple hydrological models for more than 115 individual catchments to assess likely changes in river floods.

Flood hazard maps together with flood risk maps provide basis for the proposal of the way to reduce the risk of flooding in Poland, in other words, form a basis for the development of flood adaptation scenarios in a framework of flood adaptation strategy.

Fig. 3 An example of a flood hazard map with probability of occurrence 1%, in Poland for the City of Tarnow-velocity distribution (Source: KZGW (2014) geoportal.kzgw.gov.pl 30.04.2015 3:40 PM)

Building the adaptation scenarios: methods of flood risk management, application of physical measures and spatial planning (step 2)

Building the adaptation scenarios means preparation of a set of possible scenarios of consecutive adaptation actions regarding control measures and adaptation measures.

Control measures consist of flood water transfer, flood proofing of buildings and technical infrastructure, drainage and pumping systems, flood water storage and channel conveyance and capacity. Adaptation measures include land use and river corridor management. Land use management consists of spatial planning, an infrastructure and a categorization of land cover. The set of criteria for defining the scenarios of adaptation to floods in future climate conditions should be based on future climate projections, economic growth projections, and projected population growth. In particular, under present Polish and Norwegian conditions, not all above listed criteria are introduced to the urban planning and there is a problem of dealing with the uncertainty of flood risk.

The Norwegian Report on Adapting to climate change (NOU 2010) acknowledges that providing too much flexibility allows for appropriate local planning decisions but at the same time allows local planners to ‘opt in or out’ of implementing climate change measures, depending on their willingness or ability.

Unsustainable development of river side areas exists both in Norway and Poland. In Poland, insufficiently balanced planning regulations are one of the reasons of that situation. In addition, audits of Polish Head Audit Office (NIK 2013) have shown that spatial planning has not been sufficiently or effectively used as an instrument to reduce flood risk. Unsustainable development of riverside areas is assumed to result from a lack of:

- clear guidelines created by national authorities,
- financial resources,
- control of progress.

Inappropriate spatial planning causes the devaluation of private and public property including the national heritage. For this reason, it is important to address methods of

Fig. 4 An example of a flood risk assessment for the City of Tarnów-adverse consequences for people and flood loss map (Source: KZGW (2014) geoportal.kzgw.gov.pl 30.04.2015 3:40 PM)

protecting existing and planned housing areas in Poland, including infrastructure and the condition of water control structures. Franczak et al. (2016) proposed a method for the preliminary evaluation of flood hazard maps by a comparison of historical water extents and the flood hazard extents which results with the conclusion that the extents for medium size catchments are underestimated. The authors also raise the issue of high vulnerability at local scale (catchments <50 km²) where flood hazard areas are not defined but frequent flash floods increase the risk and

possible urban flood losses. IPCC (2013) highlights the importance of increasing frequency of flash flood events in Europe in future climate which leads to the conclusion that also small catchments should be included in spatial plans for the future. This issue raises the following questions:

- What are the differences between the adaptation of existing buildings and planned investments?
- How to reduce the depreciation of land and property in flood-prone areas?

Fig. 5 An example of flood inundation map with probability of occurrence 0.5%, Naustdal in Norway (Source: Norwegian Water Resources and Energy Directorate (NVE) rapport nr 03/2012)

Because there are no restrictions on building in flood-plain zones in Poland and prices of land near river side are competitive, the amount of housing in those areas has increased. With increased housing in inundation areas, the cost of flood losses has also increased and is almost entirely paid by the public because private “insurance in case of flood” is not obligatory and not popular in Poland. In a result, houses are often renovated or rebuilt in the same place where flood occurred.

In Norway, the technical guidelines of the Planning and Building Act (PBA) for new buildings have introduced different safety classes based on flood recurrence intervals; 1-in-1000 year for flood hospitals and schools, 1-in-200 year flood for living houses and 1-in-50 year flood for barns and garages. In addition, it is stated that climate change has to be taken into account in spatial plans. Following these needs, the Norwegian Water Resources and Energy Directorate (NVE) has developed guidelines on how to take into account floods in spatial planning. Due to the uncertainties in the projections for individual catchments and the need to generalise the results to areas outside

the calibrated catchments, a pragmatic solution was to propose three categories for use in climate change adaptation: no change, 20% increase and 40% increase. The future climate variability in the example in Fig. 5, is taken into account by increasing the 1-in-200 water level quantiles by 20%.

This also includes streams and rivers where no flood inundation maps exist. A separate chapter of the PBA is devoted to climate change adaptation. To increase the knowledge amongst spatial planners in the municipalities, the regional offices of NVE arrange workshops to inform the municipalities about existing laws and regulations, tools and information that can be used to consider flood risk in spatial planning.

This has raised the awareness and improved spatial planning, including considering the climate change effects on floods. The Norwegian PBA is an example where the technical guidelines state that climate change has to be taken into account in the spatial plans.

Changes of the flood risk in Poland and Norway can be monitored by adaptation measures described in climate

change reports (NOU 2010; IOS-PIB and KLIMADA 2013). The measures of adaptation in Poland include e.g. the percentage of the country area included in spatial planning (26.4%), the development of flood risk plans, the existence of regional and local weather-agriculture monitoring system, the development of a “vulnerable infrastructure monitoring system” an emergency communication module, participation of national and international funds in the adaptation financial system, and a value for flood losses (in PLN and % of income per capita). The adaptation measures in Norway include the development of local planning capacity, also in financial area, planning with the respect of climate change uncertainty, development of a solid, knowledge based monitoring system, development of knowledge referring to climate change, enhancement of administration capacity, and the improvement of international cooperation and national coordination in adaptation process. Both Polish and Norwegian strategies for spatial planning stress the need of appropriate legal regulations relating to planning and building as one of many steps towards ensuring safety along the riverside and reducing flood losses (NOU 2010; IOS-PIB and KLIMADA 2013).

In Norway, both houses and infrastructure have been built on flood prone areas throughout history because of inappropriate laws and regulations in the past, economical reasons or lack of knowledge. NVE is responsible for funding flood safety measures throughout the country. New measures are prioritized based on the cost benefit analysis that also considers flood risk in a future climate. To include climate change impact, each adaptation scenario built within the model led river system will undergo simulations driven by an ensemble of future climate projections.

Choice of scenario: recommendation for the future (step 3)

The choice of scenario of adaptation is an essential point for further implementation. The choice should be done according to the criteria, such as: effectiveness of adaptation, side-effects, cost and benefits, conditions for decision-making. In Polish—Norwegian case study, which focus on spatial planning particular interest should be given to the issue of possible flood losses which can arise because of damages or destruction of water control structures, infrastructure, buildings or other structures near the river or to maintain the water control structures in good technical order.

The objectives of the national authorities may need to be scenarios for individual municipalities to implement climate change adaptation measures.

Each simulation scenario should, therefore, provide estimates of indices chosen for the evaluation of adaptation strategy.

In Norway there are 428 municipalities. Spatial planning management of these units is regulated by the legislative Act for Building and Planning (PBA). It is audited by an appropriate regional unit every four years, even though the continuous procedure for the flood adaptation process is needed (Haasnoot et al. 2014) this adaptation cycle is not sufficient on its own. There is also a need to consider the cases which might not be framed in the procedure, because of extraordinary spatial location or difficult administrative status.

In Poland, which is much more densely populated, there is a four-level territorial administration (national, voivodship, districts and municipalities). At present there are 2478 local level territorial units. Spatial planning management of these units is regulated by two separate legislative Acts for Building and Spatial Planning. These legislative regulations are not sufficient to execute the formulation of local plans in each municipality (NIK 2013) and to the best of our knowledge, based on the Art. 400a of Environmental Law (Dz.U.2017.0.519) and contemporary National Budget there are no national funds allocated for municipalities for climate change adaptation. Flood management strategy does not include plan of adaptation actions and adaptation actions are not followed. Lewandowski et al. (2016) highlight that Polish national and regional strategies of flood risk management do not include in practice spatial planning, urban green infrastructure or flood insurance measures despite of official declarations.

Due to the fact that in both Norway and Poland there is a need for knowledge and competence in the municipalities on how to consider floods, including the climate change effect in spatial planning, the chosen adaptation scenario should contain the strong educational and communication compound which will highlight the spatial planning—climate change relation.

This effect can be obtained by prioritizing in the scenario climate change adaptation in the governmental policy, at each level of public administration and finally, securing additional financial resources both at the national and local levels.

Legal regulations instruments in poland and norway (step 4)

The decision of chosen adaptation scenario is half the success, the second half is the feedback from the legislative instruments. In this sub-section the regulations concerning water management which are in force in Poland and Norway are scrutinised. Legislation related to flood adaptation has a different legal basis in Poland and Norway. Poland, as a member of the European Union follows its internal water management legislation the “Floods Directive 2007” (Directive 2007/60/EC). Its provisions are consistent with

the “Water Framework Directive 2000”, officially known as Directive 2000/60/EC of the European Parliament. The fact that flood adaptation is carried out in changing climate conditions creates a need to assess all its components every six years (Directive 2007/60/EC). This is also an opportunity for the development of a single, coherent and multi-faceted risk management strategy.

Although Norway has considerable large adaptive capacity, climate change is expected to have high costs, both human and material, if it is not taken into account in planning and decision-making (NOU 2010). A relatively new Planning and Building Act (PBA) of 2008 gives more emphasis on helping the municipalities and regional authorities to incorporate climate considerations into their planning. This act grants the legal authority to define areas acting on buffer zones. This implies that spatial regulations may be introduced to land areas exposed to flooding. In the technical guidelines of the PBA different safety classes based on flood recurrence intervals, are set up for different types of buildings and in addition it is stated that climate change has to be taken into account in their spatial plans.

Strategy implementation: cooperation on scenario (step 5)

In the present study, our illustration is based on the structure of water management systems in Poland and Norway presented in Table 1.

The flowchart (Fig. 6) presents relations between units related with flood risk management and with adaptation to floods. Interactions between units, adequate to the needs of units at different levels of cooperation are shown. Cooperation is understood here as “communication-feedback-action” process between units at the same level and between units at different levels. This approach, by its structure, is an integration of top-down and bottom up approaches and it conforms to the IWRM approach.

However, not all interactions between administrative units are carried out. As far as regional-scale flood adaptation policies for Poland are concerned, the strategy is planned by regional governments (Voivodship governments) and is included in the Voivodship development plan. Regional strategies for flood management are the responsibility of Regional Water Management Boards which are controlled by the National Water Management Authority and are defined for water regions rather than voivodships. The water region strategies are introduced and included in development strategies of voivodships together with guidelines for adaptation actions identified for each voivodship. Boundaries of Regional Water Management Boards are not consistent either with administrative nor with catchment boundaries, which complicates water management in the country.

Local Government units are responsible for climate change adaptation actions identified in the adaptation policy for Poland prepared for the period up to 2020 (IOŚ-PIB and KLIMADA 2013) for the local level. The adaptation actions include implementation of local monitoring and prevention systems i.e. the capacity of sewage system, speeding up the reaction time for the hazardous event, revitalization of the green infrastructure, and adaptation of city plans regarding the use of rainfall water. However, those adaptation actions require the legislative regulations related to local spatial planning in future climate which are still missing in Poland.

The Norwegian white paper on climate change adaptation (Climate change adaptation in Norway — Meld. St. 33 2012–2013) states that the Ministry of Climate and Environment, has the overall responsibility to coordinate climate change adaptation. However, the responsibility to assess climate change vulnerability, adaptation needs and to implement adaptation needs in practice is the responsibility of the individual sectors. The administrative flood management structures have three levels: national, regional (county) and local (municipality) (Table 1). However, in practice it is the Norwegian Water Resources and Energy

Table 1 Administrative and natural units for Poland and Norway classified according to local, regional and national levels

Level	Administrative units		Water management advisors		Hydrological unit
	Poland	Norway	Poland	Norway	
Local	Municipality/ province	Municipality	–	–	Sub-catchment (contains first order tributary) and catchment (contains second or higher order tributaries)
Regional	Voivodships	County governor and county authority	Regional Water Management Boards	Norwegian Water and Energy Directorate (NVE)	Catchment and river basin (contains main channel and all its tributaries)
National	Ministry of Environment	Ministries and Directorates	National Water Management Board/ Polish Water Industry	NVE	Basin (contains main channel and all its tributaries)

Fig. 6 The structure of implementation of flood adaptation strategy

Directorate (NVE) that is responsible for giving advice to the municipalities on how to reduce flood risks both at present and in the future. This means that NVE has the role of both the national and the regional level authority.

In general, municipality plans in Norway are renewed every four years to provide pathways of behavior and knowledge on possible improvements. The municipality is required to check that measures are implemented in compliance with permits and applicable laws and regulations. The municipality may choose to audit all building activities and in compliance with the building application regulations, prepare a strategy for the control work.

The NVE has a responsibility to follow-up the plans regarding river floods and flooding, including climate change adaptation. The PBA gives the municipality the responsibility to protect and secure the population from flood, but they will receive governmental guidance and assistance in this work. For the river basins most prone to flood damages, NVE has produced flood risk maps and checks that the flood risks have been evaluated in the municipalities' land-use planning.

Conclusions

The framework for the formulation of a realistic strategy for adaptation to future floods was outlined and can be implemented in five, universally applicable, steps. These are: (1) Flood risk assessment; (2) building the scenarios of adaptation; (3) scenario choice; (4) analysis of legislative instruments; (5) implementation. The schematic representation of the proposed guidelines for the adaptation to floods (Fig. 1) shows the feedback between the choice of adaptation scenario and its legal feasibility to be implemented. The scheme also shows that the assessment of flood risk and the choice of the adaptation strategy is influenced by climate and society changes. This points out the necessity of taking into account uncertainty of the adaptation process.

Analyses of the current state of flood adaptation in Poland and Norway were used to illustrate how the

implementation of the proposed adaptation guidelines could improve the flood adaptation strategy. Due to a simpler administrative structure, the less dense population and more experience in the implementation of spatial planning, flood risk management in Norway is much further advanced than in Poland. In Norway there is still a need to bridge the gap between scientific knowledge regarding climate change effects on floods and how to use this information in local spatial planning. This can be achieved by the adaptation scenario building (step 2). There is also a need to increase the adaptive capacity in smaller municipalities and to overcome internal coordination barriers and provide political and administrative anchoring of climate change adaptation (Amundsen 2012; NOU 2010). Following the steps of guideline these problems could be solved by application of steps 4 and 5.

In Poland, successful adaptation to climate change requires a solid and accessible knowledge-based expertise to be developed. The capacity for flood adaptation work is not as yet supported by appropriate units and adaptation scenarios. These two problems could be solved by following steps 1–3 from the proposed guidelines.

Acknowledgments This work was supported by Norway Grants Programme and National Center for Research and Development of Poland within project Climate Change Impact on Hydrological Extremes (CHIHE)—No DZP/POL-NOR/1873/2013. The authors would in particular like to thank to Barbara N. Romanowicz and Ray Macdonald for language amendments. We are grateful to whole team of CHIHE project for useful advices and comments.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

- Adger WN, Arnell NW, Tompkins EL (2005) Successful adaptation to climate change across scales. *Global Environmental Change* 15(2):77–86. Adaptation to Climate Change: Perspectives

- Across Scales. <http://www.sciencedirect.com/science/article/pii/S0959378004000901>
- Amundsen H (2012) Illusions of resilience? an analysis of community responses to change in northern norway. *Ecology and Society* 17. <http://hdl.handle.net/10535/8687>
- Arnell NW, Gosling SN (2016) The impacts of climate change on river flood risk at the global scale. *Clim Change* 134(3):387–401. doi:10.1007/s10584-014-1084-5
- Bresch D (2017) Climada manual. https://github.com/davidnbresch/climada/blob/master/docs/climada_manual.pdf. Accessed 17 Mar 2017
- Brown RR, Farrelly MA (2009) Delivering sustainable urban water management: a review of the hurdles we face. *Water Sci Technol* 59(5):839
- Bruce C, Madani K (2015) Successful collaborative negotiation over water policy: substance versus process. *J Water Resour Plan Manag* 141(9):04015009. doi:10.1061/(ASCE)WR.1943-5452.0000517
- Burningham K, Fielding J, Thrush D (2007) It'll never happen to me': understanding public awareness of local flood risk. *Disasters* 32(2):216–238
- Climate Change Adaptation in Norway — Meld. St. 33 (2012–2013) Report to the storting (white paper). Norwegian Ministry of Climate and Environment. <https://www.regjeringen.no/contentassets/e5e7872303544ae38bdbdc82aa0446d8/en-gb/pdfs/stm201220130033000engpdfs.pdf>. Accessed 05 June 2017
- Davis MD (2007) Integrated water resource management and water sharing. *J Water Resour Plan Manag* 133(5):427–445
- Di Baldassarre G, Castellarin A, Brath A (2009) Analysis of the effects of levee heightening on flood propagation: example of the river po, Italy. *Hydrol Sci J* 54(6):1007–1017. <http://www.tandfonline.com/doi/abs/10.1623/hysj.54.6.1007>
- Di Baldassarre G, Viglione A, Carr G, Kuil L, Salinas JL, Blöschl G (2013) Socio-hydrology: conceptualising human-flood interactions. *Hydrol Earth Syst Sci* 17(8):3295–3303. <http://www.hydrol-earth-syst-sci.net/17/3295/2013/>
- Franczak P, Listwan-Franczak K, Dzialek J, Biernacki W (2016) Planowanie przestrzenne na obszarach zalewowych w zlewniach górskich różnego rzędu w dorzeczu górnej wisły oraz górnej i środkowej odry. *Prace i Studia Geograficzne* 61(4):25–45
- Haasnoot M, van Deursen W, Guillaume J, Kwakkel J, van Beek E, Middelkoop H (2014) Fit for purpose? building and evaluating a fast, integrated model for exploring water policy pathways. *Environ Model Softw* 60:99–120. <http://www.sciencedirect.com/science/article/pii/S1364815214001595>
- Hanssen-Bauer I, Førlund EJ, Haddeland I, Hisdal H, Mayer S, Nesje A, Nilsen JEØ, Sandven S, Sandø AB, Sorteberg A, Ådlandsvik B (2015) Klima i Norge 2100 Kunnskapsgrunnlag for klimatilpassing oppdatert i 2015. NCCS Report no. 2/2015
- IOŚ-PIB, KLIMADA (2013) SPA Strategiczny plan adaptacji dla sektorów i obszarów wrażliwych na zmiany klimatu do roku 2020. Strategic adaptation plan for areas vulnerable for climate change 2020 perspective (in Polish). Ministry of Environment, Warsaw. https://www.mos.gov.pl/fileadmin/user_upload/SPA_2020.pdf. Accessed 05 June 2017
- IPCC (2003) Climate Change 2001: the scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge. http://www.grida.no/climate/ipcc_tar/wg1/index.htm
- IPCC (2013) Climate Change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, p 1535. <http://www.ipcc.ch/report/ar5/wg1/>
- IPCC (2014a) Climate Change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge. <http://www.ipcc.ch/report/ar5/wg2/>
- IPCC (2014b) Climate Change 2014: impacts, adaptation, and vulnerability. Part B: regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge. [http://www.ipcc.ch/report/ar5/wg2/\(31,1,2017\)](http://www.ipcc.ch/report/ar5/wg2/(31,1,2017))
- IPCC (2014c) Climate Change 2014: mitigation of climate change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press. <http://www.ipcc.ch/report/ar5/wg3/>
- Jacob D, Petersen J, Eggert B, Alias A, Christensen OB, Bouwer LM, Braun A, Colette A, Déqué M, Georgievski G, Georgopoulou E, Gobiet A, Menut L, Nikulin G, Haensler A, Hempelmann N, Jones C, Keuler K, Kovats S, Kråne N, Kotlarski S, Kriegsmann A, Martin E, van Meijgaard E, Moseley C, Pfeifer S, Preuschmann S, Radermacher C, Radtke K, Rechid D, Rounsevell M, Samuelsson P, Somot S, Soussana J-F, Teichmann C, Valentini R, Vautard R, Weber B, Yiou P (2013) EURO-CORDEX: new high-resolution climate change projections for european impact research. *Regional Environ Change* 14(2):563–578
- Kuruppu N, Liverman D (2011) Mental preparation for climate adaptation: the role of cognition and culture in enhancing adaptive capacity of water management in kiribati. *Global Environ Change* 21(2):657–669
- Lawrence D, Hisdal H (2011) Hydrological projections for floods in Norway under a future climate. NVE Report 5-2011. Norwegian Water Resources and Energy Directorate (NVE), Oslo, Norway
- Lewandowski J, Chorynski A, Matczak P (2016) Czy więcej zawsze oznacza lepiej? analiza dominacji i dywersyfikacji strategii zarządzania ryzykiem powodziowym w wybranych krajach unii. *Prace i Studia Geograficzne* 61(4):85–100
- Marlow D, Moglia M, Cook S, Beale D (2013) Towards sustainable urban water management: a critical reassessment. *Water Res* 47(20):7150–7161. Cited By 42. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84888846092&partnerID=40&md5=affaf80e51c9928908836d3429cac941>
- Merz B, Aerts J, Ambjerg-Nielsen K, Baldi M, Becker A, Bichet A, Blöschl G, Bouwer LM, Brauer A, Cioffi F, Delgado JM, Gocht M, Guzzetti F, Harrigan S, Hirschboeck K, Kilsby C, Kron W, Kwon H-H, Lall U, Merz R, Nissen K, Salvati P, Swierczynski T, Ulbrich U, Viglione A, Ward PJ, Weiler M, Wilhelm B, Nied M (2014) Floods and climate: emerging perspectives for flood risk assessment and management. *Nat Haz Earth Syst Sci* 14(7):1921–1942. <http://www.nat-hazards-earth-syst-sci.net/14/1921/2014/>
- Næss LO, Bang G, Eriksen S, Vevatne J (2005) Institutional adaptation to climate change: flood responses at the municipal level in norway. *Glob Environ Change* 15(2):125–138
- NIK (2013) Planowanie i realizacja inwestycji na terenach zagrożonych powodzią, No.195/2013/P/13/077/KIN. <https://www.nik.gov.pl/plik/id,6180,vp,7927.pdf>. Accessed 05 June 2017
- NOU (2010) Adapting to changing climate - Norway's vulnerability and the need to adapt to the impacts of climate change, Official Norwegian Reports NOU 2010:10
- Prudhomme C, Wilby R, Crooks S, Kay A, Reynard N (2010) Scenario-neutral approach to climate change impact studies: application to flood risk. *J Hydrol* 390(3–4):198–209
- Salas JD, Rajagopalan B, Saito L, Brown C (2012) Special section on climate change and water resources: climate nonstationarity and water resources management. *J Water Resour Plan Manag* 138(5):385–388. doi:10.1061/(ASCE)WR.1943-5452.0000279
- Sivapalan M, Savenije HHG, Blöschl G (2012) Socio-hydrology: a new science of people and water. *Hydrol Process* 26(8):1270–1276. doi:10.1002/hyp.8426

- Urwin K, Jordan A (2008) Does public policy support or undermine climate change adaptation? exploring policy interplay across different scales of governance. *Glob Environ Change* 18(1):180–191
- Venema H, Drexhage J (2009) Creating adaptive policies, IDRC, chapter. The need of adaptive policy. http://www.ebook.de/de/product/23044044/creating_adaptive_policies.html
- Werkheiser I, Piso Z (2015) People work to sustain systems: a framework for understanding sustainability. *J Water Resour Plan Manag* 141(12):A4015002. doi:10.1061/(ASCE)WR.1943-5452.0000526