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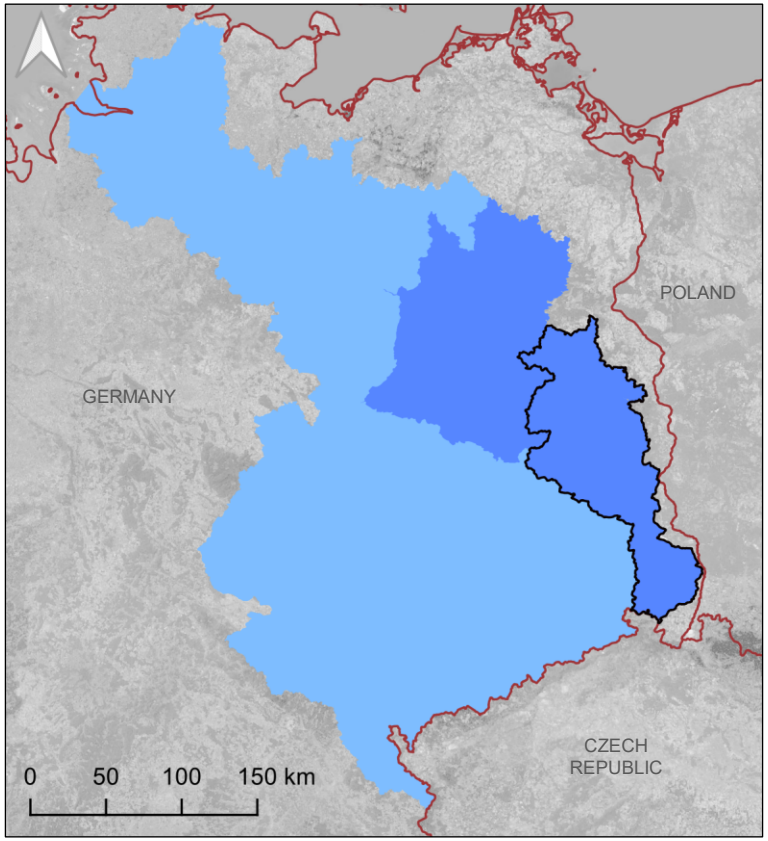
Current status of water-related planning for climate change adaptation in the Spree river basin, Germany

Saskia Arndt and Stefan Heiland

Correspondence to: Saskia Arndt (saskia.arndt@tu-berlin.de)

Figure S1. Analysed water management plans at the river basin level and their planning area.



Legend

Planning area

FRMP_Elbe_2021 (Coordination area “Havel”)*
RBMP+PoM _Elbe_2021 (Coordination area “Havel”)*

River basin

German Elbe river basin

Boundaries

Spree river basin

State

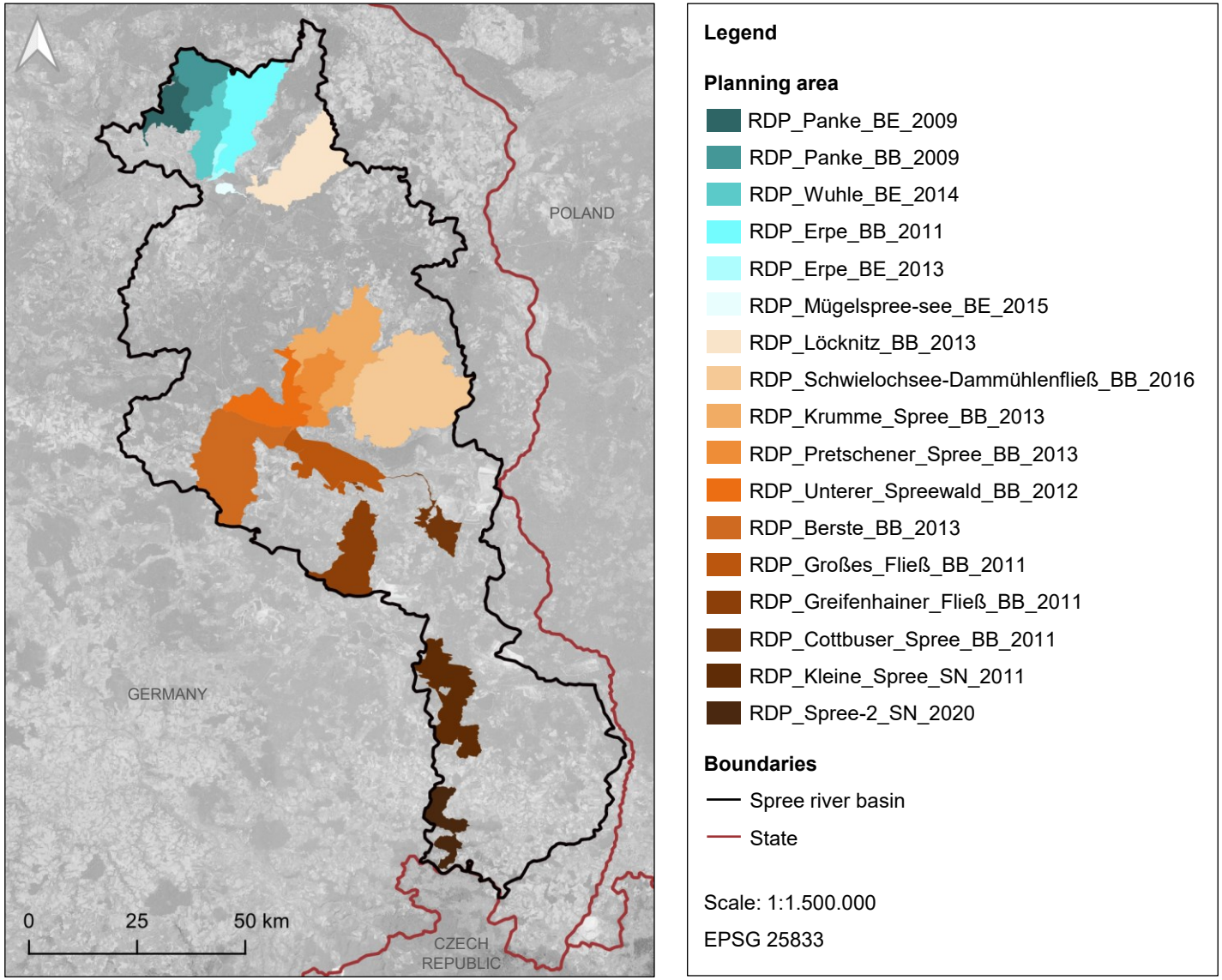
Scale: 1:5.000.000

EPSG 25833

* As the German Elbe river basin is considerably larger than the study area (Spree river basin), only measures relating to a smaller part of the Elbe river basin, the “Havel” coordination area, were considered in the analysis.

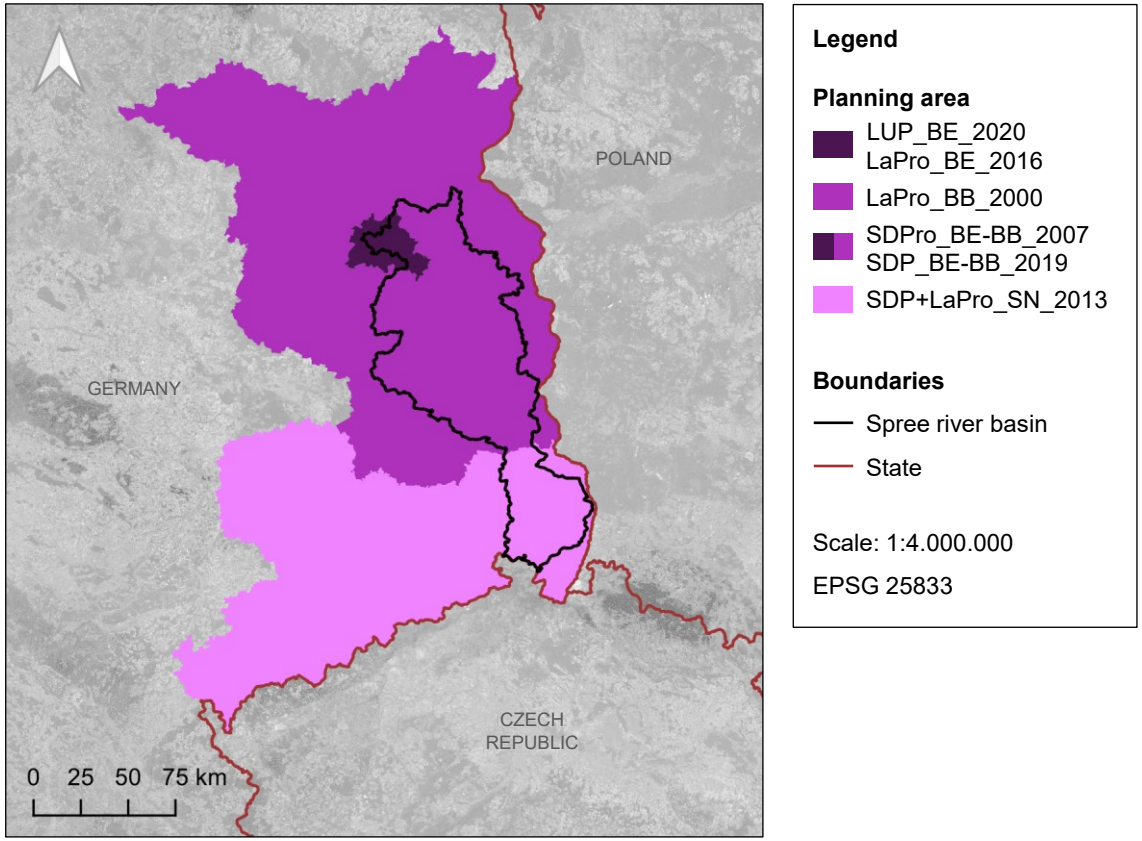
Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronyms are FRMP (flood risk management plan), RBMP (river basin management plan) and PoM (programme of measures). Area allocation is the German Elbe River basin (Elbe). Map data acquired from © Esri, Maxar, Earthstar Geographics, and the GIS User Community (2024), EC/ESTAT/GISCO (2020) and WasserBLIcK-/BfG & Zuständige Behörden der Länder (2016). For full map data references see Table S19 in the Supplement.

Figure S2. Analysed water management plans at the river sub-basin level and their planning area.



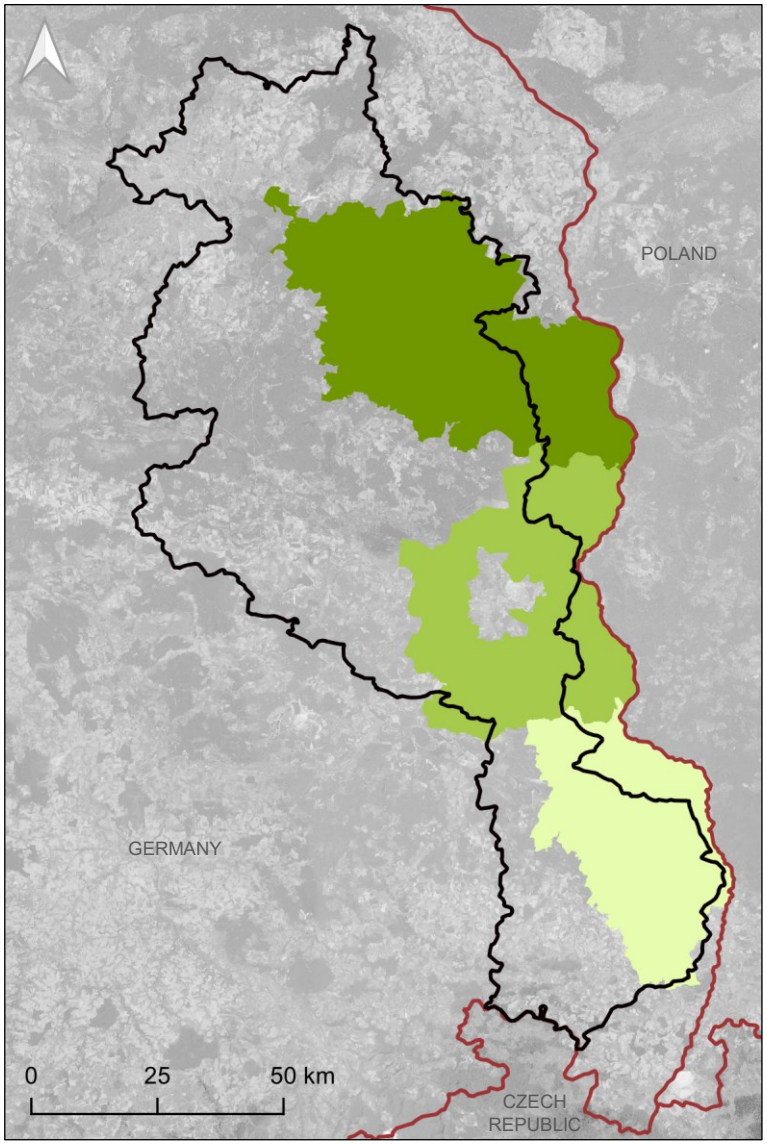
Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronym is RDP (river development plan). Area allocations are Spree river sub-basins (divers) with federal state affiliation (BB for Brandenburg, BE for Berlin, SN for Saxony). Map data acquired from © Esri, Maxar, Earthstar Geographics, and the GIS User Community (2024), EC/ESTAT/GISCO (2020), WasserBLIcK-/BfG & Zuständige Behörden der Länder (2016), LfU (2014) and LfULG (2021). For full map data references see Table S19 in the Supplement.

Figure S3. Analysed spatial and landscape plans at the federal state level and their planning area.



Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronyms are SDPro (state development programme), SDP (state development plan), LUP (land use plan) and LaPro (landscape programme). Area allocations refer to their respective federal state. Map data acquired from © Esri, Maxar, Earthstar Geographics, and the GIS User Community (2024), EC/ESTAT/GISCO (2020), BKG (2009) and WasserBLIcK-/BfG & Zuständige Behörden der Länder (2016). For full map data references see Table S19 in the Supplement.

Figure S4. Analysed spatial and landscape plans at the district and region level and their planning area.



Legend

Planning area

- LaMaP_Oder-Spree_BB_2021
- LaMaP_Spree-Neiße_BB_2009
- RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019

Boundaries

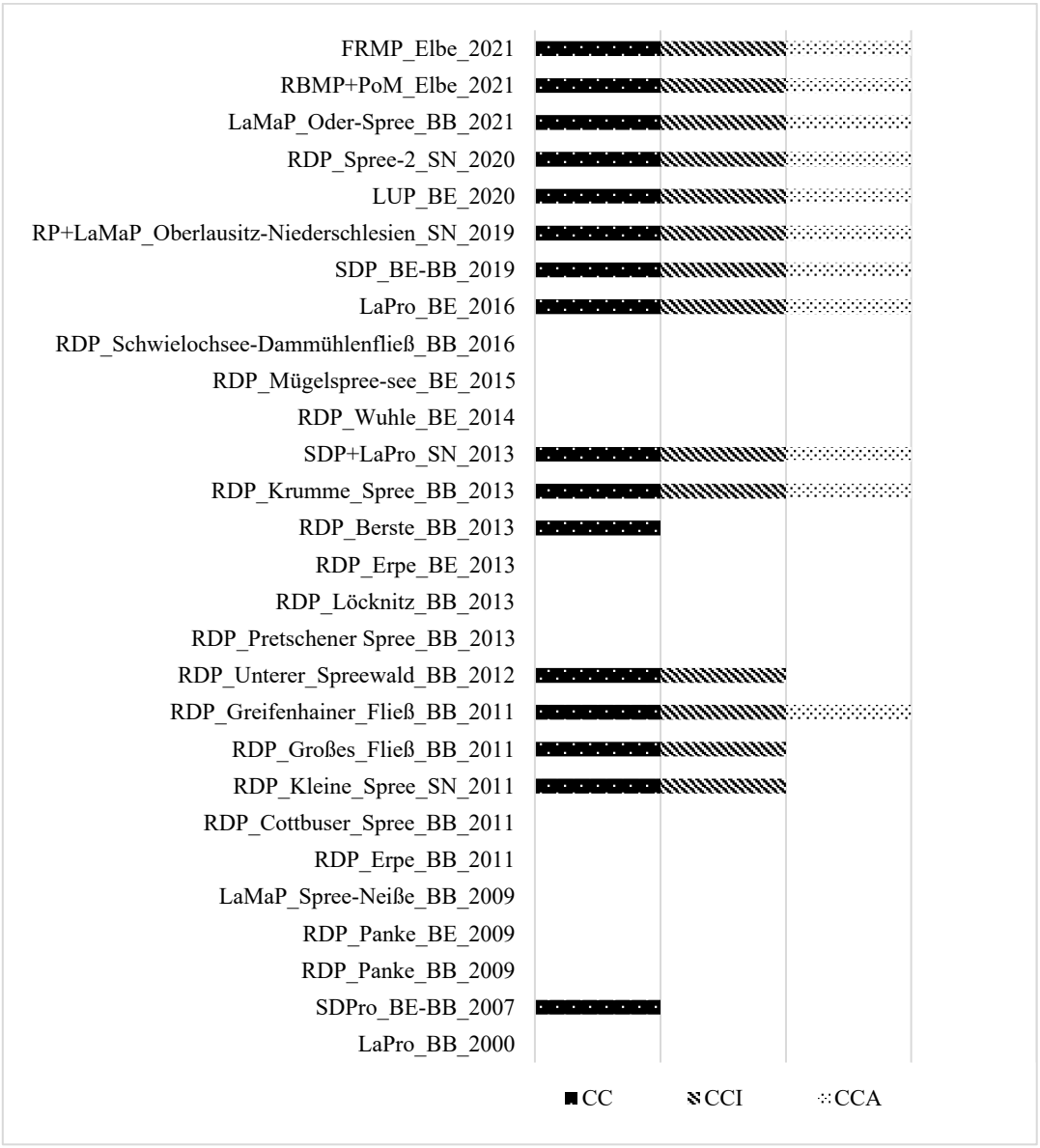
- Spree river basin
- State

Scale: 1:1.500.000

EPSG 25833

Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronyms are RP (regional plan) and LaMaP (landscape master plan). Area allocations refer to their respective region/county with federal state affiliation. Map data acquired from © Esri, Maxar, Earthstar Geographics, and the GIS User Community (2024), EC/ESTAT/GISCO (2020), BKG (2009) and WasserBLIcK-/BfG & Zuständige Behörden der Länder (2016). For full map data references see Table S19 in the Supplement.

Figure S5. Consideration of climate change (CC), its impacts (CCI) and adaptation (CCA) in plans covering the Spree river basin by year of publication from 2000-2021 (*N* = 28).



Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronyms are FRMP (flood risk management plan), RBMP (river basin management plan), PoM (programme of measures), RDP (river development plan), SDPro (state development programme), SDP (state development plan), RP (regional plan), LUP (land use plan), LaPro (landscape programme) and LaMaP (landscape master plan). Area allocations for water management plans are the German Elbe River basin (Elbe) or Spree River sub-basins (divers) with federal state affiliation (BB for Brandenburg, BE for Berlin, SN for Saxony). Area allocations for spatial and landscape plans refer to their respective administrative levels, either labelled with the federal state or the region/county with federal state affiliation.

Table S1. Water management field of action "Low water management": Overview of climate change adaptation measures and potential actions. Adopted from the Climate Change Report (LAWA, 2020; Appendix II, p. 106-113).

Climate change adaptation measures	Actions (Selection)
Low water and temperature forecasting	- Adapting the monitoring network and gauges to low water levels - Reinforcing monitoring during low water phases - Developing and expanding forecasting models - Including water temperature and other water quality parameters in the models - Developing worst-case forecasts
Water use restrictions	- Restrictions on owner, neighbour and public use of surface waters - Restrictions on service water abstraction for the public (e.g., for watering gardens, washing cars) - Regulations on abstraction for agricultural use - Restrictions on recreational use (e.g., kayaking) - Targeted communication of restrictions - Adaptation of water law decisions
Ensuring water quality	- Reducing nutrient and pollutant inputs - Reducing cooling water withdrawals and discharges - Shading from woody vegetation on watercourse banks - Aeration - Dismantling of impoundments - Low water elevation
Oxygen management through aeration	- Turbine aeration - Aeration using weir overfall, sprinkler irrigation via cascades - Introduction of technical oxygen - Monitoring of discharge, water temperature, and oxygen content
Artificial raising of low water levels	- New construction or expansion of water reservoirs and dams - Optimised management of multifunctional existing reservoirs - Transfers from neighbouring catchment areas
Creating artificial water reservoirs	- Retention basins with permanent reservoirs - Dams
Promoting natural water retention	- Providing floodplains - Rewetting of wetlands - Restoring near-natural habitats - Adapting land management - Increasing the proportion of green spaces, reducing sealing - Improving the water storage capacity of the soil

Table S2. Water management field of action "Groundwater protection and use": Overview of climate change adaptation measures and potential actions. Adopted from the Climate Change Report (LAWA, 2020; Appendix II, p. 61-67).

Climate change adaptation measures	Actions (Selection)
Climate-specific evaluation and adaptation of groundwater monitoring	- Maintaining and expanding groundwater monitoring (networks) - Increasing the recording of groundwater temperatures and possibly other parameters not previously focussed on (e.g., groundwater fauna) as part of groundwater monitoring
Promoting groundwater-friendly agriculture (quality and quantity)	- Compliance with the requirements of the Fertiliser Ordinance - Promoting organic agriculture - Precision Farming - Fast-growing plants as catch/winter crop - Groundwater management planning in agricultural areas - Change of use
Land use changes	- Organic agriculture - Converting arable land to grassland or forest - Converting intensive grassland to extensive grassland - Afforestation
Protecting groundwater-dependent terrestrial ecosystems (peatlands)	- Rewetting of drained peatlands - Designation of peatlands as nature reserves - Alternative uses for peatlands (e.g., paludiculture) - Site-appropriate land use (grassland use) for mineral groundwater soils - Cessation of agricultural use of peatlands
Promoting groundwater recharge	- Rewetting of wetlands - Restoration of near-natural water structures - Forest restructuring to an increased share of deciduous trees - Reducing land sealing - Increasing the share of green spaces - Exploitation of infiltration potentials - Conservative soil cultivation
Increasing groundwater supply	- Artificial infiltration of surface water treated for drinking water in infiltration systems
Sustainable groundwater management	- Management with consideration of climate change impacts - Groundwater level-dependent control of groundwater extractions - Determination of local groundwater levels that may not be undercut - Tying water rights to the requirement of groundwater monitoring

Table S3. Water management field of action "Public water supply": Overview of climate change adaptation measures and potential actions. Adopted from the Climate Change Report (LAWA, 2020; Appendix II, p. 68-75).

Climate change adaptation measures	Actions (Selection)
Redundant water harvesting systems	- Developing additional raw water sources - Expanding regional and supra-regional network solutions (group suppliers, special-purpose associations, long-distance suppliers)
Adapting water supply infrastructure	- Optimising existing water supply systems (e.g., deeper wells, more efficient pump systems and water extraction systems at dams) - Constructing Redundant water harvesting systems - Creating larger storage capacities in water networks and waterworks - Securing further water extraction options through comprehensive groundwater protection
Rainwater harvesting	- Collecting and storing of rainwater in rain barrels, underground cisterns, ponds, etc.
Reducing water demand	- Restricting water use (e.g., for irrigation, car washing) during dry periods - Rainwater harvesting - Reusing service water - Steering through drinking water pricing
Improving water quality in the pipeline network	- Adjusting network flushing - Regular draining of water from network end sections - Post-disinfection during storage and distribution - Reducing heating, e.g., by unsealing overlying surfaces, greater installation depths or insulating the pipes
Advanced drinking water treatment	- Reducing nutrients - Disinfecting - Diluting with less contaminated water - Removing particles through e.g., filtration, flocculation, membrane filtration
Comprehensive water supply management	- Regional or nationwide water supply management based on prioritising water supply - Prioritising drinking water supply in the event of uncertain power supply - Climate change-orientated water supply planning - Adapted reservoir management

Table S4. Water management field of action "Agricultural irrigation": Overview of climate change adaptation measures and potential actions. Adopted from the Climate Change Report (LAWA, 2020; Appendix II, p. 92-99).

Climate change adaptation measures	Actions (Selection)
Soil and erosion protection	- Expanding crop rotation - Avoiding cultivation of root crops - Cultivating catch crops - Avoiding soil compaction (fewer ruts, wider tyres) - Avoiding trampling damage and overgrazing - Utilising grassland in areas at high risk of erosion - Accumulating humus layer - Conserving soil cultivation
Conservation tillage	- Non-turning and plough less tillage - Minimal tillage - Strip-tillage
Humus accumulation	- Leaving crop residues on the field - Using organic fertiliser - Cultivating catch and nurse crops (e.g., legumes) - Using no-tillage and mulch seeding methods - Conserving soil cultivation - Preserving the natural soil water balance and avoiding drainage
Adaptations in cultivation	- Choosing drought-tolerant crops - Choosing crops that require the most water outside the summer months - Cultivating winter crops - Avoiding large-scale cultivation of erosion-promoting crops (e.g., maize, beetroot) - Alternating cultivation of different crops in strips - Shading (e.g., through agroforestry systems or by installing solar panels) - Adapting seeding and harvesting dates
Efficient irrigation	- Drip irrigation - Demand-orientated irrigation control - Precision Irrigation
Groundwater substitution	- Utilising water from surface waters - Rainwater utilisation (storing winter precipitation, e.g., in ponds) - Water storage systems (e.g., under swards of field boundaries, under parts of the cultivated area or yard area)

Table S5. Water management field of action "Water ecosystem protection": Overview of climate change adaptation measures and potential actions. Adopted from the Climate Change Report (LAWA, 2020; Appendix II, p. 51-60).

Climate change adaptation measures	Actions (Selection)
Improving continuity of flowing waters	- Constructing passable structures - Dismantling/rebuilding transverse structures - Optimising control of culvert structures
Variation of hydromorphological structures	- Removing bed and bank stabilisation - Installing flow deflectors - Widening watercourse channel - Inserting boulders and deadwood - Rewetting floodplains and wetlands
Protecting and developing riparian strips	- Planting and developing riparian woodland - Structuring wooded edges - Planting reeds - Creating riparian strips on farmland
Installing sedimentation barriers	- Greening riparian strips - Creating structures for sedimentation in riparian and floodplain areas
Nature-conserving watercourse maintenance	- Removal of washed-in, deposited material - Leaving mowed and cleared material on the bank for 1-2 days, allowing small animals to escape - Restrict clearing times to September and October (considering spawning and bird breeding seasons as well as main periods of plant and insect development) - Avoiding bed desilting during frost periods (many organisms hibernate in the mud)
Conservation and expansion of protected areas and biotope networks	- Special Areas of Conservation (SACs) under the Habitats Directive, where water-dependent habitat types should be conserved - Water protection areas
Reducing diffuse pollutant entry and nutrient inputs	- Promoting organic farming - Implementing conservation tillage, using mulching methods - Optimising the use of fertilisers and pesticides - Creating and developing wide riparian strips - Forest protection and afforestation - Peatland protection
Adapting abstraction and discharge threshold values	- Considering climate change when issuing water law authorisations for water withdrawals from and discharges into water bodies - Determining minimum water discharges for power plant discharges, taking future climatic developments into account

Water quality warning service	- Introducing a public reporting system with different reporting stages, which is used at certain threshold values for water temperature and other parameters:
	  - Pre-warning stage (critical temperatures to be expected soon)
	  - Warning stage (critical conditions in the water body)
	  - Alarm stage (significant impact on water biology, including fish)

Climate-specific adaptation and evaluation of water monitoring	- Monitoring of particularly affected water bodies - Evaluating previous developments

Table S6. Water management field of action "Flood protection during heavy rain": Overview of climate change adaptation measures and potential actions. Adopted from the Climate Change Report (LAWA, 2020; Appendix II, p. 32-42).

Climate change adaptation measures	Actions (Selection)
Retention through changes in forest management	- Reforestation - Forest restructuring towards more deciduous trees
Establishing and securing emergency waterways	- Equipping road areas with raised kerbs or ground-level gutters - Providing gutters in garden areas - No new building constructions in water drainage paths
Object protection in case of flood risk	- Installing water barriers outside buildings (e.g., thresholds, walls) - Waterproofing on buildings - Providing protective gates at yard entrances - Providing basements with floor drains - No storage of water-polluting substances in flood-prone areas (e.g., oil tanks)
Organised measures in case of extreme rainfall and flash flooding events	- Emergency strategies for transport and supply infrastructure - Flood alarm and operational planning - Coordination and cooperation with neighbouring fire services - Improved early warning of affected areas - Mobile warning systems
Behavioural precautions and training in the event of extreme rainfall and flash flooding	- Including climate change-specific topics in school and training curricula - Training courses - Information events - Fact sheets and guidelines - Raising awareness, especially in so-called "dormant" waters - Advising local authorities (e.g., flood audits) - Support programmes for self-prevention
Regular maintenance and inspection of the drainage systems	- Using spatial rakes (sediment traps) - Carrying out water inspections - Calling on the public to report blockages - Removing sediment accumulations and plant growth
Flood risk assessment (e.g., heavy rain hazard and risk maps)	- Creating local heavy rain hazard and risk maps - Analysing heavy rain hazard and risk maps - More detailed analyses with site inspections, local surveys and interviews in areas at risk

Table S7. Water management field of action "Inland flood protection": Overview of climate change adaptation measures and potential actions. Adopted from the Climate Change Report (LAWA, 2020; Appendix II, p. 5-16).

Climate change adaptation measures	Actions (Selection)
Technical flood protection	- Designating floodplains - Raising or reinforcing dykes, dams, terps, flood defence walls - Installing mobile flood defences (sandbags, dam beams, protective walls) - Adapting or building new dams (reservoirs, flood retention basins)
Recovery of flood plains and renaturation of floodplains	- Reconnecting terrain structures with retention potential (e.g., cut-off meander) - Dismantling of dykes and dams - Removing bank stabilisation - Raising of river bed
Activating additional and optimising existing retention areas	- Constructing flood retention basins and polders - Restoring and reconnecting floodplains - Installing a control system for existing flood polders - Emptying existing reservoirs before a flood event occurs
Land use regulations in flood plains/areas at risk of flooding	- Flood-adapted planning, building and renovating - No designation of development areas - Amending or updating urban land-use plans - Removing or dismantling flood-sensitive uses - Adapting agricultural cultivation (e.g., grassland)
Designation of *Vorranggebiet* and *Vorbehaltsgebieten*	- Designation of *Vorranggebiet* and *Vorbehaltsgebieten* for preventive flood protection in state and regional plans for keeping areas free for, e.g., dyke relocation or flood retention basins
Flood hazard and risk maps	- Creating flood hazard maps in accordance with the Floods Directive - Referring to flood hazard maps when drawing up flood risk maps for the environment, health, economic activities and cultural assets as well as planning and optimising precautionary measures
Identifying and mapping areas at risk of waterlogging (groundwater)	- Providing basic data and maps - Information platform on current groundwater conditions and maximum groundwater levels - Information and advice on waterlogging problems and solutions
Property protection in the event of damaging high groundwater levels	- Waterproofing of the house wall - New buildings without basement
Flood partnerships	- Association of municipalities, specialised administrations and institutions within a river basin to strengthen flood hazard awareness, to pass on experience in prevention and to establish networks of responsible institutions
Organised measures in case of an extreme inland flooding event	- Emergency strategies for transport and supply infrastructure - Flood alarm and operational planning - Coordination and cooperation with neighbouring fire services - Improved early warning of affected areas - Mobile warning systems
Behavioural precautions and training in the event of extreme inland flooding	- Including climate change-specific topics in school and training curricula - Training courses - Information events - Fact sheets and guidelines - Flood markers that remind people of past flood events - Advice for local authorities (e.g., flood audits) - Support programmes for self-prevention

Table S8. Water management field of action "Urban drainage and wastewater treatment": Overview of climate change adaptation measures and potential actions. Adopted from the Climate Change Report (LAWA, 2020; Appendix II, p. 25-31).

Climate change adaptation measures	Actions (Selection)

Optimising the construction and operation of existing sewer systems	- For low flow rates:
	  - Needs-based flushing (possibly high-pressure flushing and use of chemicals or machines)
	- For minimising the combined wastewater discharge:
	  - Network control
	  - Sewer network control
	  - Measures for urban rainwater management

Adapting wastewater treatment operations	- Aeration tank settling - Optimising secondary clarification - Flocculant addition

Installations for precipitation water treatment	- Centralised:
	  - Rain clarifier
	  - Reed lamella sedimentation
	  - Retention soil filter basin
	- Decentralised:
	  - Sedimentation shaft, pipe, channel, basin
	  - Infiltration (with special filter material)
	  - Swamp plant roof

Water retention in urban areas	- Centralised:
	  - Stormwater overflow basin for intermediate storage of combined sewage
	  - Rainwater retention basins and cisterns for the storage and utilisation of rainwater
	- Decentralised:
	  - Multifunctional areas that can be used for water retention (e.g., streets, car parks, playgrounds)
	  - Green roofs, roof gardens
	  - Green spaces (e.g., unpaved tram lines as grass tracks, roadside lawns, trees, parks)
	  - Extending inner-city woodland areas
	  - Water areas
	  - Green-blue roofs

Exploiting infiltration potentials	- Constructing infiltration systems, infiltration swales, swale-trench systems - Unsealing - Using water-permeable coverings (e.g., gravel, drainage asphalt coverings) - Improving the infiltration potential (e.g., use of ground-covering vegetation) - Avoiding soil compaction in green spaces
Incentives for rainwater management	- Implementing the priority of decentralised rainwater management in accordance with the Federal Water Act (*Wasserhaushaltsgesetz*, WHG) Section 55 (2) - Specifications in local authority drainage regulations - Split wastewater charges (separate charges for the disposal of wastewater and rainwater) - Promoting green roofs
Protecting wastewater facilities from floods	- Dyking the facilities - Examining of raising buildings - Flood-proof construction of mechanical and electro-technical plant components

Table S9. Consideration of climate change impacts in plans covering the Spree river basin (n = 14).

Scope	Plan abbreviations (plan acronym, area allocation, publication date)	Climate change impacts		
		Increasing low water events / Decrease in water supply	Increasing heavy rainfall events and/or flooding	Deterioration of water status
Water management (according to the WFD and FD)	FRMP_Elbe_2021		1	
	RBMP+PoM _Elbe_2021	1	1	1
	RDP_Greifenhainer_Fließ_BB_2011	1		
	RDP_Großes_Fließ_BB_2011	1		
	RDP_Kleine_Spree_SN_2011	1		
	RDP_Krumme_Spree_BB_2013	1		
	RDP_Spree-2_SN_2020	1		1
	RDP_Unterer_Spreewald_BB_2012	1		
Spatial planning	SDP_BE-BB_2019	1	1	
	SDP+LaPro_SN_2013	1	1	1
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019	1	1	1
	LUP_BE_2020		1	
Landscape planning	LaPro_BE_2016	1		
	LaMaP_Oder-Spree_BB_2021	1	1	1
		12	**7**	**5**

Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronyms are FRMP (flood risk management plan), RBMP (river basin management plan), PoM (programme of measures), RDP (river development plan), SDPro (state development programme), SDP (state development plan), RP (regional plan), LUP (land use plan), LaPro (landscape programme) and LaMaP (landscape master plan). Area allocations for water management plans are the German Elbe River basin (Elbe) or Spree River sub-basins (divers) with federal state affiliation (BB for Brandenburg, BE for Berlin, SN for Saxony). Area allocations for spatial and landscape plans refer to their respective administrative levels, either labelled with the federal state or the region/county with federal state affiliation.

Table S10. Overall analysis of the consideration of climate change adaptation in water-related planning for each water management field of action adopted from the Climate Change Report by the LAWA from 2020 (n = 11; 1 = climate change adaptation measure concerning the water management field of action is proposed by the plan)

Scope	Plan abbreviations* (plan acronym, area allocation, publication date)	Water management fields of action								Total consideration of water management fields of action per plan
		(a) Low water management	(b) Groundwater protection and use	(c) Public water supply	(d) Agricultural irrigation	(e) Water ecosystem protection	(f) Flood protection during heavy rain	(g) Inland flood protection	(h) Urban drainage and wastewater treatment	
Water management	FRMP_Elbe_2021				1	1	1	1	1	**5**
	RBMP+PoM_Elbe_2021	1	1	1	1	1		1	1	**7**
	RDP_Greifenhainer_Fließ_BB_2011	1	1			1				**3**
	RDP_Krumme_Spree_BB_2013	1				1				**2**
	RDP_Spree-2_SN_2020	1				1				**2**
Spatial planning	SDP_BE-BB_2019	1	1	1	1	1		1	1	**7**
	SDP+LaPro_SN_2013	1	1	1	1	1	1	1	1	**8**
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019	1	1	1	1	1	1			**6**
	LUP_BE_2020					1		1	1	**3**
Landscape planning	LaPro_BE_2016	1	1	1		1	1		1	**6**
	LaMaP_Oder-Spree_BB_2021	1	1	1	1	1	1	1	1	**8**
		9	**7**	**6**	**6**	**11**	**5**	**6**	**7**	

Table S11. Climate change adaptation measures proposed by the plans corresponding with the climate change adaptation measures for the water management field of action "Low water management" of the Climate Change Report by the LAWA from 2020 (n = 9; 1 = climate change adaptation measure is mentioned)

Scope	Plan abbreviations* (plan acronym, area allocation, publication date)	Measures of the water management field of action "Low water management"							Total of climate change adaptation meassures
		Low water and temperature forecasting	Water use restrictions	Ensuring water quality	Oxygen management through aeration	Artificial raising of low water levels	Creating artificial water reservoirs	Promoting natural water retention	
Water management	FRMP_Elbe_2021								
	RBMP+PoM_Elbe_2021		1	1		1	1	1	**5**
	RDP_Greifenhainer_Fließ_BB_2011					1		1	**2**
	RDP_Krumme_Spree_BB_2013		1	1		1			**3**
	RDP_Spree-2_SN_2020		1	1					**2**
Spatial planning	SDP_BE-BB_2019							1	**1**
	SDP+LaPro_SN_2013		1	1				1	**3**
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019		1					1	**2**
	LUP_BE_2020								
Landscape planning	LaPro_BE_2016							1	**1**
	LaMaP_Oder-Spree_BB_2021			1				1	**2**
		5	**5**	**3**	**1**	**7**			

*Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronyms are FRMP (flood risk management plan), RBMP (river basin management plan), PoM (programme of measures), RDP (river development plan), SDPro (state development programme), SDP (state development plan), RP (regional plan), LUP (land use plan), LaPro (landscape programme) and LaMaP (landscape master plan). Area allocations for water management plans are the German Elbe River basin (Elbe) or Spree River sub-basins (divers) with federal state affiliation (BB for Brandenburg, BE for Berlin, SN for Saxony). Area allocations for spatial and landscape plans refer to their respective administrative levels, either labelled with the federal state or the region/county with federal state affiliation.

Table S12. Climate change adaptation measures proposed by the plans corresponding with the climate change adaptation measures for the water management field of action "Groundwater protection and use" of the Climate Change Report by the LAWA from 2020 (n = 7; 1 = climate change adaptation measure is mentioned)

Scope	Plan abbreviations* (plan acronym, area allocation, publication date)	Measures of the water management field of action "Groundwater protection and use"						Total of climate change adaptation meassures
		Climate-specific evaluation and adaptation of groundwater monitoring	Promoting groundwater-friendly agriculture (quality and quantity)	Land use changes	Protecting groundwater-dependent terrestrial ecosystems (peatlands)	Promoting groundwater recharge	Increasing groundwater supply	Sustainable groundwater management	
Water management	FRMP_Elbe_2021								
	RBMP+PoM_Elbe_2021		1	1	1	1	1	1	**6**
	RDP_Greifenhainer_Fließ_BB_2011				1	1			**2**
	RDP_Krumme_Spree_BB_2013								
	RDP_Spree-2_SN_2020								
Spatial planning	SDP_BE-BB_2019			1	1	1			**3**
	SDP+LaPro_SN_2013		1	1	1	1		1	**5**
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019		1	1	1	1		1	**5**
	LUP_BE_2020								
Landscape planning	LaPro_BE_2016				1	1			**2**
	LaMaP_Oder-Spree_BB_2021		1	1	1	1			**4**
			4	**5**	**7**	**7**	**1**	**3**	

Table S13. Climate change adaptation measures proposed by the plans corresponding with the climate change adaptation measures for the water management field of action "Public water supply" of the Climate Change Report by the LAWA from 2020 (n = 6; 1 = climate change adaptation measure is mentioned)

Scope	Plan abbreviations* (plan acronym, area allocation, publication date)	Measures of the water management field of action "Public water supply"							Total of climate change adaptation meassures
		Redundant water harvesting systems	Adapting water supply infrastructure	Rainwater harvesting	Reducing water demand	Improving water quality in the pipeline network	Advanced drinking water treatment	Comprehensive water supply management	
Water management	FRMP_Elbe_2021								
	RBMP+PoM_Elbe_2021	1	1		1			1	**4**
	RDP_Greifenhainer_Fließ_BB_2011								
	RDP_Krumme_Spree_BB_2013								
	RDP_Spree-2_SN_2020								
Spatial planning	SDP_BE-BB_2019				1			1	**2**
	SDP+LaPro_SN_2013		1						**1**
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019							1	**1**
	LUP_BE_2020								
Landscape planning	LaPro_BE_2016			1	1				**2**
	LaMaP_Oder-Spree_BB_2021		1						**1**
		1	**3**	**1**	**3**			**3**	

Table S14. Climate change adaptation measures proposed by the plans corresponding with the climate change adaptation measures for the water management field of action "Agricultural irrigation" of the Climate Change Report by the LAWA from 2020 (n = 6; 1 = climate change adaptation measure is mentioned)

Scope	Plan abbreviations* (plan acronym, area allocation, publication date)	Measures of the water management field of action "Agricultural irrigation"						Total of climate change adaptation meassures
		Soil and erosion protection	Conservation tillage	Humus accumulation	Adaptations in cultivation	Efficient irrigation	Groundwater substitution	
Water management	FRMP_Elbe_2021	1	1	1				**3**
	RBMP+PoM_Elbe_2021	1	1	1				**3**
	RDP_Greifenhainer_Fließ_BB_2011							
	RDP_Krumme_Spree_BB_2013							
	RDP_Spree-2_SN_2020							
Spatial planning	SDP_BE-BB_2019	1						**1**
	SDP+LaPro_SN_2013	1	1	1				**3**
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019	1	1	1				**3**
	LUP_BE_2020							
Landscape planning	LaPro_BE_2016							
	LaMaP_Oder-Spree_BB_2021	1			1	1		**3**
		6	**4**	**4**	**1**	**1**		

*Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronyms are FRMP (flood risk management plan), RBMP (river basin management plan), PoM (programme of measures), RDP (river development plan), SDPro (state development programme), SDP (state development plan), RP (regional plan), LUP (land use plan), LaPro (landscape programme) and LaMaP (landscape master plan). Area allocations for water management plans are the German Elbe River basin (Elbe) or Spree River sub-basins (divers) with federal state affiliation (BB for Brandenburg, BE for Berlin, SN for Saxony). Area allocations for spatial and landscape plans refer to their respective administrative levels, either labelled with the federal state or the region/county with federal state affiliation.

Table S15. Climate change adaptation measures proposed by the plans corresponding with the climate change adaptation measures for the water management field of action "Water ecosystem protection" of the Climate Change Report by the LAWA from 2020 (n = 11; 1 = climate change adaptation measure is mentioned)

Scope	Plan abbreviations* (plan acronym, area allocation, publication date)	Measures of the water management field of action "Water ecosystem protection"										Total of climate change adaptation meassures
		Improving continuity of flowing waters	Variation of hydromorphological structures	Protecting and developing riparian strips	Installing sedimentation barriers	Nature-conserving watercourse maintenance	Conservation and expansion of protected areas and biotope networks	Reducing diffuse pollutant entry and nutrient inputs	Adapting abstraction and discharge threshold values	Water quality warning service	Climate-specific adaptation and evaluation of water monitoring	
Water management	FRMP_Elbe_2021		1	1	1	1						**4**
	RBMP+PoM_Elbe_2021	1	1	1	1	1	1	1	1			**8**
	RDP_Greifenhainer_Fließ_BB_2011		1									**1**
	RDP_Krumme_Spree_BB_2013		1									**1**
	RDP_Spree-2_SN_2020		1					1	1		1	**4**
Spatial planning	SDP_BE-BB_2019						1					**1**
	SDP+LaPro_SN_2013		1				1		1			**3**
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019		1	1	1		1	1	1			**6**
	LUP_BE_2020						1					**1**
Landscape planning	LaPro_BE_2016		1				1					**2**
	LaMaP_Oder-Spree_BB_2021				1			1				**2**
		1	**8**	**3**	**4**	**2**	**6**	**4**	**4**		**1**	

Table S16. Climate change adaptation measures proposed by the plans corresponding with the climate change adaptation measures for the water management field of action "Flood protection during heavy rain" of the Climate Change Report by the LAWA from 2020 (n = 5; 1 = climate change adaptation measure is mentioned)

Scope	Plan abbreviations* (plan acronym, area allocation, publication date)	Measures of the water management field of action "Flood protection during heavy rain"							Total of climate change adaptation meassures
		Retention through changes in forest management	Establishing and securing emergency waterways	Object protection in case of flood risk	Organised measures in case of extreme rainfall and flash flooding events	Behavioural precautions and training in the event of extreme rainfall and flash flooding	Regular maintenance and inspection of the drainage systems	Flood risk assessment (e.g., heavy rain hazard and risk maps)	
Water management	FRMP_Elbe_2021					1	1	1	**3**
	RBMP+PoM_Elbe_2021								
	RDP_Greifenhainer_Fließ_BB_2011								
	RDP_Krumme_Spree_BB_2013								
	RDP_Spree-2_SN_2020								
Spatial planning	SDP_BE-BB_2019								
	SDP+LaPro_SN_2013	1			1	1			**3**
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019	1							**1**
	LUP_BE_2020								
Landscape planning	LaPro_BE_2016	1							**1**
	LaMaP_Oder-Spree_BB_2021			1		1			**2**
		3		**1**	**1**	**3**	**1**	**1**	

*Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronyms are FRMP (flood risk management plan), RBMP (river basin management plan), PoM (programme of measures), RDP (river development plan), SDPro (state development programme), SDP (state development plan), RP (regional plan), LUP (land use plan), LaPro (landscape programme) and LaMaP (landscape master plan). Area allocations for water management plans are the German Elbe River basin (Elbe) or Spree River sub-basins (divers) with federal state affiliation (BB for Brandenburg, BE for Berlin, SN for Saxony). Area allocations for spatial and landscape plans refer to their respective administrative levels, either labelled with the federal state or the region/county with federal state affiliation.

Table S17. Climate change adaptation measures proposed by the plans corresponding with the climate change adaptation measures for the water management field of action "Inland flood protection" of the Climate Change Report by the LAWA from 2020 (n = 6; 1 = climate change adaptation measure is mentioned)

Scope	Plan abbreviations* (plan acronym, area allocation, publication date)	Measures of the water management field of action "Inland flood protection"											Total of climate change adaptation meassures
		Technical flood protection	Recovery of flood plains and renaturation of floodplains	Activating additional and optimising existing retention areas	Land use regulations in flood plains / areas at risk of flooding	Designation of "Vorranggebiet" and "Vorbehaltsgebieten"	Flood hazard and risk maps	Identifying and mapping areas at risk of waterlogging (groundwater)	Property protection in the event of damaging high groundwater levels	Flood partner-ships	Organised measures in case of extreme inland flooding event	Behavioural precautions and training in the event of extreme inland flooding	
Water management	FRMP_Elbe_2021	1	1	1	1	1	1		1	1	1	1	**10**
	RBMP+PoM_Elbe_2021		1	1									**2**
	RDP_Greifenhainer_Fließ_BB_2011												
	RDP_Krumme_Spree_BB_2013												
	RDP_Spree-2_SN_2020												
Spatial planning	SDP_BE-BB_2019	1	1	1	1		1			1		1	**7**
	SDP+LaPro_SN_2013	1	1	1							1	1	**5**
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019												
	LUP_BE_2020	1			1		1						**3**
Landscape planning	LaPro_BE_2016												
	LaMaP_Oder-Spree_BB_2021	1	1	1	1		1		1			1	**7**
		5	**5**	**5**	**4**	**1**	**4**		**2**	**2**	**2**	**4**	

Table S18. Climate change adaptation measures proposed by the plans corresponding with the climate change adaptation measures for the water management field of action "Urban drainage and wastewater treatment" of the Climate Change Report by the LAWA from 2020 (n = 7; 1 = climate change adaptation measure is mentioned)

Scope	Plan abbreviations* (plan acronym, area allocation, publication date)	Measures of the water management field of action "Urban drainage and wastewater treatment"							Total of climate change adaptation measures
		Optimising the construction and operation of existing sewer systems	Adapting wastewater treatment operations	Installations for precipitation water treatment	Water retention in urban areas	Exploiting infiltration potentials	Incentives for rainwater management	Protecting wastewater facilities from floods	
Water management	FRMP_Elbe_2021				1	1			**2**
	RBMP+PoM_Elbe_2021	1	1	1		1			**4**
	RDP_Greifenhainer_Fließ_BB_2011								
	RDP_Krumme_Spree_BB_2013								
	RDP_Spree-2_SN_2020								
Spatial planning	SDP_BE-BB_2019					1			**1**
	SDP+LaPro_SN_2013				1	1			**2**
	RP+LaMaP_Oberlausitz-Niederschlesien_SN_2019								
	LUP_BE_2020				1	1			**2**
Landscape planning	LaPro_BE_2016	1			1	1			**3**
	LaMaP_Oder-Spree_BB_2021	1				1		1	**3**
		3	**1**	**1**	**4**	**7**		**1**	

*Plan abbreviations are composed of plan acronym, area allocation and publication date. Plan acronyms are FRMP (flood risk management plan), RBMP (river basin management plan), PoM (programme of measures), RDP (river development plan), SDPro (state development programme), SDP (state development plan), RP (regional plan), LUP (land use plan), LaPro (landscape programme) and LaMaP (landscape master plan). Area allocations for water management plans are the German Elbe River basin (Elbe) or Spree River sub-basins (divers) with federal state affiliation (BB for Brandenburg, BE for Berlin, SN for Saxony). Area allocations for spatial and landscape plans refer to their respective administrative levels, either labelled with the federal state or the region/county with federal state affiliation.

Table S19. Map data references.

Data theme	Publisher	Year of publication	Product title	Link for download (last access: 3 December 2024)
Base map	Esri, Maxar, Earthstar Geographics, and the GIS User Community	2024	World Imagery (*in grey shading)	Download: https://services.arcgisonline.com/arcgis/rest/services/World_Imagery/MapServer/WMTS/1.0.0/WMTSCapabilities.xml
State boundaries	EC/ESTAT/GISCO – European Commission, Eurostat (ESTAT), GISCO	2020	Local Administrative Units 2019	https://gisco-services.ec.europa.eu/distribution/v2/countries/
Federal state boundaries	BKG – Bundesamt für Kartographie und Geodäsie	2009	WFS Verwaltungsgebiete 1:250 000 (Bundesland)	https://geoportal.de/Metadata/cfbe95dc-81b9-4704-a61c-d71070d15fd3 Download: https://sgx.geodatenzentrum.de/wfs_vg250?SERVICE=WFS&Request=GetCapabilities
County/Region boundaries in Brandenburg and Saxony (Oder-Spree, Spree-Neiße, Oberlausitz-Niederschlesien)	BKG – Bundesamt für Kartographie und Geodäsie	2009	WFS Verwaltungsgebiete 1:250 000 (Verwaltungsgebiete, Kreis)	https://geoportal.de/Metadata/cfbe95dc-81b9-4704-a61c-d71070d15fd3 Download: https://sgx.geodatenzentrum.de/wfs_vg250?SERVICE=WFS&Request=GetCapabilities
German Elbe river basin	WasserBLIcK-/BfG & Zuständige Behörden der Länder	2016	Einzugsgebietsgrenzen-DE	https://geoportal.bafg.de/download/opendata/einzugsgebietsgrenzen/einzugsgebiete/datasetfeed.xml
Coordination area “Havel”	WasserBLIcK-/BfG & Zuständige Behörden der Länder	2016	Einzugsgebietsgrenzen-DE	https://geoportal.bafg.de/download/opendata/einzugsgebietsgrenzen/einzugsgebiete/datasetfeed.xml
Spree river basin	WasserBLIcK-/BfG & Zuständige Behörden der Länder	2016	Einzugsgebietsgrenzen-DE	https://geoportal.bafg.de/download/opendata/einzugsgebietsgrenzen/einzugsgebiete/datasetfeed.xml
Spree river sub-basins in Saxony	LfULG – Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie	2021	WFS - WRRL: Messstellen zur Bewertung des Zustandes der Oberflaechenwasserkoerper 2022-2027	https://geoportal.de/Metadata/2cbf68cb-0096-4012-a31d-b0784888d138 Download: https://geoportal.umwelt.sachsen.de/arcgis/services/wasser/wrrlmessstellenowk_22_27/MapServer/WFSServer
Spree river sub-basins in Brandenburg	LfU – Landesamt für Umwelt Brandenburg	2014	Gebiete der Gewässerentwicklungskonzepte nach WRRL im Land Brandenburg (Einzugsgebiete der Oberflaechenwasserkoerper)	https://geoportal.de/Metadata/2C462EAF-DB2A-45F3-A3B0-92F4E9A92532 Download: https://data.geobasis-bb.de/geofachdaten/Wasser/WRRL/wrrl_gek.zip
Spree river in Brandenburg	LfU – Landesamt für Umwelt Brandenburg	2024	Wasserrahmenrichtlinie Daten zum Entwurf 3. Bewirtschaftungszyklus 2020 – Datensammlung (Fließgewässerwasserkörper, Seewasserkörper)	https://geoportal.brandenburg.de/detailansichtdienst/render?view=gdibb&url=https://geoportal.brandenburg.de/gs-json/xml?fileid=DE9CDB3B-3EF3-4E73-8CE8-81481E3DB01D# Download: https://data.geobasis-bb.de/geofachdaten/Wasser/WRRL/wrrl_2020.zip
Spree river in Saxony	LfULG – Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie	2021	WFS - WRRL: Messstellen zur Bewertung des Zustandes der Oberflaechenwasserkoerper 2022-2027 (Standgewaesser, Fliessgewaesser)	https://geoportal.de/Metadata/2cbf68cb-0096-4012-a31d-b0784888d138 Download: https://geoportal.umwelt.sachsen.de/arcgis/services/wasser/wrrlmessstellenowk_22_27/MapServer/WFSServer