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Storylines articulating scenarios for an assessment of the importance of woody buffers along European streams

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PRINCIPAL
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COVER PICTURE
Isar flowing North at Lenggries (Bavaria, Germany). Photo: Jan Vermaat

NØKKELORD
Scenario nedskalering, klima-endring, endring i arealbruk, skogdekkede elvebredder, økosystemtjenester

KEY WORDS
Scenario downscaling, climate change, land use change, riparian woodland, ecosystem services

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Abstract

Woodlands and lines of trees along streams can have multiple effects on stream water quality stream biota and ecosystem functions of the riparian zone and wider floodplain. One of the tasks of the research project OSCAR is to assess and explore plausible future development of these woody buffer strips in the near future with 2050 as time horizon. For this purpose, the current study used existing scenarios of climate (RCPs) and societal change (SSPs) and selected three, SSP1, 2 and 3 (respectively 'sustainability', 'middle of the road' and 'regional rivalry'). We downscaled the SSPs in an articulate and consistent way to reflect three different, contrasting overall pathways of change in society and three corresponding plausible ways river management would develop accordingly (dubbed Riparian Management Packages). In this way, we produced an elaborate tabulation of possible changes in a.o. land use, agriculture, economic strength, institutional focus which can be applied in modelling exercises in OSCAR.

Sammendrag

Kantsoner langs elver med trær eller skog kan ha ulike effekter på vannkvalitet, livet i vannet og økosystemets funksjoner langs elvens bredder. En av de oppgaver av forskningsprosjektet OSCAR er å definere plausible scenarier for framtiden av slike kantsoner til og med 2050. Vi har utredet i detalj hva eksisterende scenarier av klima (RCPs) og samfunnets utviklinger (SSPs) kunne bety. Vi har utvalgt SSPs 1,2 og 3, nedskalert disse og koplet dem opp til 'vann-forvaltingspakker'. Slik har vi produsert en utarbeidet tabell med plausible utviklinger i blant annet jord- og skogbruket, økonomi, institusjonell vinkling so er klar til bruk i videre modelleringsarbeid i OSCAR.

1. Introduction

The objective of this task was to combine two frequently used SRES scenarios for global change (i.e. A2 and B1) with local 'management scenarios of woody buffer configuration' into a set of storylines. These storylines shall be specific and relevant for understanding the socio-economic and climate changes that may plausibly occur around European rivers, and useful to derive modelling input for wp3 and wp5. The global change scenarios should be seen as 'external'; they thus set the scene for the river basin manager and affect the playing field and rules of the game, whereas they themselves cannot be influenced by the manager. In contrast, river basin management can design and implement a wide range of measures that can be 'management scenarios', which are within their span of control (cf fig 1). We have labelled these as Riparian Management Packages (RMPs), since such measures generally come as a logical combination. During the development of this task, we encountered the need for a clarification of how these 'external' scenarios and the RMPs should be understood, how they should be delineated from each other, and how they would plausibly combine. An iterative process of refinement is foreseen in the project proposal through dialogue with local stakeholder representatives. To date, the consultation has been carried out for one of our catchments, the Nahe.

This report first describes our approach, where we also include the development in our line of thinking, and then describes the chosen scenarios and RMPs as extensively and quantitatively as we deem feasible. We treat the geophysical climate aspects and the socio-economic aspects of the scenarios separately. We explain below that adjustments after local stakeholder workshops may be necessary, hence this working document is labelled as version 1.1.

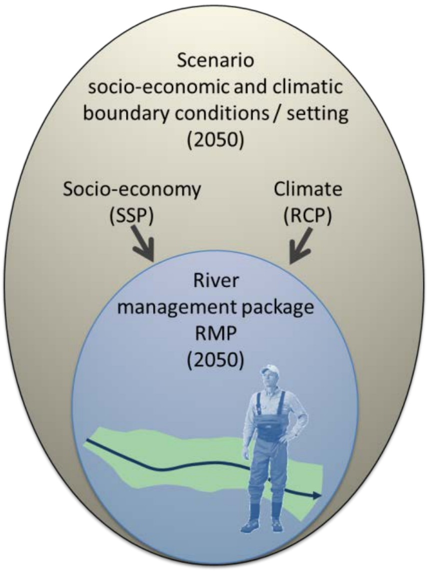

Fig. 1: Riparian management packages (RMPs) describing the measures that can be taken locally by river managers (according to the expert opinion of the stakeholders) given the socio-economic and climatic boundary conditions set by the scenarios (described in OSCAR based on recent scenario literature).

2. Approach

Using published literature and a freely available climate modelling tool from the CLIMSAVE project we articulated the two global change scenarios and separated their geophysical and socio-economic dimensions. We then iteratively discussed how these would relate to the local RMPs and what combinations would form a feasible and relevant set of modelling input conditions. These are then presented to stakeholder representatives in a series of dedicated workshops for each separate catchment under study. Discussion during the first stakeholder workshop in Mainz in December of 2017 led to adjustments. Since similar workshops are foreseen later in 2018, the current articulation of scenarios and RPMs may still undergo local adjustments. Hence, this document cannot be regarded as completely finalized. Revisions will be included as annexes in order to keep track of such changes in an orderly and traceable fashion.

3. Development in our line of thinking over time

In the proposal, it is mentioned that a set of 4 'riparian management packages on local woody buffer configurations (structure/design and spatial arrangement) will be combined with 3 more large-scale, global climate change scenarios. During the development of this document, our view on how to make this combination has gradually changed. We use this section to document this development.

During the OSCAR kick-off meeting in Berlin 20-22 March 2017 the task has been specified further. We decided that riparian management packages should reflect four options: 'current state, best practice, realistic, and pessimistic'. In addition, we assembled some ideas on how to operationalize the four riparian management packages, i.e. how to implement them in GIS. For example, for the realistic package we suggested to assume that all measures of the 2nd RBMP have been put into practice. The climate change scenarios selected in the OSCAR proposal were the two most contrasting of the benchmark family of SRES global change scenarios (Nakicenovic et al., 2000, Busch 2006): A2, reflecting a rapidly warming four degree world (2100) and B1, reflecting a two degree world.

In current global change scenario literature, the socio-economical side of global change is split from the geophysical aspects (cf Van Vuuren & Carter, 2014). It is argued that different pathways of societal change can lead to similar global warming, i.e. that socio-economic and climate scenarios cannot be linked one to one. The socio-economic scenarios are called Shared Socio-economic Pathways or SSPs in recent literature. Briefly, A2 corresponds largely to SSP3 and B1 to SSP1 (cf annex 1). The recent climate scenarios are based on Representative Concentration Pathways (RCP). The geophysical climate change aspects of A2 are grasped by Representative Concentration Pathway RCP 8.5 (e.g. Van Vuuren and Carter, 2014), and B1 is assumed to correspond to RCP4.5. In the OSCAR proposal, however, we mentioned only two 'coupled' global change scenarios, each being a combination of socio-economic trends and corresponding climate conditions. We still think that it is useful not to separate the socio-economic and climatic scenarios since we found that stakeholders have difficulty to distinguish future socio-economic from geophysical / climatic conditions.

Therefore, we first decided to consider two combined socio-economic and climate scenarios in OSCAR, namely A2 (corresponding to SSP3 and RCP 8.5) and B1 (corresponding to SSP1 and RCP4.5). We agreed to use 2050 as a time horizon. In addition, the OSCAR proposal included a 'baseline' scenario, to reflect the current socio-economic and climate conditions, which we take to correspond with 2010, in line with the 2006-2010 period used for the MONERIS modelling in WP2. For brevity, we use 2010 as label for our current baseline period, and acknowledge a bandwidth of ± 5 years.

Table 1. Different combinations of four management practices and the coupled climate and socio-economic scenarios for use in OSCAR.

	Current (~2010)	B1 (RCP 4.5, SSP1)	A2 (RCP 8.5, SSP3)
Pessimistic practice			x
Current practice	X		x
Realistic practice		X	
Best practice		X	

This matrix of 4 management packages x 3 scenarios provides a potential set of 12 different combinations (Table 1). In practice, however, not all combinations are equally plausible or equally practical for use in a stakeholder workshop for the following reasons: (a) A lower number of strongly contrasting combinations is more efficient and easier to communicate than a larger number with lower contrasts among each. (b) The socio-economic storylines of the two selected scenarios will strongly drive the options available for local river managers. (c) As we will show in the next section, particularly in the German catchments, climate change will not yet differ much between RCP4.5 and RCP8.5. The difference will become increasingly marked towards 2100. (d) Finally, 'current' management practice coincides with the 'current' climate and societal conditions.

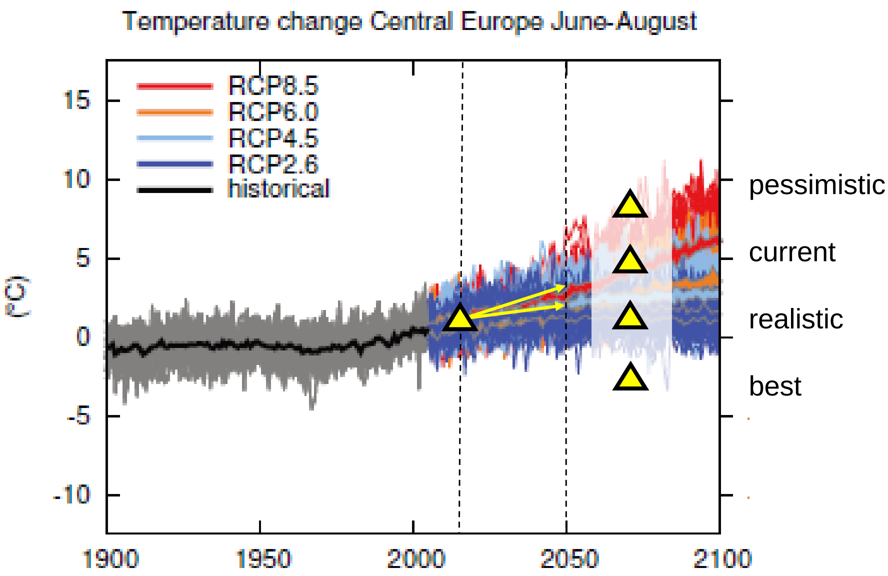

Fig 1. Mapping the four management practices onto probable climate change towards 2050. The latter here depicted as projected summer temperature change for Central Europe (from fig A1.36 in IPCC, 2013). Triangles symbolize the different management packages.

Therefore, only 5 combinations have been selected for discussion with the different local stakeholders (Table 1, Figure 1) in task 5.1. Such a combination of scenarios and management packages will be used as input for BBN modelling in task 4.2.

In the discussion with representatives for the Nahe catchment, however, our choice appeared difficult to explain. These representatives expressed a need for a third, intermediate scenario to fit with the three river management practices (best-practice, realistic, pessimistic). We have decided to follow this advice and therefore adjusted our combination to 4 scenarios with 4 corresponding management packages. Hence, we deviate from the original selection of the two SRES scenarios A2 and B1, or SSP1 and SSP3, and include the intermediate socio-economic scenario SSP2 from O'Neill et al. (2017). For consistency, we then also decided to refer to A2 as SSP3/RCP8.5 and to B1 as SSP1/RCP4.5, and use SSP2/RCP6.5 as the intermediate scenario.

Table 2. New simple one-to-one combinations of scenarios and river management packages (RMP) and two different scenario runs for each scenario to disentangle riparian management package effects from climate effects. Since climate scenarios only slightly differ between RCP8.5, 6.5, and 4.5 in the Nahe until 2050, results of the first scenario runs (only changing climate) will only slightly differ between scenarios in the Nahe catchment.

	Scenario run only changing climate	Scenario run changing climate and RMP
Baseline socio-economic, climate, and river management current conditions	Baseline to which both scenario runs are compared	
Pessimistic scenario (SSP3/RCP8.5) and RMP	x	x
Realistic scenario (SSP2/RCP6.5) and RMP	x	X
Best practice scenario (SSP1/RCP4.5) and RMP	X	x

However, we still consider the original proposal idea that is useful to disentangle the effect of climate change and changes in riparian management. Therefore, we suggest performing two runs for each scenario (Table 3): One only changing climate conditions according to the climate scenario, and another one changing the riparian management practice. By comparing the two runs for each scenario, we could investigate if the changes in riparian management packages either mitigates climate effects (best-practice) or aggravate climate effects (pessimistic). In the next section, we elaborate on this.

4. Generic storylines for the socio-economic part of the scenarios

Using published projections on land use change, economic development and institutional changes, we deduce plausible articulations of the wider societal (economical, political) and geographical setting within which river managers will operate towards 2050. This wider setting will influence, but not fully determine, the day-to-day working reality of a river basin manager. The storylines were partly based on the work of Vermaat et al. (2017) - who have done a similar exercise when they worked out what the full set of four SRES scenarios would mean in terms of input variables for the BIOSCORE database tool (full presentation in Delbaere et al. 2009; www.bioscore.eu) - as well as in O'Neill et al. (2017).

An overall projection of the societal change trajectories in SSP1, SSP2 and SSP3 used in OSCAR is presented in Table 3. We also include a first attempt at projecting relevant ecological drivers and pressures operating at the river valley scale. Together these scenarios display a wide divergence in societal development as well as effects on the river and its valley. Expected geophysical characteristics of climate change are presented in Table 4.

The articulated socio-economic dimensions of the three scenarios in Table 3 suggest that SSP3 will lead to a lower priority for implementing environmental policy, as well as reduced institutional capacity and funding for measures. This will affect agricultural practices and urban pollutant loads to rivers. SSP1 is contrasting markedly with this. As such, these two scenarios indeed may form the outer edges of the band-width covering all trajectories of societal change. SSP2 is an intermediate baseline, where environmental sustainability is not a major policy focus, but is still not fully abandoned. Regional differences may occur and different 'policy patchworks' may lead to a wide range of societal change trajectories.

Table 3. Articulation of the three SSPs chosen in OSCAR for the societal and geographic setting of central European river valleys towards a time horizon of 2050, and a projection of drivers (or pressures) on river valleys. Articulation based on Vermaat et al. (2017), O'Neil et al. (2017), Riahi et al. (2017) and Popp et al. (2017) if not indicated specifically.

Scenario:	SSP1/RCP 4.5	SSP2/RCP 6.5	SSP3/RCP 8.5
Global trends in society			
Agriculture	Innovative, ecological and economically rewarding 'green' agriculture for an expanding European market; rapid diffusion of new best practices. Focus on fair prices and reduction of transport offers considerable opportunities for jobs in the countryside, often in combination with rural tourism.	Relative importance of different economic sectors continues as current and industrial innovation proceeds at a low pace. Agricultural impacts on water quality are only partly mitigated and there is limited focus on a circular economy. Agricultural enterprises continue to expand in size and reduce in number.	Productivity weakened due to climatic, technological as well as financial constraints; global trade declines, whereas e.g. seed and agrotechnology becomes increasingly monopolized by a few international companies.
Human population density	Stabilized, with substantial mobility across Europe. Gini coefficient stabilizes.	Human population increases slowly at a countrywide scale, but this occurs particularly in a limited number of urbanising centres.	Limited increases, particularly in larger cities and due to net immigration despite harsh policy, which however is implemented with limited success. Gini coefficient increases: distribution of wealth becomes more uneven.
Economic strength	Strong and regionally differentiated productivity within a common market.	Economic growth is positive, but limited. The European common market witnesses a stagnation, but European supranational institutions continue to exist and perform reasonably well despite criticism.	Weakened, local markets, slow economic growth worldwide; some global commercial players have monopolized vital resources and commodities and succeed in dominating otherwise strongly fragmenting markets.
Green, environmental focus in policy	Paris agreements on the reduction of greenhouse gas emissions are met. Strong innovative green industry; also water quality targets laid down in the WFD met by 2050. Planning and management of urbanization proceeds in an orderly and coordinated fashion.	Paris agreements are not fully met due to slow and incomplete implementation at the national level and strong, successful lobbying by important sectors such as agriculture and transport. Policy coordination is not always successful.	Limited innovation, dependence on expensive, imported fossil fuel; limited focus on sustainability, also due to limited financial resources. Urbanisation is poorly managed.
Global or national orientation in policy and culture	Global, integration into a European federation with a strong overall focus on reducing environmental footprints, and local employability with considerably successful implementation. Policy issues of health and employment are successfully linked with environmental policy.	EU-wide and national environmental policies lose momentum in competition with other major policy issues such as health, employment and security.	Regional, increased nationalism, EU disintegrates and its legal strength in opposing global monopolists declines. Democratic institutions become less effective and credibility issues arise. Defense and security industry claim substantial shares of the limited national budgets.

Recreation	Recreation in the countryside increases too, but with a focus on eco-tourism and 'leave-no-trace' outdoor life. Mediterranean tourist destinations remain important ensuring jobs in Southern Europe.	Recreation continues as currently with growing mass tourism based on air transport to favoured coasts in Europe and abroad. More Northern coasts, however, become more popular due to an increasingly adverse climate along e.g. the Mediterranean.	Recreation pressure in the national countryside increases due to limited financial resources, increased barriers on travel and increased nationalism; environmental awareness is limited however. Increasing summer temperatures however make southern areas less suitable for tourism (Vermaat et al., 2013).
Institutional strength and governance	Strong, reliable institutions at national, supra-national and global level.	Not all supranational and national institutions succeed equall well in their societal recognition and democratic effectiveness. Burocracies are only partly modernised.	Weak, unpredictable institutions. National governments dominate but are trimmed in bureaucratic strength due to a prevalence in free-market and small-government adherence among ruling politicians.
Drivers and pressures in the river valley			
Land use change (from Hellmann & De Moel, 2013*),	German cases: a slight increase in 'natural' and abandoned land at the expense of arable land. Rhone: distinct increase in natural and abandoned land at the expense of arable land.	Relative allocation of land does not change, but agricultural intensification continues and environmental effects are not fully countered.	German cases: increase in arable land at the expense of natural land. Rhone: arable land and pastures increase at the expense of natural vegetation. This will have an effect on nutrient and sediment load.
Eutrophication: nutrient load from agriculture and domestic sewage	WFD targets are largely achieved by 2050.	Nutrient load to rivers not fully in check, but current improvements are respected and in part further improved.	Phosphorus load may increase in parallel with increased top soil erosion, domestic sewage may end up in the rivers more frequently than before
Sediment load from adjacent agricultural land	Erosion control is greatly improved	Erosion control not fully effective.	Increased due to increased arable land and little attention and incentives for erosion abatement.
Organic pollution with oxygen consuming domestic load	Reduced to acceptably low levels due to the WFD	Current waste water treatment plants remain in operation and their performance is ensured through proper maintenance. Small-scale, and countryside point sources are not further targeted.	Same as current or maybe worsening because of failing infrastructure and increased intensity of storm overflows
Agricultural water use for irrigation: consequences for river flow	Efficient innovative water harvesting techniques cope with the decline in available water for irrigation	Ground- and river-water is subject to increased competitive pressure for both drinking water and irrigation purpose. Urban drinking water needs are secured at the expense of agriculture leading to short periods of water shortage in particularly dry summers, and hence to agricultural productivity drops.	Both groundwater aquifers and river water is increasingly used for irrigation purpose leading to sinking groundwater tables and dropping base flow levels in the river. This has longer-term negative impacts for drinking water and irrigation in all study catchments, but most severely in the Bresse.
Drinking water production from river water using	Surface water quality is sufficient to enable drinking water production at minimum cost	River water quality is generally sufficient for drinking water production, but extra	River water quality is often insufficient and necessary additional measures increase the cost of water;

bank infiltration and other means		measures have to be intermittently implemented.	competition with other uses of river water is strongly felt.
Hydropower water use and minimum ecological flow	Existing hydropower schemes are modernized and connected to smart grids with other renewable energy sources, including geothermal options. Inclusion of ecological considerations in hydropower, both for current schemes and in new developments.	Hydropower schemes remain in use and some measures are taken to enhance ecological connectivity of the stream network. However, the energy sector at large has not made a wholesale transition to a well-balanced mixture of renewables.	Existing hydropower schemes are not modernized, leading to relatively low energy production, but the energy market suffers from shortage hence high prices allow for continued operation of outdated infrastructure.
Land use planning in the river valley	Biodiversity objectives are included in spatial planning together with other sustainability policy items.	Increased incidence of both high floods and drought periods is recognized as an important pressure that should be coped with in spatial planning. However, the effective implementation is lagging behind, and the incorporation of biodiversity targets has only secondary importance.	Spatial planning is limited to the minimum necessary to sustain economic productivity, hence focused on agriculture, industry and roads. Flood prevention schemes are foreseen, but their implementation is limited and left to private and commercial initiatives.
Recreative use of the river, e.g. kayaking, rafting, fishing	Possibilities for green outdoor recreation are enhanced and generate local income.	River recreation generally similar as under current conditions, but increased summer droughts may impose limits.	Limited during summer due to low discharge.
Possible establishment non-native invasive species	Possibly constant.	Uncertain.	Possibly enhanced.

* Hellman & De Moel (2013) actually downscaled these scenarios for the Elbe and Loire. We take these projections to be comparable in the Nahe and Stever, as well as the Bresse and Azergues, respectively.

5. Quantitative geophysical climate change projections for the case study areas in the two most extreme scenarios

At the European scale, particularly the CLIMSAVE project has provided a useful modelling tool, which includes SRES scenarios to reflect the geophysical climate change aspects. The CLIMSAVE project, however, has developed its own socio-economic scenarios (Harrison et al. 2015) which do not fully correspond with the SSPs of O'Neill et al (2017). Because we have used the CLIMSAVE tool to derive our geophysical climate projections in a comparative and consistent fashion, we have still decided to pragmatically equate the socio-economic side of our scenarios with those of CLIMSAVE as follows: A2 = SSP3 = 'Should I stay or Should I Go' and B1 = SSP1 = 'Riders on the Storm' (see also Harrison et al. 2016).

We have obtained projections for precipitation and temperature in 2050 from the CLIMSAVE Integrated Assessment Platform (www.climsave.eu; Harrison et al., 2015). Since the CLIMSAVE platform is still based on the SRES scenarios, we were able to run the A2 scenario and B1 corresponding to SSP3/RCP8.5 and SSP1/RCP4.5, but there is no comparable SRES scenario for the intermediate scenario SSP2/RCP6.5. The scenarios A2 and B1 were run with the corresponding CLIMSAVE socio-economic storylines ('Should I Stay or Should I Go', and 'Riders on the Storm', respectively) using the MPEH5 climate model and 'intermediate' climate sensitivity (a choice out of 'low, intermediate and high'). MPEH5 is a version of the Max Planck GCM ECHOHAM, a choice out of 5, considered to perform well in a hind-cast verification by Dubrovsky et al (2015). For each of the three study catchments, we selected a mid-point coordinate set, which we used to manually extract the projected data (Table 4). We compared the overall regional patterns with those reported in Jacob et al. (2014) and found that these corresponded well over the area covering Southern France to Northern Germany.

For 2050, the differences between the two extreme scenarios in projected increases in temperature and decreases in precipitation largely correspond with those in the literature (e.g. Jakob et al. 2014). In addition, the effect of climate change is more pronounced for the southern Bresse and Azergues than for the temperate Stever; temperature increases with around 2° versus 1.5°, whilst summer rainfall drops with over 20% versus 12%. Differences in air temperature will be reflected in water temperature. Furthermore, the temperature differences between Bresse and Azergues are likely due to elevation, the relative difference between the scenario projections and 'current' are very similar. The Bresse catchments range between 170 and 300 m asl, whereas the Azergues ranges between 170 and 800 m.

An important observation to be made is that also in these local, downscaled projections of climate, the differences between the two extreme scenarios for 2050 are limited (Table 4, see also fig 1).

Table 4. Articulation of the SRES scenarios A2 (~SSP3/RCP 8.5) and B1 (~SSP1/RCP 4.5) in terms of geophysical climate parameters for the four selected catchments and 2050. Source: the CLIMSAVE integrated assessment tool (www.climsave.eu). CLIMSAVE 'mid-point' coordinates used follow each case study areas in brackets. Current baseline is assumed to be 2010.

Scenario:	Current	B1	A2
Stever (51.9N 7.4E)			
Mean minimum annual temperature (degrees C)	5.6	7.0 (+1.4)	7.5 (+1.9)
Mean maximum annual temperature	13.0	14.4 (+1.4)	14.8 (+1.8)
Mean maximum summer temperature	21.1	22.6 (+1.5)	23.1 (+2)
Mean annual precipitation (mm)	770	762 (-1%)	761 (-1%)
Mean summer precipitation	230	203 (12%)	199 (-13%)
Alteration in the hydrograph (qualitative)		summer base flow may decline around 10%, summer peak storm events may increase in frequency and severity; no change in winter flow	
Nahe (49.7N 7.3E)			
Mean minimum annual temperature (degrees C)	4.2	5.8 (+1.6)	6.2 (+2)
Mean maximum annual temperature	11.9	14.2 (+2.3)	14.6 (+2.7)
Mean maximum summer temperature	21.6	23.4 (+1.8)	23.0 (+1.4)
Mean annual precipitation (mm)	776	760 (-2%)	755 (-3%)
Mean summer precipitation	225	186 (-17%)	179 (-20%)
Alteration in the hydrograph (qualitative)		summer base flow may decline between 10 and 20%, spring snow melt peak is far less pronounced because the length of snow cover on the hills is estimated to be halved to around 2 weeks; summer peak storm events may increase in frequency and severity	
Bresse (46.2N 5.0E)			
Mean minimum annual temperature (degrees C)	6.6	8.4 (+1.8)	9.0 (+2.4)
Mean maximum annual temperature	15.4	17.3 (+1.9)	17.5 (+2.1)
Mean maximum summer temperature	24.8	27.1 (+2.3)	27.7 (+2.9)
Mean annual precipitation (mm)	877	810 (-8%)	794 (-9%)
Mean summer (JJA) precipitation (mm)	219	173 (-21%)	162 (-26%)
Alteration in the hydrograph (qualitative)		summer base flow probably drops by at least 20%; winter snow cover is reduced to a few days at most with little effect on flow pattern, but winter rains may become more intense leading to higher but unpredictable short-term peaks year round.	
Azergues (46N 4.3E)			
Mean minimum annual temperature (degrees C)	4.5	6.3 (+1.8)	6.8 (+2.3)
Mean maximum annual temperature	13.3	15.1 (+1.8)	15.6 (+2.1)
Mean maximum summer temperature	22.3	24.6 (+2.3)	26.3 (+4.0)
Mean annual precipitation (mm)	870	792 (-9%)	773 (-11%)
Mean summer (JJA) precipitation (mm)	247	195 (-21%)	182 (-26%)
Alteration in the hydrograph (qualitative)		As Bresse	

*run-off is estimated as expert judgment based on the result of the change in rainfall plus the change in evapotranspiration due temperature increase. The difference in projected temperature increase between two scenarios is less than 0.5°,

6. Riparian management packages

For the OSCAR project, the four different riparian management packages reflect an intuitively logical set of alternatives: ‘current state, best practice, realistic, and pessimistic’. The first (‘current’), is to be used as a baseline, which largely corresponds to a partial implementation of the first River Basin Management Plan of the Water Framework Directive.

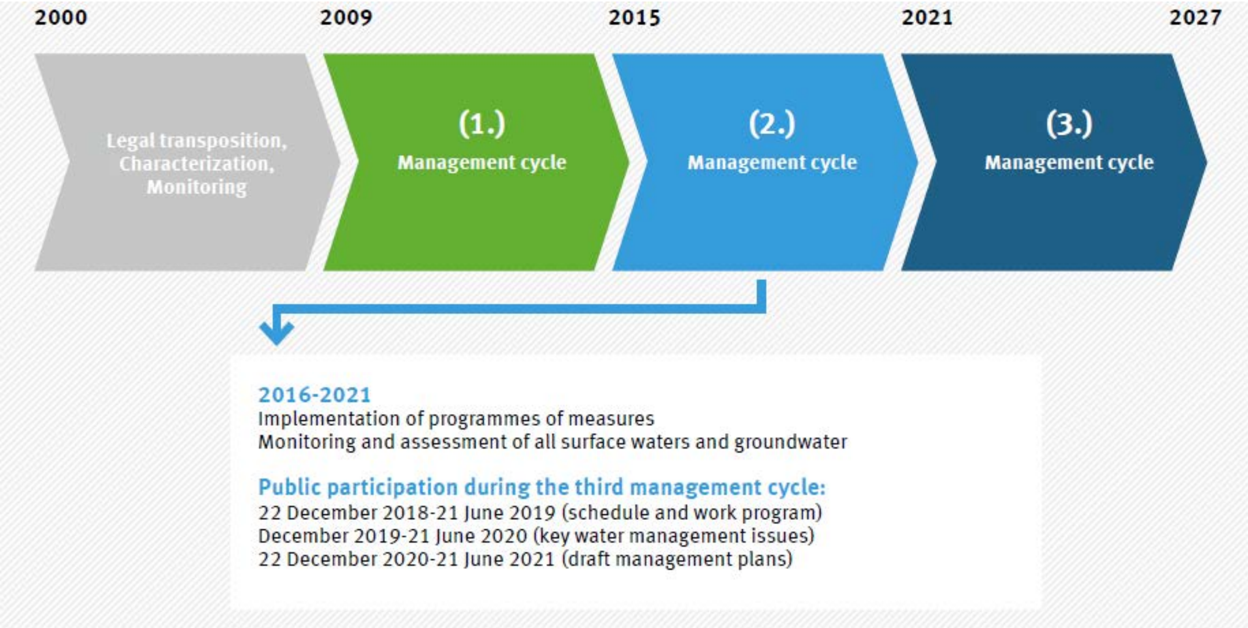

Fig. 2. The iterative implementation cycles of the water framework directive (source: BMUB/UBA, 2016).

For the realistic package, we assume that all measures of the 2nd RBMP have been put into practice. This means that the plans that have been submitted in 2015 will be fully implemented towards the time horizon for the next river basin management plan in 2021 (Figure 2). This further suggests that similar measures will be implemented until 2050 in this ‘realistic’ package, and stakeholders were asked at the workshops how these future RBMP measures could be realistically assessed and systematically implemented in GIS.

The ‘best practice’ package should reflect more far reaching efforts of the member states to improve the status of their water bodies towards a good ecological status. This should include pronounced changes in the river corridor to reflect a condition close to what can be considered near-natural. As a first starting point for the discussion with the stakeholders, we suggested to implement this in GIS in a standardized way by assuming woody vegetation in the whole river corridor, approximately corresponding to the meander belt width in meandering rivers. This was based on a recent suggestion and position paper of the German Working Group of Federal States on Water Problems LAWA for the corridor needed to reach ‘high ecological status’ under the WFD. It appears consistent that this implies a series of iterations beyond the third cycle ending in 2027.

Finally, we interpret the ‘pessimistic’ package as a step back from the current practice, which can have a political or purely economic basis. This should imply that any infrastructural measures that have been taken during the first RBPM are left without maintenance funding and will risk deterioration and decay. Institutional measures, such as governance bodies with monitoring, surveillance and enforcement capacity will probably be terminated. It is difficult to arrive at sensible estimations of the extent of the impact of this alternative and approaches to systematically operationalize this riparian management package in GIS. As a first starting point for the discussion with stakeholders, we suggested to assume that this would entail the removal of woody buffers where they are presently adjacent to arable land.

We summarize the Riparian Management Packages in Table 5. A visualization of how the river corridor would look like in 2050 is given in Fig. 3 for SSP1/RCP 4.5/ best practice and SSP3/RCP 8.5/pessimistic. This should only be interpreted as an illustration.

Fig 3. Visualisation of the woody buffer riparian corridor for a small and mid-sized river in in 2050 under SSP1-best practice (upper photos) and for a larger river under SSP3-pessimistic (lower photo) riparian management packages.

Table 5. Different combinations of four riparian management practices (RPMs) and the coupled climate and socio-economic scenarios for use in OSCAR.

Riparian Management Package	Scenario	In brief	Details: choices for implementation
Pessimistic	SSP3, RCP8.5 (A2)	WFD no longer pursued, intensity of non-ecological agriculture is increased	• Woody buffers along cropland removed • Optional: Conversion of grassland to cropland on areas well above the groundwater table and suitable for agriculture. • Optional: Nature reserves may be converted to agricultural land where feasible.
Current	Current	current	Current
Realistic	SSP2, RCP6.5	River management according to the current WFD	• All woody buffer measures as planned in the first RBMP cycle implemented and this is continued iteratively. • Between 2021 and 2050, woody buffers are developed along all segments that are classified as priority (Schwerpunktgewaesser). This is realistic since already between 2000 and 2015 1000 of the 8000 km in Rheinland-Pfalz have been restored. • Different options for woody buffer configuration / spatial arrangement will be considered in sub-scenarios to derive management recommendations for the realistic scenario: (a) random addition, (b) filling gaps of existing woody buffers, (c) upstream location. • Optional: Quality aspects may be considered. For example, woody buffers may be used for the extraction of wood for various purposes including short rotation coppice for biofuel.
Best	SSP1, RCP4.5 (B1)	A further development of the WFD towards a more sustainable water use	• Use the river corridor for acquiring good ecological status. • But exclude the following areas from the woody buffer river corridor: urban areas, roads, electricity transmission corridors, open, non-forested nature reserves. • Optional: Consider quality aspects. For example, assume natural broad leaved not coniferous woody buffers,wood is not extracted, hence biomass outtake is near zero.

7. Converting the different tables into input for modelling

Together, the different aspects of scenarios and management practices will form an input matrix to the BBN models. These aspects need a stepwise deliberation when considering the input state variables at catchment, corridor and reach scale. Management practices be reflected mainly in reach hydro-morphology and upstream water quality measures, whereas the scenarios will set the scene in terms of land use, rainfall and air temperature. It could be practical to aggregate several of these aspects into a few, broad-brush characteristics that are then easily amenable to the BBN modelling. So, the RMP and scenario descriptions in this report (Tables 3-5) will need one further conversion step into an input table with the specific BBN variables and units for our modelling exercises.

8. References

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9. Terminology

- Scenarios = coherent sets of projected socio-economic, political and resulting climatic conditions that cannot be influenced locally by river managers. Scenarios are often described by a 'storyline', which justifies the chosen combination of conditions as 'plausible'. These should be understood as plausible projections rather than as more or less precise predictions of future societal development.
- Riparian management packages = combinations of different measures that can be decided on locally by river managers under the general socio-economic, political and resulting climatic conditions.

Annex 1. Summary narratives for the Shared Socio-economic Pathways SSP1, SSP2 and SSP3. From Riahi et al. (2017).

SSP1 Sustainability – Taking the Green Road

The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.

SSP2 Middle of the Road

The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain.

SSP3 Regional Rivalry – A Rocky Road

A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialized and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.