Regional scale socio-economic and ecological impacts

Introduction

The SCENES project has sought to develop likely future state of Europe's waters. Because the future is uncertain we have developed a range of possible scenarios that are dependent on two aspects. First aspect is changes to the climate particularly alterations to precipitation and temperature that affect evaporation. These changes will have direct impacts on the overall water resource in Europe and its availability for domestic supply, agriculture and industry and supporting the important services provided by our natural environment. The uncertainty in climate expresses itself as different climate models that show different future conditions. In this study we selected climate input (temperature and precipitation) which was generated by two climate models IPCM4 and MIMR[1] in the IPCC AR4 framework. In general IPCM4 projects drier, warmer conditions.

The second aspect is changes in human numbers and our behaviour. Some of these changes, such as population growth show general independent trends. Others may be reactions to climate change, such as farmers selecting different crop types to withstand drier conditions. In additional to change in individual behaviour, the European Union and our national governments may follow different policy options depending on a multitude of drivers and objectives. Within SCENES, four socio-economic scenarios were developed based on UNEP's GEO4 scenarios and adjusted in a participatory exercise with European stakeholders. (1) Economy First (EcF) where the priority is for economic growth; (2) Fortress Europe (FoE) in which the priority is to be self sufficient; (3) Policy Rules (PoR) where policy dictates over a free-market; and (4) Sustainability Eventually (SuE), which aims at sustainable development.

The combination of storylines and climate data provided inputs to a pan-European water model (WaterGAP – Water: Global Assessment and Prognosis) covering all of 'Greater' Europe (EU countries and neighbours i.e. Iceland, Norway, western part of Russia, Belarus, Ukraine, Moldova, Turkey, non-EU Balkan countries) and including the Mediterranean rim countries of north Africa and the near East. The model produces river flow time series for major water courses of Europe for current day and future, 2050s, scenarios.

Regions and indicators of impact

A key aim of the SCENES project was to determine the impacts on Europe's freshwater that were likely to occur under the different scenarios. To achieve this, a set of 23 indicators of freshwater change was defined, divided into five broad categories.

- Generic water indicators, showing broad water availability and scarcity
- Water for food, showing impacts on rain-fed and irrigated agriculture
- Water for nature, showing water available to maintain the health of river and wetland ecosystems
- Water for people, showing availability for public supply
- Water for industry, including cooling water for power stations.

[1] Both IPCM4 and MIMR are under emission scenario SRES A2 which describes a very heterogeneous world with high population growth, slow economic development and slow technological change. Global greenhouse gas emissions are projected to grow steadily during the whole 21st century and possibly to double by 2050 compared to the year 2000.

The indicators are depicted on a series of maps, on which the rivers or regions and colour coded to define categories of impacts, such as using a traffic-light system to show little or no impact (green), moderate impact (amber), high impact (red). In general, eight maps were produced for each indicator (two for each storyline, one of which used the IPCM4 climate model, the other using the MIMR model). This produced 23 x 8 = 184 indicator maps. The maps were analysed to define broad impacts at pan-European scale and for seven different regions of Europe (Figure 1).

- Southern Europe (including Spain, Italy and Greece)
- Western Europe (including France and Germany)
- North Europe (UK and Scandinavia)
- Central Eastern Europe (including Poland and Hungary)
- Eastern Eastern Europe (including Romania, Ukraine and Russia)
- North Africa (including Morocco and Egypt)
- Western Asia (including Turkey)

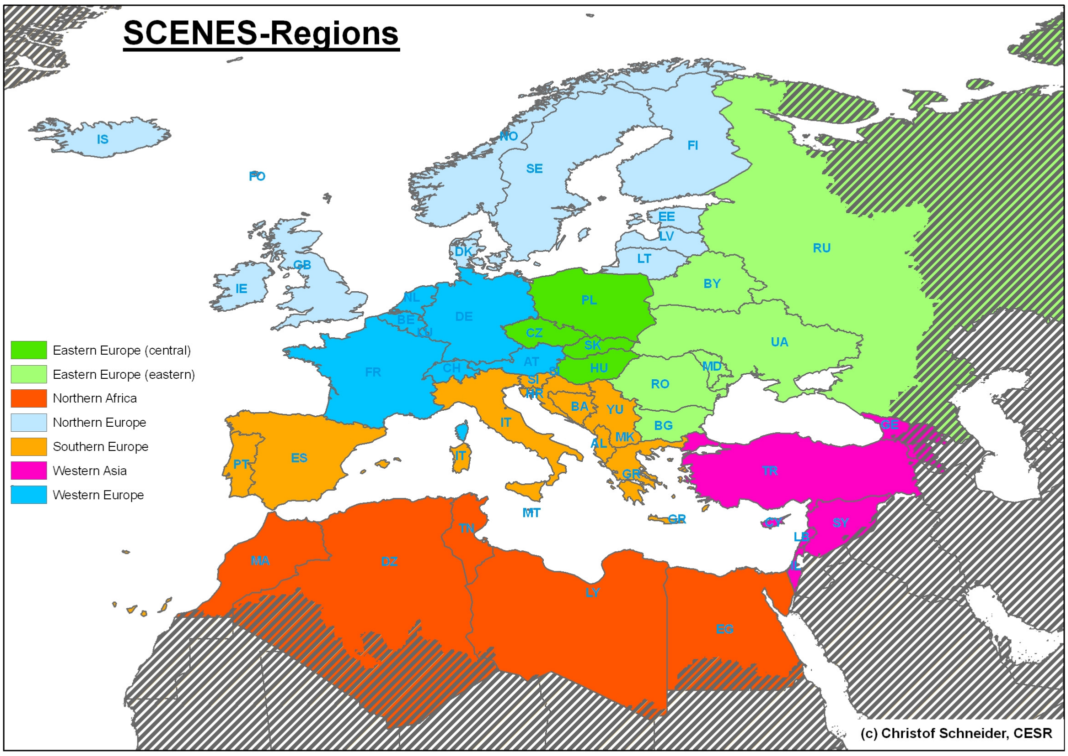

Figure 1 SCENES regions

The broad picture

Maps of change in gross water availability (Figure 2) in terms of mean river flows in the 2050s help to show general regional patterns. Impacts are broadly related to latitude. From the IPCM4 model (Figure 2a). Severe reductions in water availability are evident in parts of Tunisia, Egypt, Turkey, Morocco, Greece, Bulgaria Macedonia, and south east Spain. Significant reductions are projected across central Europe from Portugal to Ukraine. Limited change is anticipated in the UK, Denmark. Southern Finland, Latvia and north west Russia. Increased water availability is more likely for Norway, Sweden northern Finland. From the MIMR model (Figure 2b) less severe impacts are expected with little change from current conditions throughout central Europe, increases in water availability in northern Europe, but reductions along the Mediterranean coast of north Africa, south east Spain and Turkey.

a b

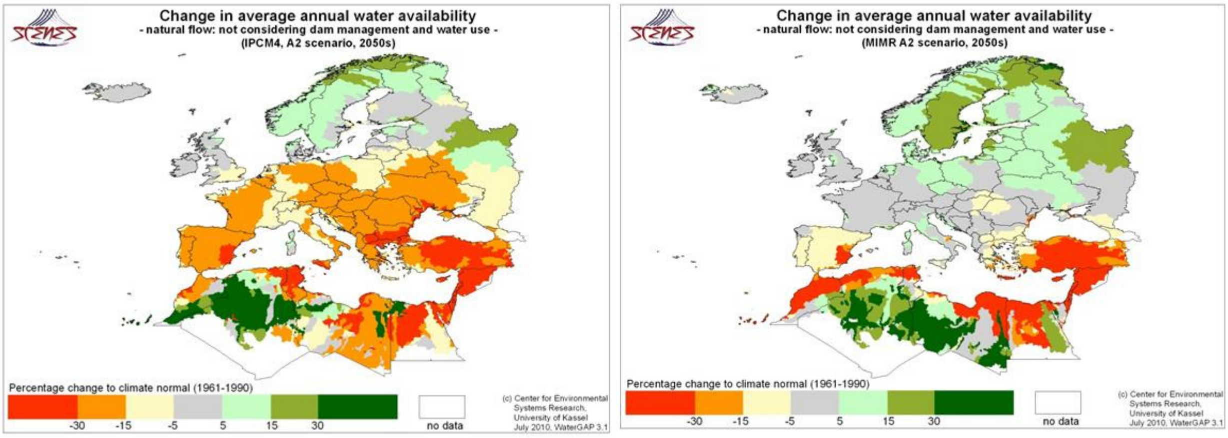

Figure 2 Changes in water availability according to two different climate models (a) IPCM4 (b) MIMR

Analysing socio-economic impacts, EcF and FoE scenarios on water use result for almost all regions in increases in consumptive use of water, which includes water evaporated, incorporated into products or crops and consumed by humans and livestock. Exceptions are southern Europe where consumptive use decreases and western Asia where water use remains constant. For PoR and SuE scenarios all regions show either no change or a decrease in consumption, except for north Africa where consumptive use increases.

Regional impacts

Southern Europe

Consumptive use generally declines in southern Europe by 2050, however there is great spatial variation in water availability. Whilst parts of Spain, particularly the south show high or over-exploitation by 2050, in many other areas impacts are low or medium, with a few hot spots in Italy and Greece. The EoF scenario tends to exhibit the most severe results, followed by FoE. The IPCM4 scenarios consistently show a worse situation than MIMR. The least severe results are for SuE and PoR with only a few mid and high spots in Spain and Italy. Water stress shows a similar pattern with severe stress in parts of Spain, Italy and Greece. The most severe conditions are expected under EcF in combination with IPCM4 climate, with lower severity under MIMR and least impacts under SuE. Water scarcity will also be high in Spain, Portugal & Greece, whereas no problems are expected for the northern Adriatic countries. Droughts are likely to become more frequent in Spain, parts of northern Italy and Balkans, particularly from IPCM4. In contrast, under MIMR, droughts may be less frequent in northern Italy, Croatia and Bosnia. Drought severity is likely to be significantly worse by 2050 with severe reduction in low river flows particularly in northern Spain and northern Italy. There are no significant differences between scenarios, but drought severity is critically dependent on the climate change model; under IPCM4 indicators show significant reductions, but under MIMR there are major increases in the magnitude of low flows.

Impacts on agriculture are complex. The potential to grow rain-fed crops, such as maize, decreases in southern Europe by 2050, due to reduced yields, owing to higher temperatures and lower precipitation. There appears to be a shift in irrigated area from southern Europe to western Europe. Simulated yields are particularly low in Spain and Portugal. Annual water stress in irrigation in southern Europe decreases slightly in 2050 compared to the baseline as a result of increased irrigation efficiency and a reduction in irrigated land. Nevertheless, irrigation water stress is still severe in, for example, Spain and Portugal. Decreases in irrigated area are estimated to occur in Italy, Greece and Portugal, but a move to more intensive irrigation on remaining land. Differences in water stress in irrigation under different climate scenarios are caused partially by a different distribution of water availabilities in Europe under the two models IPCM4 and MIMIR.

Water available for rivers and wetlands is expected to decrease under all scenarios very significantly in Spain and Greece probably leading to major degradation of freshwater ecosystems; the situation is slightly worse for IPCM4 than MIMR. Flood volumes are likely to decrease by 50% or more under IPCM4 in northern Spain and north-western part of Italy with an associated small decrease in flood duration, leading to a degradation of floodplain ecosystems. This is sharply contrasted by a 25-50% increase in flood volume everywhere in southern Europe under MIMR. Major losses in ecosystem services are more likely under IPCM4 particularly for the EcF scenario. Losses in south west Spain are notable with minor losses in countries along the northern Adriatic coast. Impacts are less severe under MIMR with minor losses of ecosystem services in south west Spain. It is interesting that PoR and FoE show fewer losses in ecosystem services than SuE, resulting from land-use changes.

Water temperature will be poor in Spain, northern Italy, north east Greece for all scenarios and models, but good for Croatia and Bosnia. There will be high extra demand for cooling water across most of the region, particularly Spain, Portugal and northern Italy.

<u>Western Europe</u>

Water consumption is high by 2050 under EcF and FoE in France, Benelux countries and northern Germany and water scarcity is very high in these areas as a result of demand during low flow periods. There are also spots of high or over-exploitation around major urban areas. Impacts are generally highest under EcF and least under SuE scenarios, with marginally greater impacts under IPCM4 than MIMR. For example, under EcF IPCM4 there is high water exploitation in parts of northern France, Belgium and Holland and mid-level exploitation in northern Germany and southern France. At the other extreme, almost all of western Europe has low exploitation under SuE MIMR. Droughts are likely to get worse and be more frequent in terms of low flows, they will be most significant in France and Germany and to a lesser extent southern Holland. Impacts are greater under IPCM4 than MIMR.

Maize production is likely to decrease in southern France by 2050 due to higher temperatures and less rainfall reducing yields. However, further north in western Europe, maize may growth better as temperatures increase and approach an optimum, although potential yield increases are limited. Winter crops, such as winter wheat, may profit from the climate change expected in the year 2050. The EcF scenario shows that France and Northern Germany may have the highest irrigation withdrawals. Germany is expected to show improved technology and irrigation efficiency. As a result, water stress for irrigation will be medium in France and low elsewhere in western Europe. For 2050, annual water stress for agriculture does not change substantially compared to the baseline. Summer water stress will significantly increase in western Europe (*e.g.* France), where the irrigated area is expected to increase.

Water available for river ecosystems is likely to decrease under all scenarios with impacts greater in southern France and downstream (for example, some French headwaters are un-impacted in MIMR). Water availability for wetlands is likely to reduce with greater drying in the north and less in the south; northern France, Benelux (only under IPCM4) and eastern Germany are most impacted. Under MIMR, Benelux countries are not impacted, and some areas show an increase in water availability. IPCM4 shows a 50% decrease in flood volume over whole region leading to degradation of floodplain ecosystems. In contrast, MIMR suggests much more regional variation with a 50% increase in France, but a 50% decrease in Germany. In general floods may occur earlier in the year. Ecosystem services show some losses in the region, especially around the Alps (south east France, southern Germany). Generally impacts are worst for EcF and best for FoE; under PoR there is more regional variation in loss of services. Water temperature is likely to be poor (too high) for all scenarios and climate models.

All scenarios expect significant problems for water availability for industry with high extra demand for cooling water across the region, particularly Spain, Portugal and northern Italy, although a little less so under SuE MIMR.

Northern Europe

There are generally very few impacts on water availability for consumption (as indexed by water consumption index) with the exception of south east UK and south east Sweden under IPCM4. Water stress is likely to be severe in these areas, particularly in the summer but low elsewhere. The lowest impacts are simulated under SuE combined with MIMR where only south east UK shows moderate stress. Patterns of water scarcity generally match water stress with severe impacts in south east UK under IPCM4 EcF and FoE, but less under MIMR SuE in this area and low impact everywhere else. Increases in drought frequency and severity are also limited to local areas of southern UK and south east Sweden.

Agriculture is broadly little impacted in northern Europe. Production of maize may improve due to higher temperatures, but increases in yield will be limited. Winter rain-fed crops, such as winter wheat, may profit from the climate change expected in the year 2050. Irrigation efficiency shows stagnation under EcF and PoR and modest increases under FoE and SuE. However, irrigation withdrawals will be very low, except in places of water shortage, such as southern UK and south east Sweden.

Water available for river ecosystems is likely to decrease moderately under all scenarios with impacts lowest in northern and western UK, northern Sweden and southern Finland (some un-impacted rivers). Generally impacts are greater under IPCM4 than MIMR. There no impacts on water for wetlands in UK, Sweden and northern Finland, whereas some reduction is possible in Norway and southern Finland. Floods may increase in magnitude by 10% or more under IPCM4 in north west UK and Norway, but decrease in south east UK and Finland. Under MIMR there is a consistent increase across northern Europe resulting in wetter floodplain ecosystems. There are likely to be only minor changes in ecosystem services in the region with little different between scenarios. The east coast of UK may be slightly more impacted than the west coast. Water temperature is projected to remain good across the region in 2050, apart from southern England.

All the scenarios are consistent in showing no additional demand for cooling water for industry across the region with the exception of south east UK.

Eastern Europe Central

As the SCENES region with the smallest surface area, there is a high level of internal consistency within and between sectors and scenarios, with a low to medium variation in impacts across the region. For some indicators, the western, southern and/or eastern parts of the region follow the behaviour of the adjacent regions.

Generally, water availability (as indexed by mean river flow) across the region will likely show a moderate decrease under IPCM4, compared to a small increase under MIMR. The general pattern for exploitation of water is largely unchanged in 2050 compared to the baseline, with parts of the region likely to experience water stress and/or scarcity and irrigation water stress throughout much of the year, except in the winter season. Domestic water availability may decrease slightly

The western part of the region may start requiring irrigation withdrawals, such as the Czech Republic. In Poland and Hungary water needs remain low increased technological innovations in irrigation water demands for EcF and FoE scenarios and a mix of small decreases and increases in the other scenarios.

Environmental flows show moderate impacts in terms of water quantity. Losses in ecosystem services, significant changes in water supply to wetlands, a decrease in diversity and a decrease in fish habitat suitability are to be expected for all scenarios except SuE. Almost all water bodies are already at high risk under the baseline, and this situation changes very little, with a very minimal improvement for SuE. Overall, flood volumes and durations may decrease, though timing will remain the same or be slightly earlier due to changes in snow/glacial melt patterns.

Cooling water demand and cooling water stress for industry increase, putting pressure on power plants' demand for cooling water during periods of low flows. This is largely temperature (i.e. climate) driven, compounded by increased demands. A low incidence of low flows may cause some navigation problems in the Danube.

MIMR scenarios are slightly better than IPCM4, and EcF and FoE scenarios are worse than those for PoR and SuE. Whilst SuE is usually the scenario with lowest impacts, for food production PoR is the lowest. In EEc, the current situation is likely to largely remain under PoR and SuE scenarios, but worsen under EcF and FoE scenarios. However, while the results show that water quantity should not be a regular problem in Eastern Europe Central, the quality of that water may make it unusable without expensive treatment.

Eastern Europe Eastern

This is one of the largest SCENES regions, extending from Arctic in the north to the Black Sea in the south, and from Poland in the west to the Urals in the East. The region is spatially heterogeneous, with low internal consistency within and between sectors and scenarios, and a usually high variation in impacts across the massive region. The far southern part of EEE often shows more similarity to WA, than to the rest of EEE.

The general patterns for exploitation of water largely replicate the baseline. Parts of EEE, particularly the southern part of the region, already show medium-high overexploitation of water under all scenarios due to high demand relative to availability, and experience water stress and/or scarcity and domestic and irrigation water stress throughout much of the year, except the winter season. Under all scenarios, there may be serious problems associated with domestic water stress in parts of the region that do not currently experience it; in other parts, the situation may improve. In the southern part of the region, irrigation water withdrawals are already high under the baseline and this situation remains unchanged an improvement in technology counterbalancing any increase in demand. Specific hotspots include the Danube Delta and the Black Sea coast. Cooling water demand increases and cooling water stress increase, especially in the southern part of the region for the EcF and FoE scenarios, putting pressure on power plants' demand for cooling water during periods of low flows. This is largely temperature (*i.e.* climate) driven, compounded by increased demands. A frequent future low flows may cause some navigation problems in the Danube.

Mean annual flows across the region will likely show an increase to the north and a decrease to the south, more severe under IPCM4 than MIMR. Overall, flood volumes and durations may decrease moderately or severely throughout most of the region, except in the far south which may remain unchanged; timing will remain the same or be slightly earlier due to changes in snow/glacial melt patterns. Environmental flows show moderate to high impacts in the centre, south and west of the region and lower impacts to the north and east. Losses in ecosystem services and changes in water supply to wetlands are expected under all scenarios, with the worst impacts in the southern part of the region. Decreases in diversity and fish habitat suitability are to be expected for all scenarios except PoR and SuE, with the highest impacts in the southern part of the region. Around 25% of water bodies are at no or low risk during the baseline, and this proportion increases slightly for the PoR and SuE scenarios, with similar risks to the baseline for the EcF and FoE scenarios.

MIMR scenarios are slightly better than IPCM4, and EcF and FoE scenarios are worse than PoR and SuE ones. In EEE, the current situation is likely to largely remain under PoR and SuE scenarios, but worsen under EcF and FoE scenarios, particularly in the southern part which already experiences some problems due to high demand relative to availability.

Western Asia

This is a spatially heterogeneous SCENES region including parts of the Mediterranean and Black Sea coasts, the near East and Turkey. These different areas behave similarly or differently within and between sectors and scenarios, with a high variation in impacts across the region for some sectors and scenarios, and low variation for others. For some indicators the southern part of the region may behave like the adjacent part of North Africa, whilst the northern part of the region may follow the behaviour of the southern part of EEE.

Water consumption is expected to stay constant until 2050 under all scenarios and the general patterns for exploitation of water largely replicate the baseline. Parts of WA already show medium-high overexploitation of water and experience severe water stress and/or scarcity, and domestic and irrigation water stress throughout much of the year, due to high demand relative to availability. However, parts of WA that do not currently experience problems with domestic water availability and water stress may start experiencing them.

Rain-fed crop (*e.g.* maize) yields will decrease in western Asia due to higher temperatures increasing respiration losses and the limited precipitation amounts during the growing season. Under all scenarios there may be moderate reductions in the extent of areas requiring irrigation withdrawals, leading to a decrease in the quantity of water required accompanied by technological improvements which may save water, too.

Cooling water demand is already high under the baseline and increases under all scenarios putting pressure on power plants' demand for cooling water during periods of low flows. This is largely temperature (i.e. climate) driven, compounded by increased demands. Cooling water stress which is already high remains unchanged or may decrease in some areas, though parts of WA still show severe cooling water stress under the PoR and SuE scenarios.

Mean annual flows across the region will likely show a large decrease under both climate scenarios. All Nature indicators show significant negative impacts for WA. Environmental flows show moderate to high impacts in terms of water quantity. A decrease in diversity and a decrease in fish habitat suitability are to be expected for all scenarios. The number of water bodies in WA at high risk is expected to increase significantly (currently around 25% are at no or low risk) from the baseline.

In WA, the current water situation is likely to worsen under all scenarios by 20050, especially in the areas that already experience low river flows and low water availability relative to demand. The water situation is particularly acute for the EcF and FoE scenarios. In general the MIMR climate model projects less severe water conditions than the IPCM4 model. EcF and FoE socio-economic scenarios are generally worse than for PoR and SuE.

North Africa

This is one of the largest SCENES regions and one of the most spatially heterogeneous, with low internal consistency within and between sectors and scenarios, with a high variation in impacts across the region for some sectors and scenarios, and low variation for others.

The general patterns for exploitation of water largely replicate the baseline. Parts of NA, particularly the Morocco-Algeria-Tunisia coastal part and the Nile valley, already show medium-high overexploitation of water and experience water stress and/or scarcity, and domestic and irrigation water stress throughout much of the year, due to high demand relative to availability. Under all scenarios there may be serious problems associated with these stresses increasing in parts of the region that do not currently experience it such as inland areas.

Yields of rain-fed crop will decrease in north Africa due to higher temperatures increasing respiration losses and the limited precipitation amounts during the growing season. An increase in irrigation water withdrawals can be seen for northern Africa in 2050 because of an expansion of the irrigated area. Water stress in agriculture is likely to be very high, particularly along the Mediterranean coast in Tunisia and Morocco and along the lower Nile. Impacts are slightly less under SuE and PoR than EcF and FoE.

Cooling water stress increases, putting pressure on power plants' demand for cooling water during periods of low flows. This is largely temperature (i.e. climate) driven, compounded by increased demands.

Mean annual flows across the region will likely show an increase to the west of the region and inland, apart from the costal zones which experiences a high decrease, and a decrease to the east. Areas already experiencing low mean annual flows are likely to find this situation worsens. Environmental flows show low impacts inland to high impacts in the Morocco-Algeria-Tunisia coastal zone.

The minor differences between the socio-economic scenarios suggest that climate is the dominant driver. MIMR scenarios are slightly better than IPCM4, particularly in the Nile Valley. EcF and FoE scenarios are worse than PoR and SuE ones. In NA, the current situation is likely to largely remain under PoR and SuE scenarios, but worsen under EcF and FoE scenarios particularly in the Morocco-Algeria-Tunisia coastal zone that already experiences low water availability relative to demand.

Summary

There are large differences between regions in terms of the direction and severity of impacts, and the uncertainty with respect to the direction of future change varies over Europe. The IPCM4 climate scenario consistently showed more severe impacts on water than the MIMR scenario across Europe. Impacts are broadly related to latitude, with most negative impacts in southern Europe and north Africa. There is a clear distinction between the four socio-economic scenarios. In the majority of cases, Sustainability Eventually (SuE) leads to the lowest impacts with most regions showing either no change or a decrease in consumption, except for north Africa where consumptive use increases. Economy First (EcF) results in the most severe impacts, due to increased consumptive use of water. The heterogeneity at regional and sub-regional level means that this scale of assessment is only a broad starting point; a river basin focus is required to make precise local assessments.