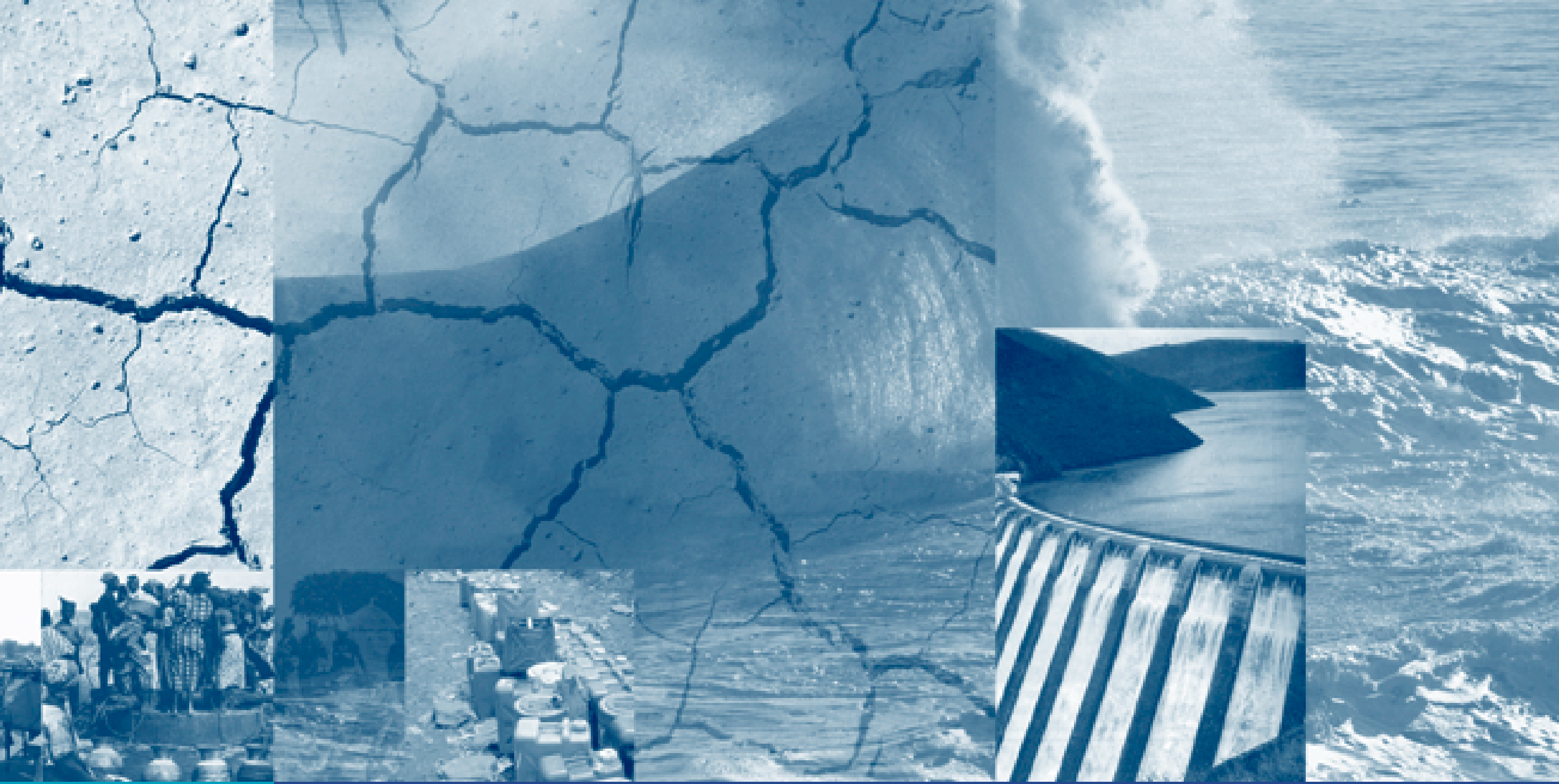

Humans, Water and Climate Change

why worry about climate and water

W.P.A. van Deursen

NRP

The Dutch National Research Programme on Global Air Pollution and Climate Change

What is in this brochure

- explain interactions between climate, hydrology and humans
- explain possible climate change scenarios
- give a regional overview of vulnerability of hydrological systems to climate change
- explain consequences of climate change on hydrology and humans
- explain why it is important to incorporate future climate change in present day water management policy making
- promote adaptation of sound policy strategies to deal with the future

A project of

NRP The Dutch National Research Programme on Global Air Pollution and Climate Change,

W.P.A. van Deursen

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art work visual lab - Rotterdam The Netherlands

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N R P

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march 2000

Human society is very dependent on water

Water is very dependent on climate

Climate might change

Hydrology, Society and Climate

The availability of adequate, safe water is critical to health, economy and environment. This is not only true for the arid and semi-arid regions of the world, but also for the humid regions. Insufficient water supply will seriously hamper the welfare of people, industrial and agricultural production and the quality of the environment. However, excess of water, resulting in floods and inundation, may cause many casualties and seriously damage property. Our human society depends very much on a timely and reliable supply of water and adequate handling of excess water. Climate change has the potential to alter the water boundary conditions of our society.

There is plenty of water. Only not at the time and place when we need it most. Or sometimes too much when we do not need it. The resources of water are highly irregularly distributed in both space and time. The Amazon carries 20 percent of global average runoff, while the Sahel region receives less than 1 percent. Thirty percent of the total runoff of Africa flows in a single river basin. Many regions receive their precipitation during a brief, intense rainy season. This large variability is responsible for many of the problems facing water management. Although the driving forces of the distribution of water are natural, mankind has intervened heavily in the flow of water. Man has built dams, reservoirs, canals, irrigation systems, dikes and sluices, all to ensure a proper operation of the natural system for human purposes. Nevertheless, modern water management has to deal with increasing stresses. Climate change has the potential to alter these stresses.

Climate change has the potential to alter the patterns of stress and will thus have its impact on water management. Some parts of the world will receive more river runoff (possibly at the expense of increased flooding), while other parts will experience a decrease in water availability. Water resources would become even more vulnerable than they are now. In areas where climate change causes reduced precipitation, freshwater storage, primarily in the form of groundwater, will steadily shrink. Increased temperature will result in larger water demand by crops and vegetation (higher evapotranspiration rates). Areas with increased or more intense precipitation events would experience floods and higher lake and river levels. An increase in extreme events such as droughts and floods would undermine the reliability of many critical sources. Worsening droughts combined with the over-exploitation of water resources would cause salt to leach from the soil, thus raising the salinity of the soil. In coastal zones, a lowered water table would also draw salt-water from the sea into the fresh groundwater. Leaching and intrusions of salt-water into freshwater stores would make groundwater unfit for household and agricultural use. Changing precipitation and evapotranspiration patterns would damage croplands, forests, marshes, and other ecosystems.

Africa

Africa is the continent most vulnerable to the impacts of the projected changes. Africa has a large population growth and experiences major problems with increasing urbanisation. Most of the countries currently classified as water-stressed are located in Africa. Their number is likely to increase, independent of climate change, as a result of increases in demand resulting from population growth, land degradation and degradation of watersheds.

Agriculture is the major economic activity in most African countries. In most African countries, farming depends entirely on the quality of the rainy season. These facts make that the variability in the physical environment, and consequently the changes of the climate have their direct impacts in the socio-economic situation. Widespread poverty, recurrent droughts, inequitable land distribution and overdependence on rain-fed agriculture increases Africa's vulnerability.

Industrialisation affects our vulnerability to climate change in two opposite ways. Industrialised societies do possess the technical (including irrigation systems and infrastructure) and social support systems (including institutional arrangements and insurance systems) to absorb disturbances generated by climate change and natural crises. However, industrialised societies become more vulnerable due to their increased water use and their increased dependency on good and timely water supply.

Modern societies rely to an increasing extent on technical and infrastructual measures to manage their water resources. Natural areas, forests and wetlands, which possess enormous buffer capacity, are destroyed and replaced by reservoirs, dams and channels. Although we would like to think we are increasingly in control over water, by destroying the natural buffer capacity and the resilience of areas with a natural water system we make our societies much more vulnerable to climate change.

Middle East and Arid Western Asia

In this arid region water shortage is already a problem. Water is an important limiting factor for ecosystems, agriculture, human settlements and human health. Huge disparities exist between water demand and water availability. The fact that neighboring countries claim access to the same water sources is one of the causes of conflicts in this region. Limited water supplies restrict present agricultural productivity and threaten the food security of some countries. Overexploitation of these limited water supplies often results in land degradation problems.

Climate change is anticipated to increase the stresses in the hydrological cycle.

Temperate Asia

Natural buffer capacity in this region is rapidly decreasing. This is due to a decrease of the mountain glaciers and an ongoing deforestation. Increased temperatures could result in a decrease of as much as 25 per cent in mountain glacier mass by 2050. Initially, runoff from glaciers in central Asia is projected to increase threefold by 2050; afterwards glacier runoff would decrease to two-thirds of its present value.

Water Resources Are Vulnerable to Climate Change

It is obvious that climate governs the weather and the weather governs the hydrologic cycle. Changes in the climate will thus have a direct impact on the hydrologic cycle. As an effect of changes in precipitation and temperature patterns, regions will experience changed inputs to their water system due to changes in precipitation, but also changed extraction rates from changes in water demand by vegetation and crops.

The IPCC, the Intergovernmental Panel on Climate Change, was jointly established by the World Meteorological Organisation and the United Nations Environment Programme in 1988. IPCC's main focus is to assess the scientific and technical literature on climate change, to assess the possible impact and to define possible mitigation strategies for climate change. The IPCC summarises the Findings on Precipitation and Water Resources as:

- Scientific models used to forecast climate change suggest a 1 - 3.5 °C rise in global mean temperature for the year 2100. This increase in temperature would result in an increase in global mean precipitation of about 3 - 10% and an accelerated sea level rise of between 15 and 95 centimetres.
- The timing and regional patterns will change and more intense precipitation events are likely in some regions.
- Detailed changes in regional distribution of precipitation are still uncertain.
- Increasing temperature results in increases in potential evapotranspiration – water evaporated from the surface and transpired from plants. Consequently, even in areas with increased precipitation, higher evapotranspiration rates may lead to a reduction in water supplies.
- Flood frequencies in some areas are likely to change. In northern latitudes and snowmelt driven river basins floods may become more frequent. However, the increase in flooding for any given climate scenario is uncertain and its impact will vary among river basins.
- The frequency and severity of droughts could increase in some areas. This is the result of changes in the total rainfall, more frequent dry spells and increased water use by crops and vegetation.

North America

Potential impacts include increased runoff in winter and spring and decreased soil moisture and runoff in summer. The Great Plains and prairie regions are particularly vulnerable. Projected increases in the frequency of heavy rainfall events and severe flooding also could be accompanied by an increase in the length of dry periods and in the occurance of droughts in parts of North America.

One important issue related to the water supply in the dry SouthWestern and Southern region of North America is the fierce competition for water. Many of the water resources in these areas suffer from inadequate replenishment or a highly uneven balance between pumping and recharge rates of aquifers. Although demand management might offer solutions to these problems, the huge economic interests in the irrigation-based agriculture make solutions far from easy to implement. Although there is plenty of fresh water in this continent, problems related to relocation of water are politically, environmentally and technically difficult to solve.

Latin America

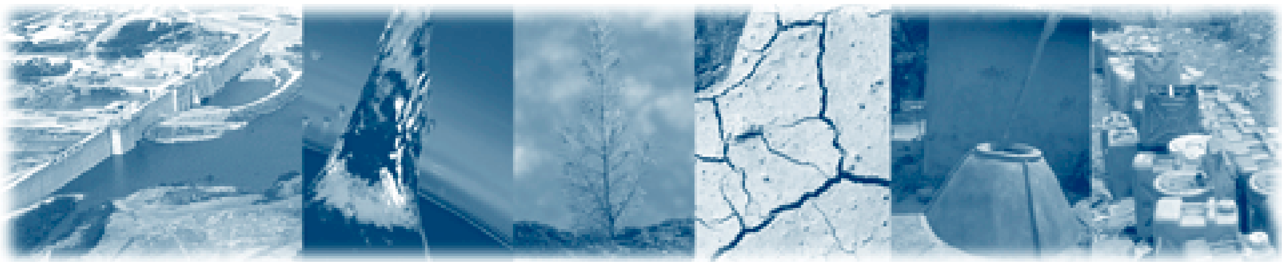
Increasing environmental deterioration (e.g., changes in water availability, losses of agricultural lands and flooding of coastal, riverine and flatland areas) arising from climate variability, climate change and land-use practices would aggravate socio-economic and health problems, encourage migration of rural and coastal populations, and deepen national and international conflicts.

The expected *changes in climate* are small compared to the *variations in present-day weather*. However, it should be realised that these small changes in mean values could result in large changes in the general conditions of the region, as well as an increased occurrence of extreme weather situations.

It is important to realise that climate change is not an isolated issue: Climate change scenarios should be evaluated in conjunction with other relevant scenarios. These other scenarios include those for increased population, increased industrialisation and increased urbanization.

The most important hydrological effects of climate change are

- Changes in climate (changes in precipitation and temperature patterns) result in changes in soil water availability.
- Increased evapotranspiration rates are not necessarily compensated by increased precipitation changes.
- Increased temperatures (increased evapotranspiration rates) will increase the demand for irrigation.
- Access to reliable water sources will become more difficult.
- Increased salinity and soil degradation problems will affect agricultural production.
- Changes in climate could intensify frequency and magnitude of drought, particularly in arid and semi-arid areas.
- Increased precipitation amount and precipitation intensity will result in increased occurrences of floods and inundation. This is true for both humid climates and arid climates, in which higher rainfall intensities might increase flash flood occurrences.



Analysing these effects yields the following conclusions

- Hydrological systems, and their associated functions for society, are vulnerable to climate change.
- Individual regions have their own vulnerability profile, dependent on both physical situation and socio-economic situation.
- Systems and situations that are currently under water stress (drought or flooding) are highly vulnerable to climate change.
- Developing countries are highly vulnerable to climate change because many are located in arid and semi-arid regions. Given their limited technical, financial and management resources, adjusting to shortages and/or implementing adaptation measures will impose a heavy burden on their national economies.

Tropical Asia

The present total population of the region is about 1.6 billion, and it is projected to increase to 2.4 billion by 2025. The population is principally rural-based, although the region includes 6 of the 25 largest cities in the world. The climate in Tropical Asia is characterised by seasonal weather patterns associated with the two monsoons and the occurrence of tropical cyclones. Major problems of this region are rapid urbanization, industrialization and economic development, which contribute to unsustainable exploitation of natural resources, increased pollution, land degradation and other environmental problems. Climate change will add to these stresses. A reduction in average flow of snow-fed rivers, coupled with an increase in peak flows and sediment yield, is to be expected. Natural buffer capacity is decreased rapidly as a result of deforestation.

Australia and New Zealand

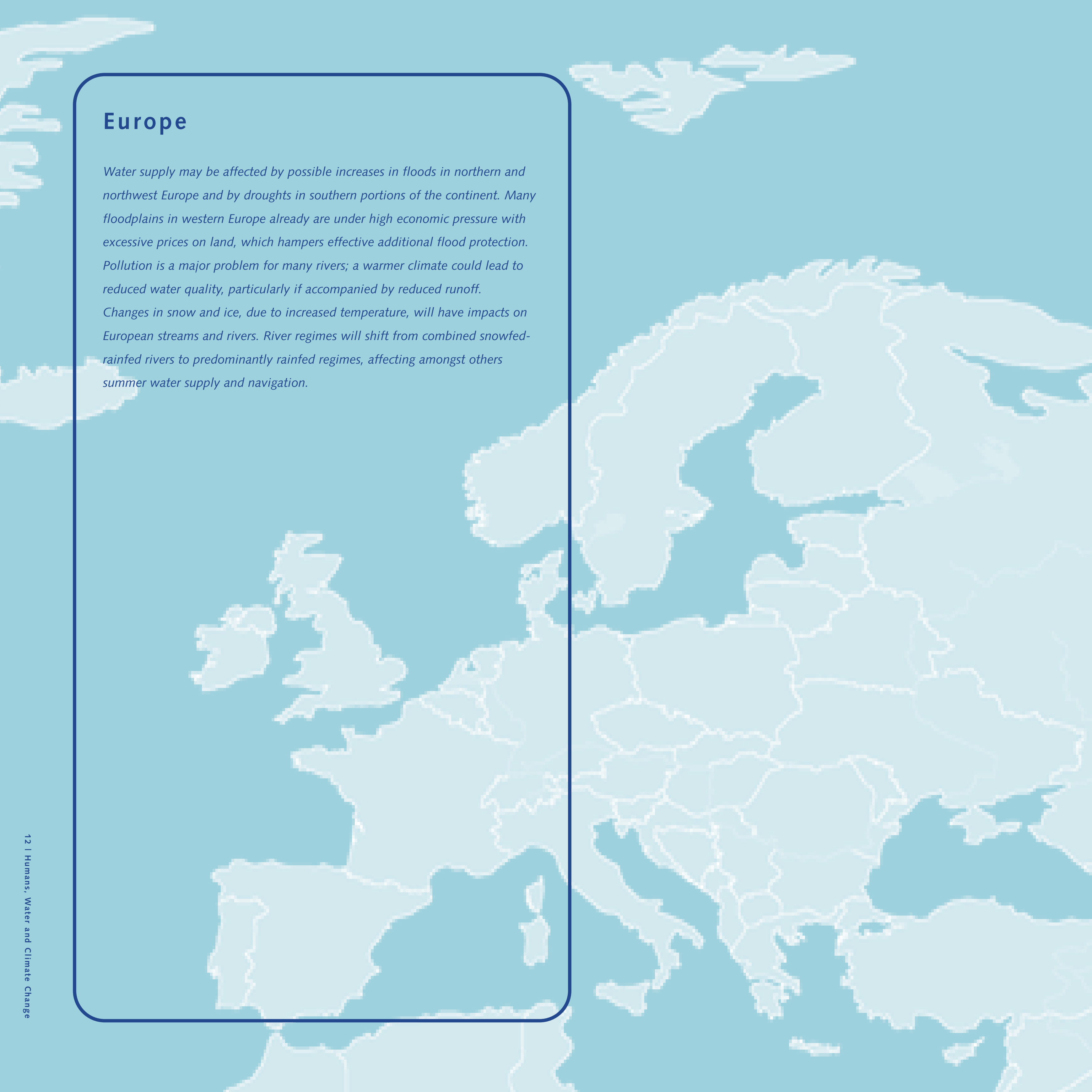
Vulnerability appears to be potentially high. Any reduction of water availability, especially in Australia's extensive drought-prone areas, would sharpen competition among uses, including agriculture and wetland ecosystem needs. Freshwater supplies on low-lying islands are also vulnerable. On the positive side are the observations that Australia has a relative low and stable population, and a high economic potential to deal with climate change related problems.

Consequences of changes in the water cycle

Although the IPCC paints a global picture with increased temperature and precipitation, the regional distribution of these changes is far from unambiguous. Some regions may experience an increase in precipitation, others a decrease. Some regions will experience larger winter precipitation, while in other regions the summer precipitation might increase. Combinations are also possible. For example, the Dutch Meteorological Organisation developed a scenario for the Dutch situation. This climate change scenario shows an increase in temperature comparable to the global values anticipated by the IPCC. The Dutch winters are expected to be shorter, but with increased precipitation during long depressions. During the summer we should expect rain showers of higher intensities.

Changes in the climate will certainly have their impact on hydrology. All the major components of the regional hydrological cycle may be affected. Possible impact will be on available soil water, river discharge, water demand and water storage in snow and glaciers. The effects may be positive, when dry regions experience an increase in water availability or flood prone regions encounter a decreased precipitation and river discharge. However, major problems and additional stress is likely to occur in those regions where increased temperature and decreased precipitation results in an even greater demand on scarce water resources, or an increased precipitation results in larger inundation problems.

Changes in climate will interact with stresses that result from actions to increase agricultural production. Depending on the types of agricultural practices and systems in place crop yields and productivity will be affected in different ways. In regions with predominantly dry-land non-irrigated agriculture where there is a likelihood of decreased rainfall, agriculture could be significantly affected. This has its direct impact on the livelihoods of subsistence farmers and pastoral peoples and will affect local and national levels. The positive effects of climate change, such as longer growing seasons, lower natural winter mortality and faster growth rates, may be offset by these negative factors. In regions where agriculture is well adapted to current climate variability and/or where market and institutional factors are in place to redistribute agricultural surpluses to make up for shortfalls, vulnerability to changes in climate means and extremes is generally low.



Europe

Water supply may be affected by possible increases in floods in northern and northwest Europe and by droughts in southern portions of the continent. Many floodplains in western Europe already are under high economic pressure with excessive prices on land, which hampers effective additional flood protection. Pollution is a major problem for many rivers; a warmer climate could lead to reduced water quality, particularly if accompanied by reduced runoff. Changes in snow and ice, due to increased temperature, will have impacts on European streams and rivers. River regimes will shift from combined snowfed-rainfed rivers to predominantly rainfed regimes, affecting amongst others summer water supply and navigation.

Currently, access to adequate supplies of safe water and access to adequate sanitation is exception rather than rule. The amount of people not having access to adequate water resources is expected to roughly double by 2025, mainly because of increases in demand resulting from economic and population growth. Climate change might introduce additional stress in this already problematic situation.

Flooding is likely to become a larger problem in many temperate and humid regions. An increased precipitation rate and increased precipitation intensity might overstress the current system in some regions. Present day infrastructure might not be designed for future conditions and safety standards may prove to be inadequate. Rivers and streams, locked in their straightjacket between dikes and dams might claim expanding areas to properly deal with increased discharges. These regions require adaptations to deal with floods, inundation and associated damage. Regions with a combination of increased drought stress and problems with increased flooding also exist.

Climate change might have an impact on natural and semi-natural ecosystems. Ecosystems are very important for environmental function and sustainability. Ecosystems provide many goods and services critical to individuals and societies. However, due to changing physical conditions (temperature and water availability) large shifts of vegetation boundaries can be expected. The mix of species within a given vegetation class is likely to change. Major alterations in productivity and species composition would occur due to altered rainfall amount and seasonality and increased evapotranspiration, although a mean temperature increase alone would not lead to such changes.

The impact of climate change will depend on the baseline condition of the water supply system and the ability of water resources managers to respond not only to climate change but also to population growth and changes in demand, technology, and economic, social and legislative conditions.

Food Security and Climate Change: decision making at various levels

Contributed by the project Impact of Climate Change in Drylands (NRP-ICCD)

One of the projects of the Dutch National Research Programme (NRP) focuses on developing a generic methodology to analyse the vulnerability of water and food security in Sub-Saharan West Africa to climate change. The framework should enable policy makers to identify policies that anticipate on consequences of climate change in which the negative effects of change are minimized and the positive effects are fully exploited.

The main characteristics of the ecological environment in semi-arid regions of Sub-Saharan West Africa are high temperatures, low and erratic rainfall patterns, and nutrient-poor soils with limited vegetation. The economy depends heavily on agriculture for the production of food products and a limited number of export products. The high rate of population growth puts further stress on both the agro-ecosystems and the socio-economic systems. Fast urbanisation results in a larger water demand of the cities, thus putting more stress on the available water resources. Climate change may be an additional stress to these systems.

Water and food security depends on agro-ecological, economic and socio-economic factors. Purely technical and agronomic techniques can only address part of the puzzle, just as pure economic and socio-cultural solutions.

The central entity of the developed framework is the Decision Making Unit or DMU. DMUs can be identified at various levels, ranging from national governments to individuals, each operating in a different environment. The environments and the DMU interact, meaning that the context in which the DMU operates is shaped by the DMU.

Uncertainty and variability characterize the environments of the DMU in Sub-Saharan West Africa. Fluctuations in volume and periodicity of rain, the appearance of locust plagues, plant diseases etc. have a tremendous effect on crop and livestock production. Fluctuations in production levels can oscillate in market prices of basic food products, affecting regional, urban and institutional environments. If large enough, these fluctuations at ecological and economic level may even endanger political stability.

The main response of people to deteriorating environments is mobility. The depopulation of large areas in the Sahel, and the inflow of large numbers of impoverished Sahelian migrants in the coastal countries may lead to social instability. Given the poor infrastructure and lack of investment capital water scarcity will become one of the main problems. This problem will affect both the rural population to produce sufficient food, and urban DMU's at various levels, to provision an increasing concentration of people with sufficient safe drinking water.

This problem can only be tackled by a renewed effort to improve water management at all levels of society, involving every category of DMU. Scientific research should focus on current strategies of DMU's to deal with environmental instability, to make best use of all DMU's creativity in policy making. Policies should aim at enhancing the availability of food and water and measures to stabilise food production and water availability.

International aspects

Leading international security specialists stress the importance of environmental, water and climate change issues in the twenty-first century. The political and strategic impact of a growing population, a continuing deforestation and soil degradation, increased flooding risks and increased tension between water use and availability are enormous. These topics will be the core of the oncoming international policy challenges.

Tensions over control and use of water resources are found around the globe. Examples include the fresh water scarcity in the Middle East, which has been a particular source of conflict in recent decades. Relations between most of the countries in the Jordan River basin have been marked by military conflict over its waters. History illustrates the importance of the Euphrates-Tigris system, but also shows an unending story of conflicts in this region. The present problems and potential conflicts between Turkey, Syria and Iraq have some of their very ancient roots in claims for water. The construction of the Ataturk dam will probably not relieve the situation. Other examples include the Danube river basin, shared by more than 10 countries and the heavy floods of the Ganges and Brahmaputra in South Asia. After flood disasters in the summer of 1993, killing more than 2,000 people, the government of Bangladesh renewed demands for shared control of the operation of dams in the Ganges and Brahmaputra rivers upstream from Bangladesh. In arid Central Asia, shared waters could quickly become the source of conflicts between the nations of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. As water demands grow the tension on these issues will certainly rise. Climate change, resulting in added variability and uncertain or diminishing water supplies has the potential to worsen the conflicts. Unfortunately, international water law offers little guidance for resolving these conflicts. As the demands of growing populations approach the limits of renewable resources, water could provide the flash point for conflict in regions with longstanding ethnic and political rivalries. Indeed, some analysts have suggested that within a decade water could overshadow oil as a scarce commodity at the centre of conflict and peacemaking.

The UNEP, the United Nations Environmental Programme, promotes monitoring of worldwide reserves of fresh water and establishing cooperative agreements for the use of bodies of water, including groundwater. This Programme calls for "economic instruments to stimulate use of new technologies" to promote water conservation. Any solution for addressing this growth must be linked with "new technologies that concentrate more on efficient use of limited natural resources" and must be available "on preferential terms to developing countries." Although UNEP promotes coordination, few countries voluntarily consider the impact of their water usage on neighbouring countries. Coordinated management of international river basins is still the exception rather than the rule.

Food Security and Climate Change: the role of agricultural policy

Contributed by the project Impact of Climate Change in Drylands (NRP-ICCD)

One of the projects of the Dutch National Research Programme (NRP) focuses on developing a generic methodology to analyse the vulnerability of water and food security in Sub-Saharan West Africa to climate change. The framework should enable policy makers to identify policies that anticipate on consequences of climate change in which the negative effects of change are minimized and the positive effects are fully exploited.

The impact of climate variability on food production is a major concern for agricultural policy makers. Erratic rainfall combined with high temperature, high evapotranspiration and low soil fertility are considered major constraints to invest in sustainable crop production systems. Agricultural research and development constantly seeks to disseminate strategies and technologies for a climate-defensive food production.

For example cotton production is entirely market-oriented, traditionally supported by intensive research efforts, a broad infrastructure for the necessary input supply, notably fertilizer and water, as well as for marketing the final product, and supportive policies with respect to extension and finance. Cereal production is much less supported by agricultural research and development policies and only a minor share is marketed against fixed prices. Despite lower prices and lesser rainfall producers have expanded cotton production. The higher production of cotton in spite of the decreased cotton prices suggests that the producers have been able to reduce production costs and increase production against lower prices. Production increase also resulted in reduced soil fertility. Investments in the soil capital are also tight to the cotton production. In areas were cotton is produced in rotation with cereals the cereal production also profited from fertilization. Other cereal production systems did not benefit from technological advances.

A supportive agricultural policy that facilitates optimal use of inputs, including fertilizers, and access to technological progress is of great importance for cash crops as well as for food crops. Particularly on the long term, technological progress supported by adequate infrastructure development is an effective policy instrument. A sound production infrastructure offsets the negative effects of adverse risk-prone production conditions. These instruments, however cannot be seen isolated from price levels for inputs and produce, otherwise the risk of rapid soil mining is real.

Growth of agricultural production is stimulated by integration of agricultural production into the market and a higher reliance on purchased inputs and yield-increasing investments. This is strongly depends on the development of rural commodity market infrastructures, as well as on the supportive policy and institutional environment required to stimulate farm-level investments. Studies point to the extreme importance of public investment in the agricultural sector (research, extension and development) to generate a sustainable growth.

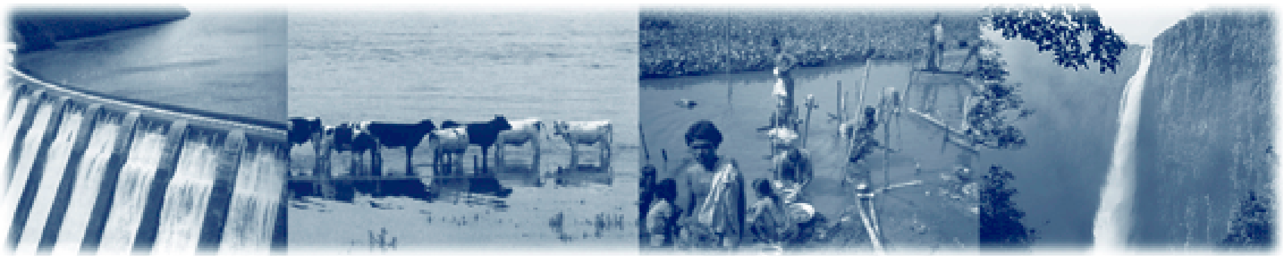
Why Develop Water Policy for Dealing with Climate Change

One important question in the climate change discussion is why we should presently develop water policies that deal with future climate change, even if we do not know the exact magnitude of changes. The main reason for questioning the necessity of developing policies for dealing with climate change comes from the observation that there is still a scientific discussion about the exact intensities of climate change, the exact regional patterns of climate change and the exact regional impact.

The following observations should be considered when trying to answer this question:

- Planning for water management is planning for an uncertain future. This uncertain future consists of uncertain scenarios for population growth, uncertain scenarios for economic development and uncertainties about future climate. Since all future scenarios include uncertainty, it would be unwise to exclude only climate change scenarios from the discussions on future water management.
- Although the intensity of climate change is still under discussion, to a large degree there is agreement in the scientific world that climate change is actually occurring.
- The expected lifetime of the hydraulic infrastructure is generally long. It seems unwise to plan infrastructure with a lifetime of more than 40 years, without at least assessing the possibilities of changes in the climate within these 40 years.
- The impact of hydrological changes resulting from climate change (floods and drought) on society and the economy is potentially severe. When developing robust and sound water management strategies for the next decades, we cannot ignore the possibilities of changing climates and their associated risks of drought and flooding.
- Vulnerability to climate change is high especially in those regions where the current water related stress is high. This means that those sectors and regions already under pressure are likely to suffer most.

Based on these observations, it is clear that the question is not whether we should define policies for dealing with the uncertain future. It is much more important, despite the inherent uncertainties, to focus on the question of how societies can develop mitigating strategies and how societies can adapt to climate change.



Climate change impact on the hydrological system of the Netherlands

Contributed by the project

The impact of climatic change on the River Rhine and the implications for water management in the Netherlands

Being a rich country with abundant fresh water the Netherlands can be characterised as a high income country with low water stress. However, this country has a long history of living with an ongoing thread of floods and inundation, and the Dutch have constantly rebuilt and restructured their country to live with these threads. Realising the risk of floods and the significance of sufficient fresh water, flood protection and the preservation of a sound water system, also in the long term, dominates all other interests.

Located in the delta of the rivers Rhine, Meuse and Scheldt, with the majority of the population and economic activities at or well below sea level and protected by dikes and dunes, the country is potentially vulnerable to changes in climate and sea level rise. This vulnerability is even greater when realising that the lower parts of the country are continuously subsiding. The impact of climate change and sea level rise on the Dutch water management system is analysed in a NRP financed research project.

The most important rivers for the water system in the Netherlands are the Rhine and the Meuse. The Rhine presently is a combined rainfall-snow melt driven river, with discharges relatively equally distributed over the year. The largest part of winter discharges originates from the German and French part of the basin, while summer discharge originate largely from snowmelt in the Swiss Alps. The Meuse is a rain-fed river, showing high discharges in winter and very low discharges in the summer period. Water quality remains problematic in these highly populated transboundary catchments. The water management issues related to these rivers are flood protection and maintaining enough space in the floodplains for regular inundation, water quality and drinking water supply, maintaining sufficient water depth for navigation and nature development in the floodplains.

The low lying areas in the western and northern regions of the country have upward groundwater seepage which in some regions is saline. This predominantly agricultural and urban area is artificially drained and due to oxidation of peat in the soil continuously subsiding. The major water management issues for these regions are drainage of excess water, maintaining the groundwater level within very narrow limits to prevent further land subsidence and the constant supply of fresh water to flush these polders.

A major component of the Dutch water management system is the IJsselmeer. This former inland sea is now an important fresh water reservoir, used for water supply and flushing of the polders. This inland lake is fed by a branch of the river Rhine, and during winter surrounding polders drain their surplus water towards the lake. To maintain this system, lake levels are regulated: low levels during the winter while summer levels are kept high. The possibilities to regulate these levels strongly depend on sea level as the IJsselmeer drains by gravity into the sea.

Modern climate scenarios show a temperature rise combined with a rainfall increase during winter in the basins of the rivers Rhine and Meuse. According to these scenarios the amplitude of seasonal discharges of the Meuse will increase further and the Rhine will change into an almost completely rain-fed river. The magnitude and frequency of high discharges will increase and to maintain the current safety standards will require

Appropriate Water Policy Allowing for Climate Change

The keywords of appropriate planning for climate change include

- **No-regret policy.**
- **Robust planning.**
- **Planning for sustainability.**
- **'Planning with water' instead of 'fighting against water'.**
- **Integrated planning.**

Many systems and policies are not well adjusted even to today's climate and climate variability. Increasing cost, in terms of human life and capital, from floods, storms and droughts demonstrate this current vulnerability. At present, many measures are proposed or implemented to improve water supply or flood protection. By a 'no-regret policy' we understand: adaptive, flexible measures and strategies that are undertaken as a response to ongoing water management problems in combination with the possible impact of climate change. Where possible, these strategies should be defined combining the primary aims of the measure with other objectives. Adaptive measures and strategies, which aim at making sectors more resilient to today's conditions are at the same time beneficial in adjusting to future changes in climate. These measures and strategies – the 'win-win' measures – could have multiple benefits and most likely would prove to be beneficial even in the absence of climate change impact. Examples include the widening of the river beds in the Netherlands, aimed at creating more space for high discharge situations, but with the additional advantage of creating areas for ecological rehabilitation along the Rhine.

Measures and strategies should be flexible. It is unlikely that we can solve all the future problems at present, and besides the current measures additional ones are necessary to deal with future situations. It is therefore important that the measures and strategies planned and implemented today are flexible towards the future. It should be possible to adapt and extend them relatively easily for changed conditions.

Planning should be robust: we do not want to implement measures or build infrastructures that are designed to function and operate only within a very specific range of conditions. If future conditions change, these measures might need very expensive alterations because they do not function correctly under these future conditions. Or, even worse, these measures might prove to be very expensive solutions for problems that no longer exist. Measures should be taken in a pro-active way: in the forthcoming period we should increase the flexibility of the system and of the water management practices to deal with an uncertain future. This also includes re-examination of existing plans and design assumptions under a wider range of climatic conditions.

additional protection and adaptation measures. Water supply in the future will be limited as dry spells will occur more often and water quality may degrade due to higher concentrations of pollutants. Preservation of water for use in dry periods could become necessary.

Future sea level rise in combination with both higher river discharges and an increasing drainage from the surrounding polders will lead to a rise of the IJsselmeer level in winter. Higher lake levels will reduce the safety situation along the lake shores, and higher lake levels will hamper drainage from the surrounding polders. In extreme dry summers the fall of the lake levels below present target levels will hinder the water supply to the polders.

As magnitude and timing of the expected changes are surrounded by uncertainties, the design of an adequate adaptation strategy is difficult. The financial investments to mitigate undesirable effects are great, and, as both the rivers Rhine and Meuse are transboundary rivers design and implementation of measures preferably requires international agreement. Until recently, the strategy for flood prevention was to raise dikes (embankments) along the floodplains. Currently this strategy is abandoned as it stirred social resistance and is nowadays considered to be too inflexible to deal with an uncertain future. Current solutions focus on reduction of water levels during floods by developing retention basins along the Rhine. Where not enough room is available, such as in the Meuse basin and in the lower parts of the Rhine, floodplains will be lowered to enlarge the cross section of the river. These solutions for the floodplains are designed to allow more natural morphological ecological processes in these floodplains.

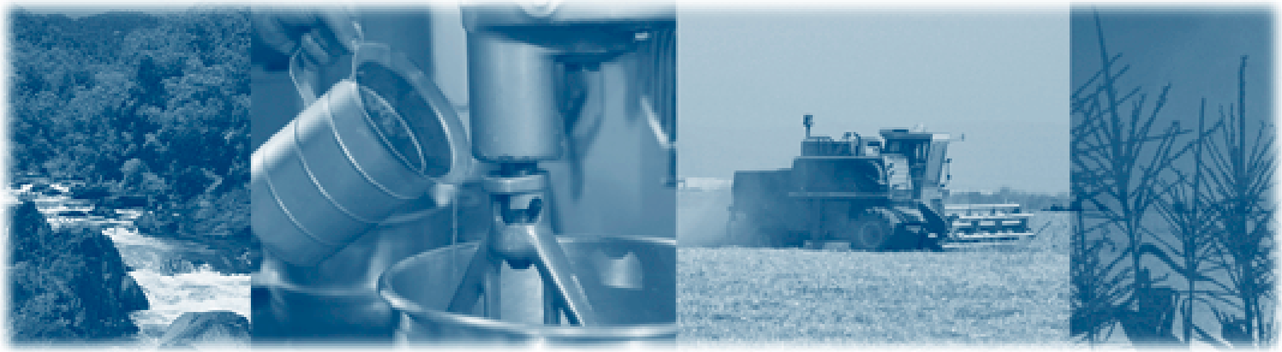
Studies on future adaptations envision a further widening of the floodplains in the delta of the rivers and the planning of 'green rivers', only to be used during floods. Focus in the upstream sections is on landscape planning and buffering of water in the smallest arteries of the system so that water will flow less quickly to the river, so that 'the future behaviour of the basins is more like a sponge than it is now'. Future water management visions mainly concentrate on flood mitigation and ecological restoration. Relatively little effort is put into dealing with low flows including future water quality developments and navigation requirements.

As sea level rise is less uncertain than climate change, the design of measures in the IJsselmeer area is more straight-forward than for the river area. Reinforcing dikes is also here an abandoned strategy and the safety situation should be maintained by creating shallow forelands that break the waves before they hit the shores. Due to the sea level rise, combined with the additional excess water drained into the IJsselmeer, maintaining lake levels will become problematic. Additional pumping capacity is foreseen to overcome the increased head loss and increased water volumes to be discharged. Visions for further future developments envisage investments in additional pumping capacity or raise of water level. This latter option will have its impacts on the safety of the surrounding areas and could imply that the surrounding dikes have to be raised. Other visions exhibit a less technological character and allow for more natural regulation of the water levels in the lake. This includes the planning of additional space for temporal storage of water in the surrounding polders or even allow the inland lake to change back into an estuary.

Water should be a leading principle in planning, instead of being the last in our list of other activities, functions and wishes and desires. We should seriously consider the boundary conditions that the water systems impose upon us. These boundary conditions define the range of problems that might be solved by implementing relatively uncomplicated measures. Beyond these boundaries, only very expensive and complex techniques could offer some solution. By adapting to and implementing measures well inside these boundary conditions, we are 'planning with water' instead of 'fighting against water'.

Strategies should include protection and restoration measures for natural areas, wetlands and forests. Once these natural buffers are destroyed, water management becomes very problematic. Protecting and enhancing the natural buffers might be the most effective way of water management.

Planning for sustainability should also contain a search for solutions related to management of our functions, adaptations of our



needs, improvement of our management methods and so on, instead of an overly optimistic confidence in technical and infrastructural solutions. An effective way to combat drought and flooding problems might be through creating awareness of the water related problems, promoting education and participation of stakeholders and the general public and through promoting adaptation options.

It is increasingly clear that water management should be integrated management. Integrated planning for water management should focus on all functions and cross-sectoral water resources management. Integrated planning should focus on the river basin as a resource management unit, and include groundwater as well as surface water, water quality as well as water quantity, socio-economic conditions and processes as well as physical and hydrological conditions and processes. Integrated management should weigh the pros and cons of infrastructural strategies against other alternative solutions such as protection and restoration of nature area and forest and changes in land use. Integrated management should focus on both the subject, the river basin, and on the management practices themselves.

Integrated planning should address issues on different levels: management of the entire river basin may include some problems to be addressed at a local level, some issues to be addressed at a regional or catchment level and some issues which should be dealt with on a national or continental scale. Integrated planning should try to provide a framework in which it is possible to implement measures in the upstream areas which would benefit downstream regions. Although there are many examples of these types of measures, it should be realised that there are also numerous examples in which neighbouring countries do not recognise each others interests.

Characterisation

countries	high water stress	low water stress
high-income	• countries that have fairly large amounts of water, but are facing stress conditions as a result of continuing overuse and pollution • countries already used most of their accessible water resources	• major problem is water quality rather than supply • major problem in excess water, flooding and inundation
low-income	• intensive use of water resources, often for farm irrigation • lack of pollution controls • limited development due to lack of extra water or financial resources • high ratio of water use to water availability • insufficient water supply, sanitation and waste-water treatment	• abundant water resources • these countries suffer from too much water • inadequate drinking water supply and sanitation • insufficient financial resources, technical and institutional support

Policy & Management

countries	high water stress	low water stress
high-income	• the allocation of water to the highest-value uses • demand management • water allocation to maximise the socio-economic value of water • pollution control • water markets with tradeable water rights • irrigated agriculture will decrease in importance • increasingly dependant on world market for agricultural products	• pollution reduction and control • water-pricing • development and distribution costs • potential for increased food production • improving local water storage and buffer capabilities
low-income	• shifts in use of water towards production of high-value products • increase irrigation efficiency • optimised water allocation among various uses • generation of foreign exchange • waste-water treatment and reuse • control of chemical pollution from agriculture	• opportunity to increase agricultural production and exports • agricultural production of high-value, low-water-intensive products • lack of sanitation and waste-water treatment • highly polluting industries

Integrated water management should include water demand management and risk management. Water demand management should deal with the prospects for limiting the growth in the demand on water resources. It should aim at significantly increased efficiencies in agricultural and industrial use. It has to define the most appropriate economic mechanisms to encourage more effective and efficient water supply and management.

Risk management deals with society's options related to anticipated risks. We can protect ourselves against these risks (building dams and dikes), prevent disaster by adapting ourselves to the conditions (changing the functions and land use of the region), or, in extreme cases: retreat from the area. Examples of risk management include the analysis of inappropriate land-use zoning and/or subsidised disaster insurance, which encourage infrastructure development in areas prone to flooding. Risk management should also include appropriate warning and contingency plans, in case the anticipated risk becomes a real threat.

The scale of analysing water stress

Contributed by the Image project of the RIVM

When analysing the number of people affected by water stress it is important to take into consideration the spatial and temporal variability of water availability and water demand. Water stress can be analysed at local level, regional level, country level and even continental level. Temporal scales can be daily, monthly, yearly or even longer. The scale at which the water stress is analysed determines to a high degree the results of this analysis.

The two maps display Water Stress Affected People aggregated to world regions (upper map) and aggregated to a 0.5 x 0.5° (lower image). North Africa does not seem to be problematic, because, even though North Africa has a considerable water stress, being sparsely populated makes the number of people affected relatively small. Although the upper map is useful for a quick scan of the problem, detailed analysis on grid level shows a number of 'hot spots' not identified on the world region level. Moreover, the world region level identifies regions such as Canada and Scandinavia as problematic, while these areas are not classified as problematic on a detailed scale. The detailed scales match the scale of water supply systems, the distribution of population and water demand better, and provide a more balanced description of the water stress.

Water stress affected people

aggregation on region scale

year 1995

Water stress affected people

on grid cell scale 0,5 deg lat/long

year 1995

The Dutch National Research Programme on Global Air Pollution and Climate Change

The Dutch National Research Programme on Global Air Pollution and Climate Change, NRP, is a strategic scientific research programme for the encouragement and financing of research on problems that, directly or indirectly, have to do with 'global change' and climate change. Characteristic of the NRP supported projects is that they are multidisciplinary and interdisciplinary, they support policy, and they have an international orientation.

The main strategic objectives of the NRP programme are the strengthening and support of:

- Dutch policy in regard to climate change and global air pollution;
- Dutch input into relevant international policy-forming frameworks;
- Dutch input to international frameworks in regard to climate change;
- research into climate issues to gain a permanent place in the Dutch research structure;
- research into climate issues to gain a position in international research frameworks.

Water related projects within the NRP are:

- *The impact of climatic change on the River Rhine and the implications for water management in the Netherlands*. Dr. H. Middelkoop, Utrecht University.
- *Impact of Climate Change in Drylands (NRP-ICCD)* Prof.dr. A.J. Dietz, University of Amsterdam & Dr. A. Verhagen, Plant Research Institute Wageningen.
- *Climate change and the vulnerability of small natural riverine ecosystems.* Ir. P.E.V. van Walsum, ALTERRA.
- *Programming study: Vulnerability water supply of the Netherlands through the river Meuse.* Prof.dr.ir. R.A. Feddes , Wageningen UR.
- *Effect of climate change on the hydrology of the river Meuse.* Ir. P.M.M. Warmerdam, Wageningen UR.
- *Integrated water management strategies for the Rhine and Meuse basins in a changing environment.* Dr. H. Middelkoop, Utrecht University.

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