Facts and Issues

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Global fresh water resources

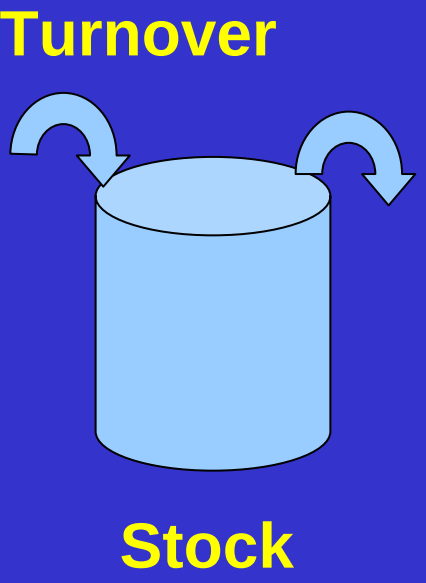
Two types

Surface water (Lakes and rivers):

- **Volume** 104,000 km^3
- **Renewal rate** 37,000 km^3/a

Groundwater (incl. soil water):

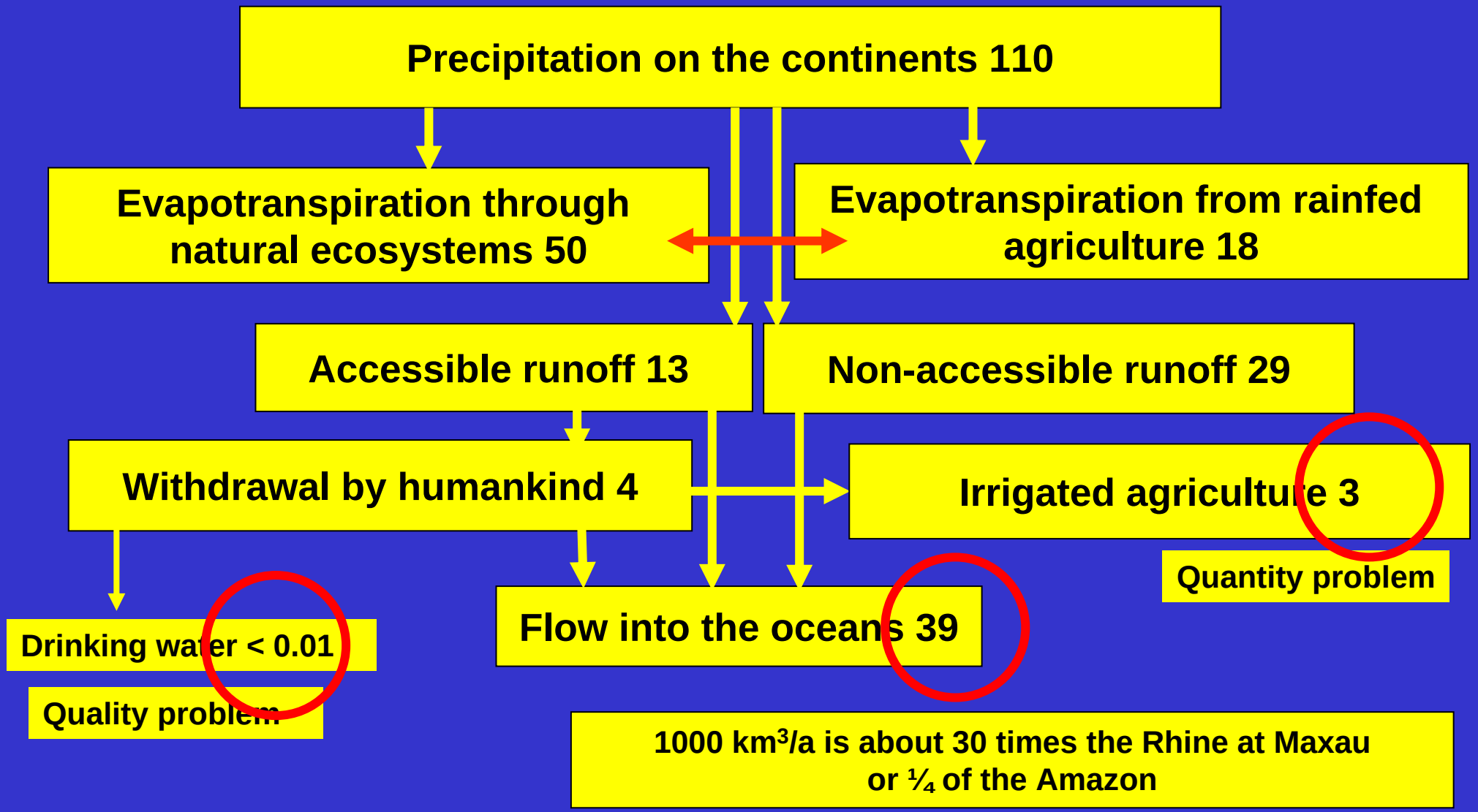
- **Volume** 10,000,000 km^3
- **renewal rate** 3,000 km^3/a



Is that much?

Global water balance

in 1000 km³/a



Resulting Issues

- Competition between natural and man-made ecosystems quantity and quality
- Main water quantity problem: Irrigation
- Main water quality problem: Drinking water
- Transport of dissolved solids to the sea

Definitions

- **Consumptive use**
  - Evaporative use, water is carried to different basin
- **Non-consumptive use**
  - Water is returned to same basin after use (e.g. waste water)
- **Green water**
  - Fraction of rainwater used by plants in evapotranspiration
- **Blue water**
  - Fraction of rainwater forming surface or subsruface runoff

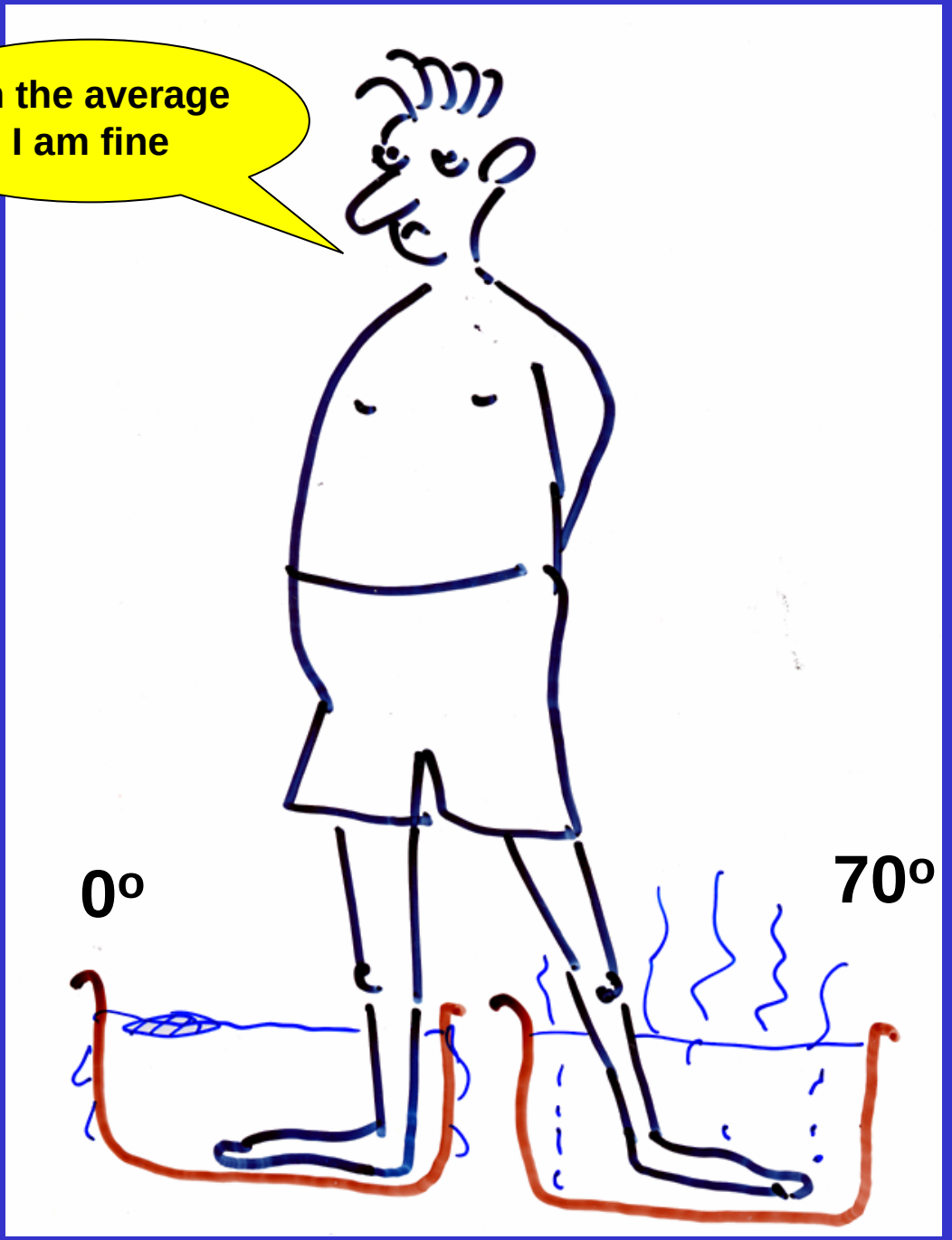
Supply and abstractions

- Accessible runoff 13000 km^3/a
- Abstraction 4000 km^3/a
  - consumptive use 70%
  - non-consumptive use 30%

Where is the scarcity?
Careful: Averaging

Averaging is misleading

Drought cannot be averaged against flooding



Is water scarce?

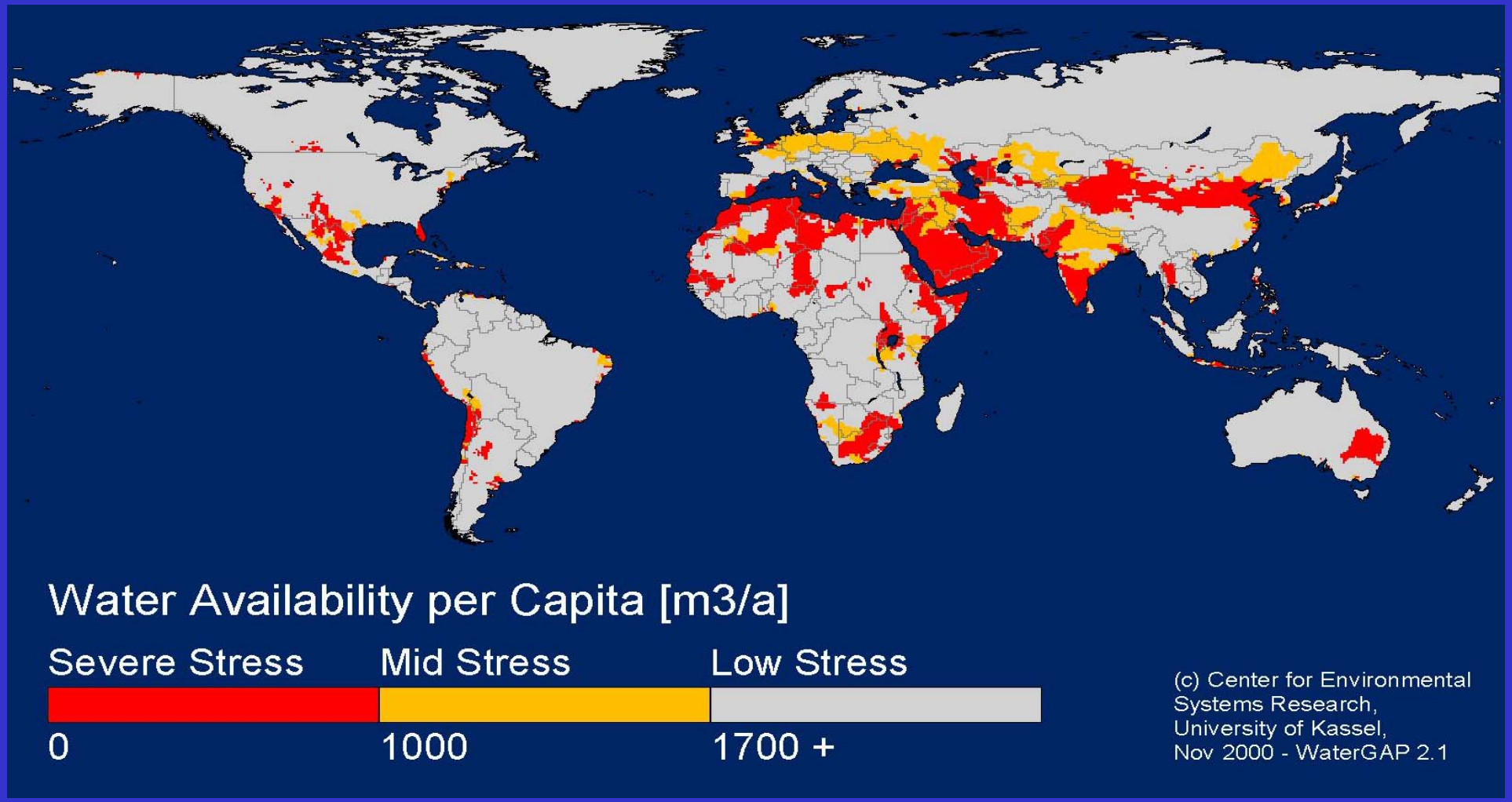
Water has already been scarce in many regions for a long time and scarcity increases due to population growth and increasing standard of living

Definition of scarcity (UNO): < 1000 m^3/a/P

2000 407 Mio. person
2025 3 Mrd. persons

Household use in Europe: 150 l/day/person
In rural Kenya: 2 l/day/person

Per capita water availability 2000



Source: WaterGAP 2.0, 2000

Indicator for water scarcity

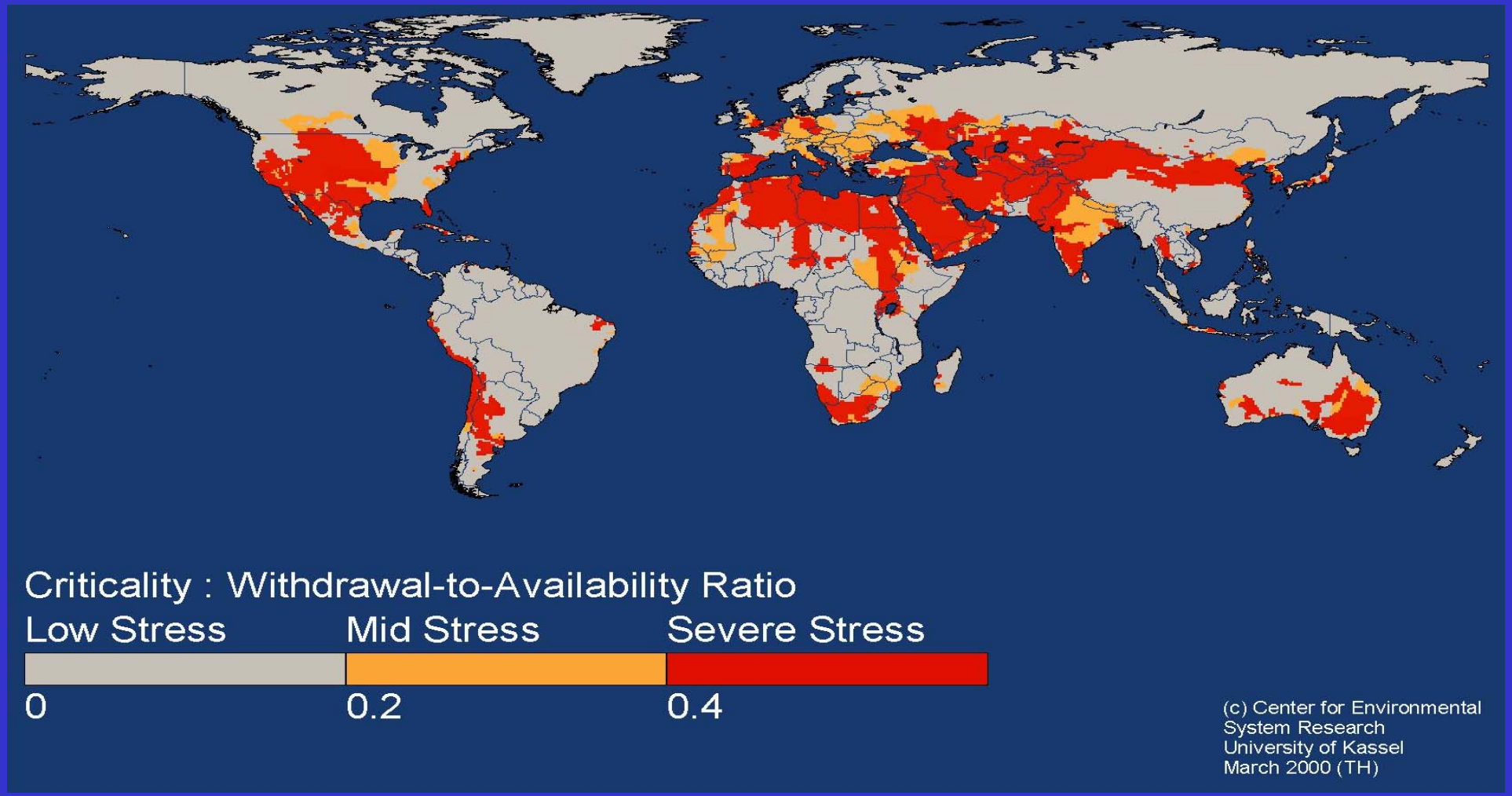
$$\alpha = \frac{Withdrawals}{available\ renewable\ resources}$$

Mild water stress: α = 0.2 - 0.4

Serious water stress: α > 0.4

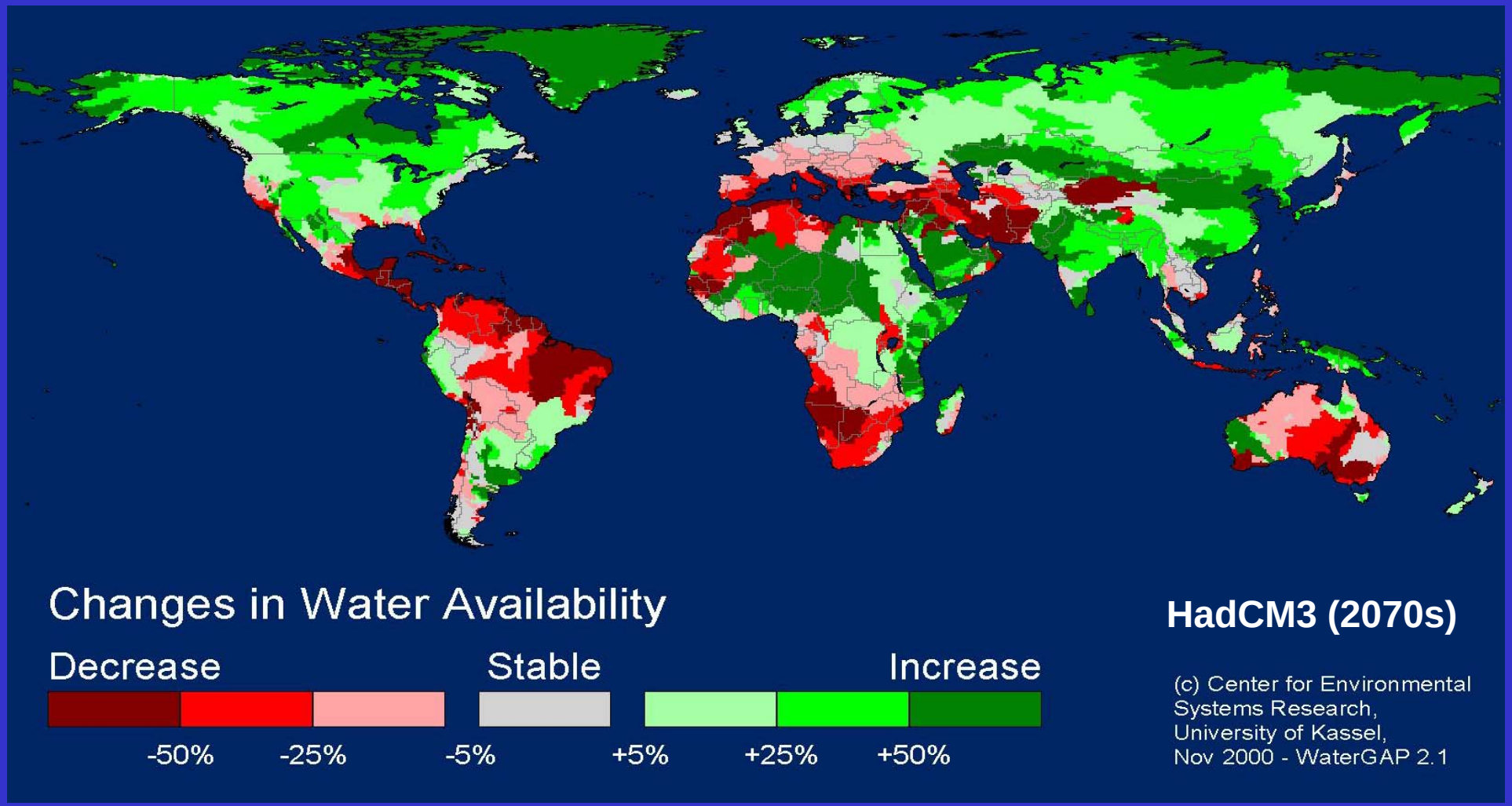
Global mean today: α = 4/13 = 0.31

Water scarcity 2000



Source: WaterGAP 2.0, 2000

Climate change and water availability



Source: WaterGAP, 2001

… and larger variability!

Some prices

- 1 m^3 irrigation water 0.01 €
- 1 m^3 drinking water 2 €

→ Not globally traded goods

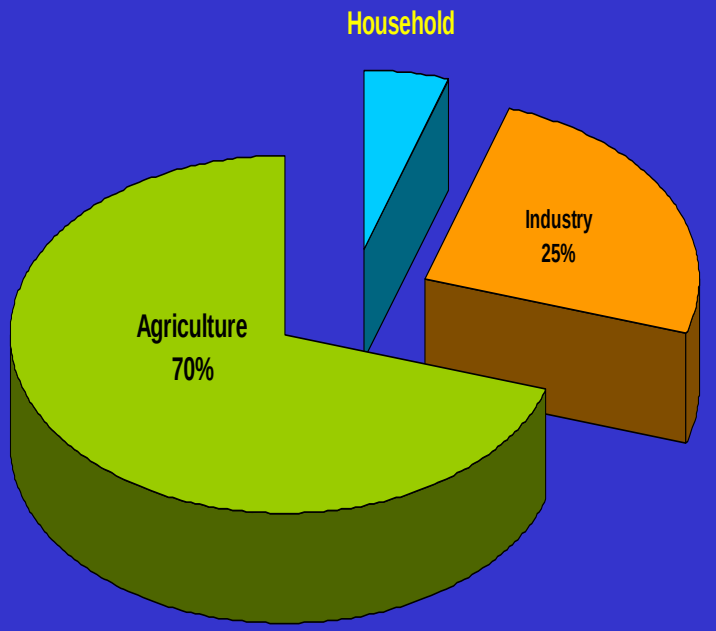
- 1 m^3 Perrier 2000 €
- 1 m^3 gasoline 1500 €

→ Globally traded goods

How can there be a global water crises?

Global aspect of water

- 70% of freshwater are used in agriculture
- Irrigated agriculture is more than twice as productive as rainfed agriculture
- It produces on roughly 20% of cultivated area more than 40% of world food
- 1 t of grain requires 1000-2000 t of water
- There is a world market for grain



If there is a global water problem it will show in the form of a global food problem and a global migration problem

Value created per unit of water used

- Car industry 100 €/m^3
- Drinking water 2 €/m^3
- Rice irrigation 0.10 €/m^3

Agricultural problem is the most severe:
Famers need most and can pay least

World drinking water problem

About 1.3 Bio. people have no access to safe drinking water

Really ingested water is less than 2 ‰ of the total freshwater demand of 4000 km^3/a!

The drinking water problem is a quality and not a quantity problem. It is in principle more easily solvable than the irrigation problem:

Required: Technology, institutions, investment, education

Source for drinking water in East Congo

Same place after fitting the spring:
material cost 150 €

Typical problems:
Proximity of latrines and wells, breakdown of techn. and administrative Infrastructure, higher prices for drinking water for the poor than for us

Estimated global investment required:
around 300 Bio. US$

Challenge till 2050

- World population increase by 3 billion people
- Majority in arid and semi-arid regions without the possibility of extending rainfed agriculture
- Majority of soils suited for agriclture are already in use
- Factors such as fertilizer, new seeds, pesticides are only effective when the water problem is solved
- At present technology an increase in irrigation water by 60% is required to feed the additional population

In addition there is the hidden water problem:

Non-sustainable use of water resources

Sustainable water management

Water management practice which

- generally avoids irreversible damage to the resource water and the resources linked to it (soils, natural ecosystems) and

- conserves in the long term the ability of the resource to extend its services (including ecological services).

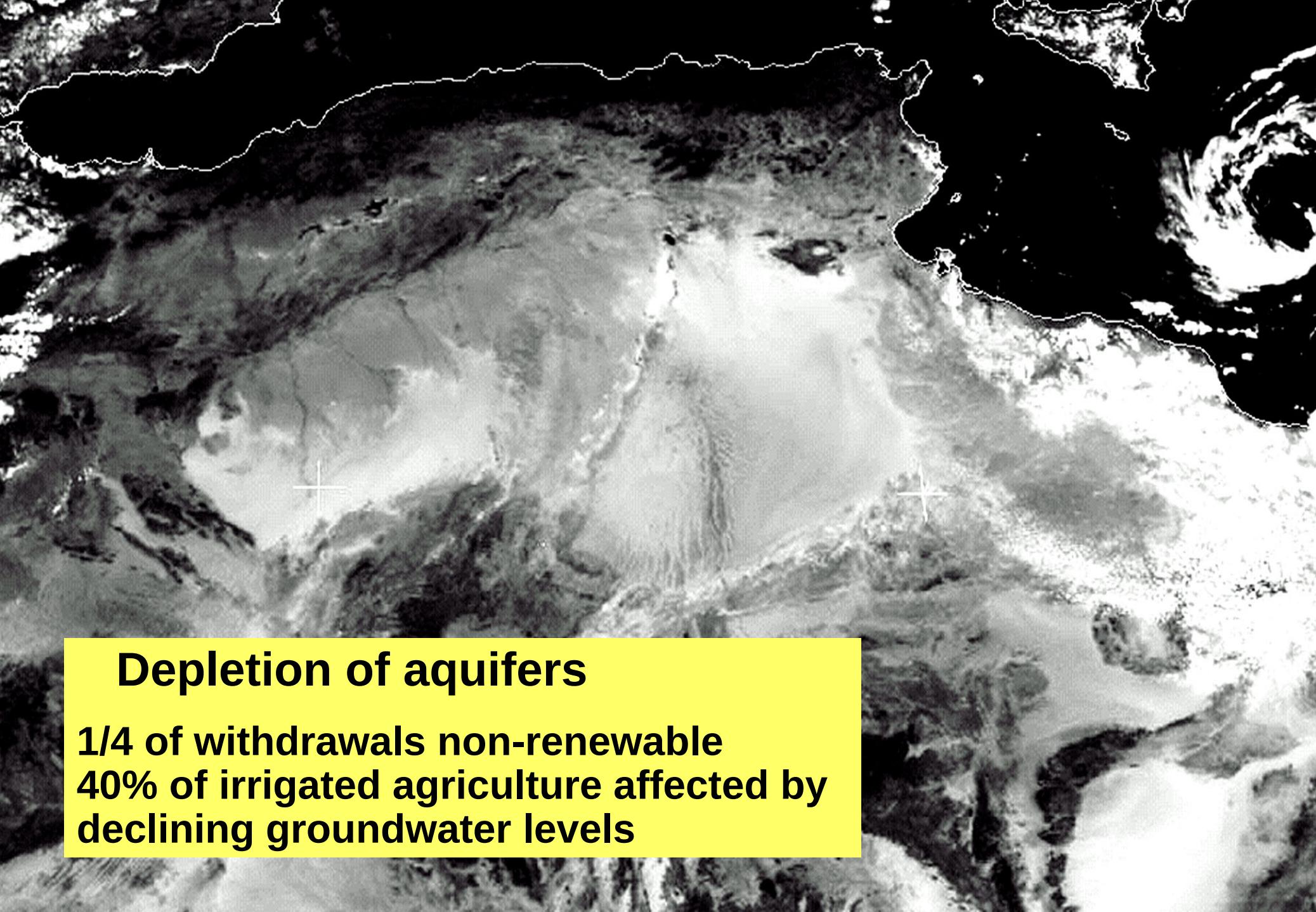
What is non-sustainable?

Non-sustainable is a practice, which is hard to change and cannot go on indefinitely without running into a crisis

Non-sustainability shows in

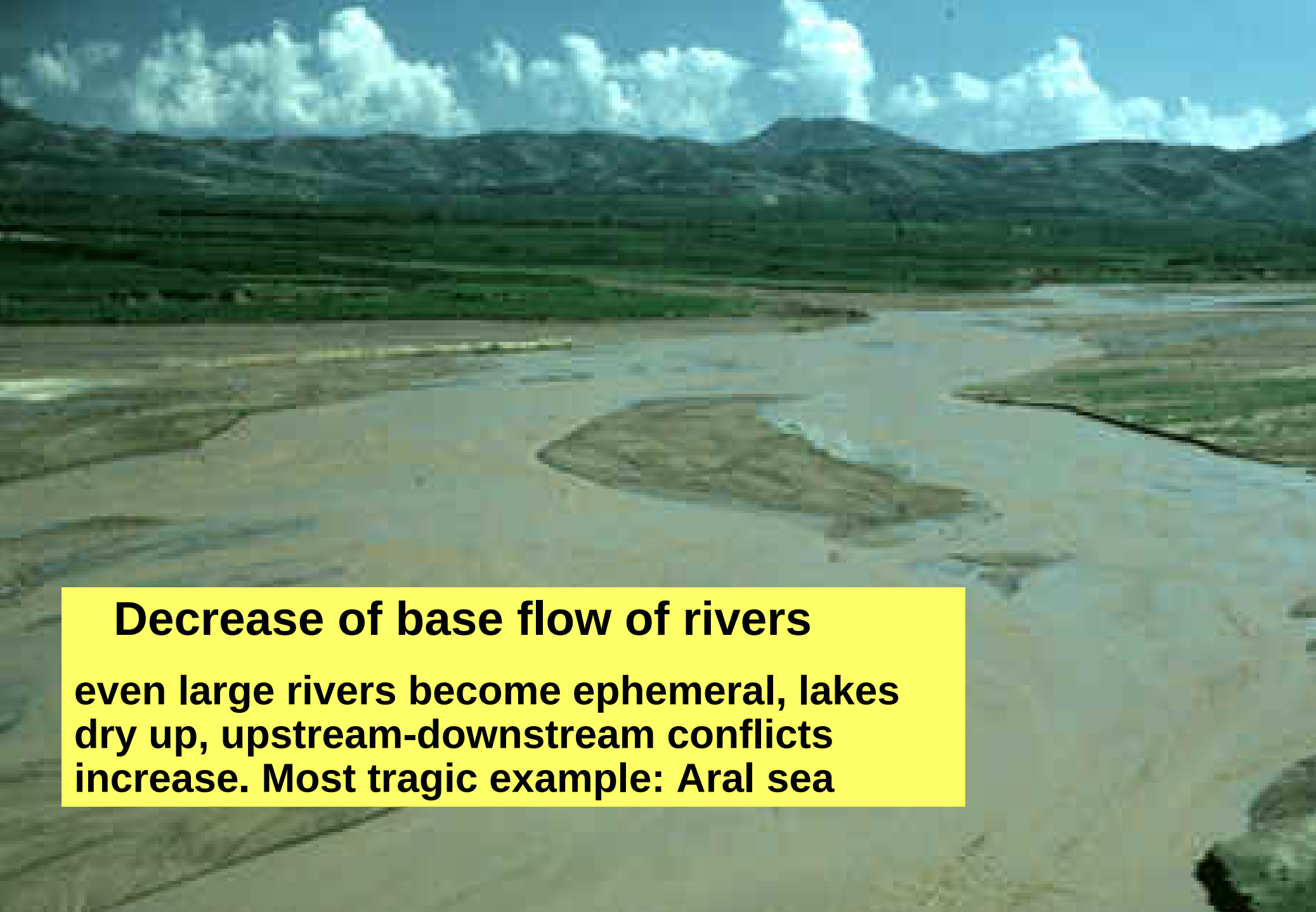
- depletion of a finite resource, which cannot be substituted (groundwater, soil, biodiversity)
- accumulation of substances to harmful levels (salts, nutrients, heavy metals, etc.)
- unfair allocation of a resource leading to conflict (upstream-downstream problem)
- runaway costs

The most serious problems of non-sustainability in the water sector on a global scale



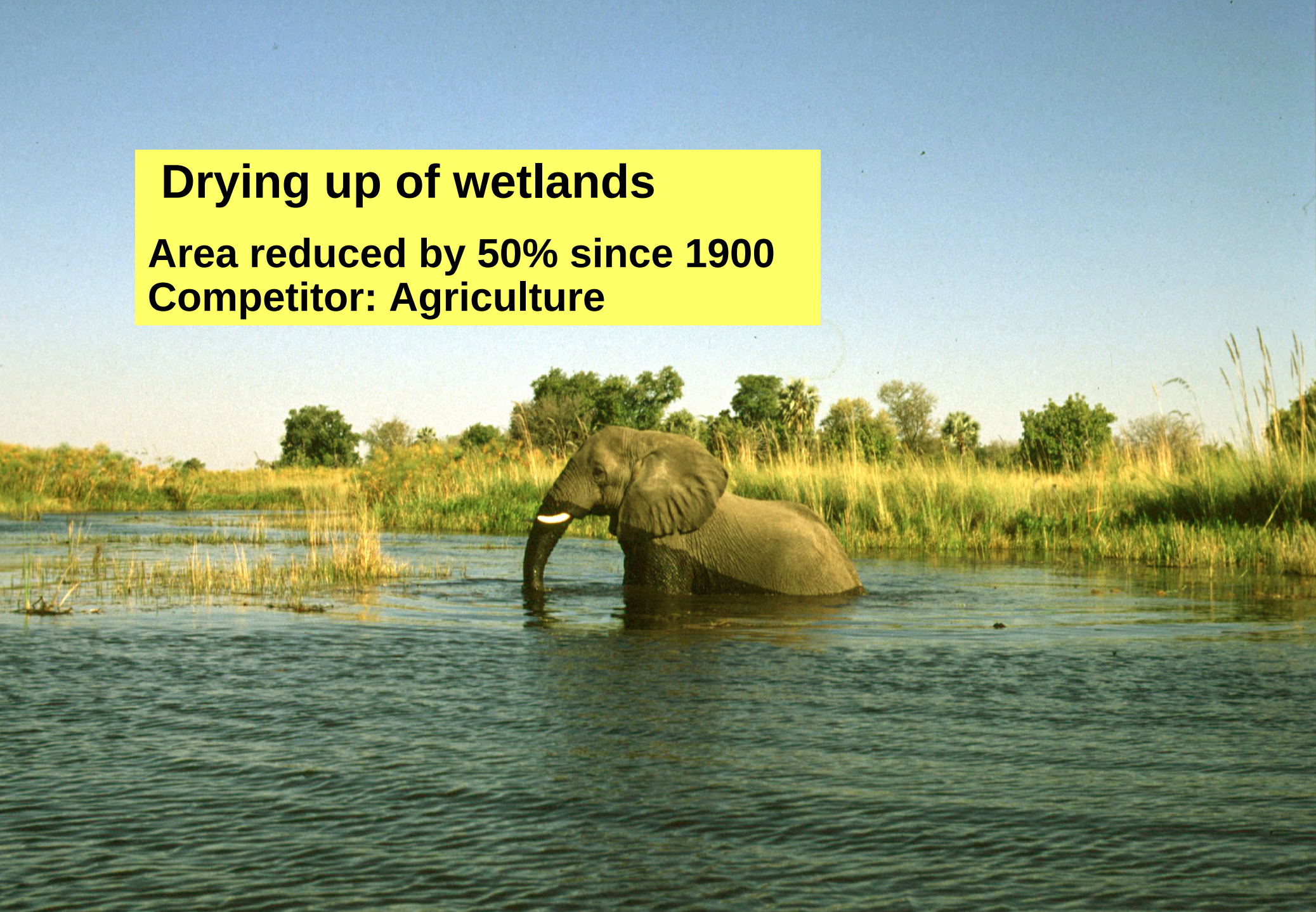
Depletion of aquifers

1/4 of withdrawals non-renewable
40% of irrigated agriculture affected by declining groundwater levels



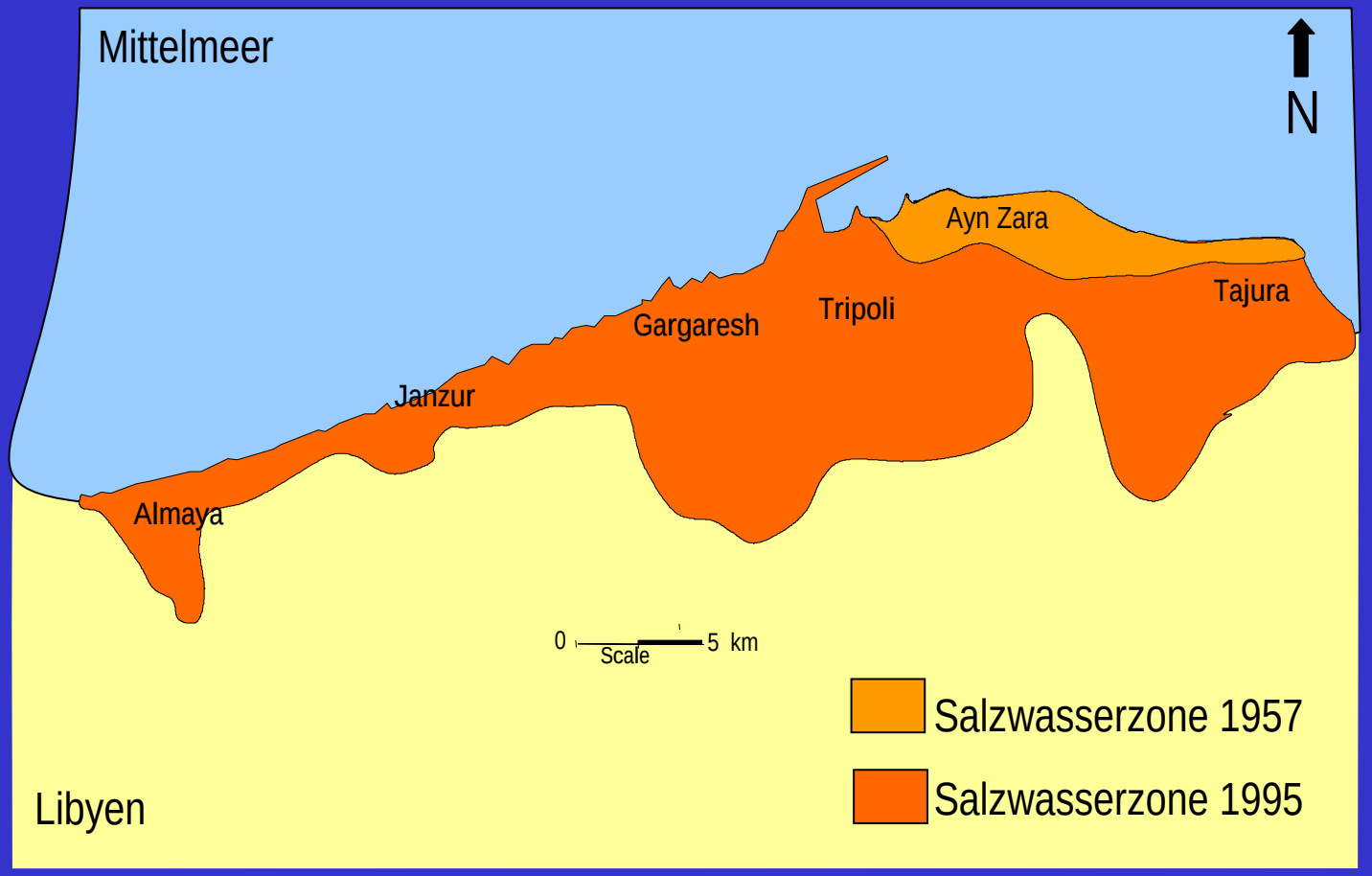
Decrease of base flow of rivers

even large rivers become ephemeral, lakes dry up, upstream-downstream conflicts increase. Most tragic example: Aral sea


Drying up of wetlands
Area reduced by 50% since 1900
Competitor: Agriculture

Soil salinization
80 Mio. of 260 Mio. ha irrigated land in some way affected

Pollution of water bodies with large residence times (e.g. groundwater) with persistent or recyclable pollutants



What about river and lake pollution?

Major problem in countries of transition

- **e.g. China: Dissolved Oxygen, Eutrophication**

But reversibility has been shown:

- **river rehabilitation: Rhine, Thames, etc.**
- **lake rehabilitation: Swiss lakes**

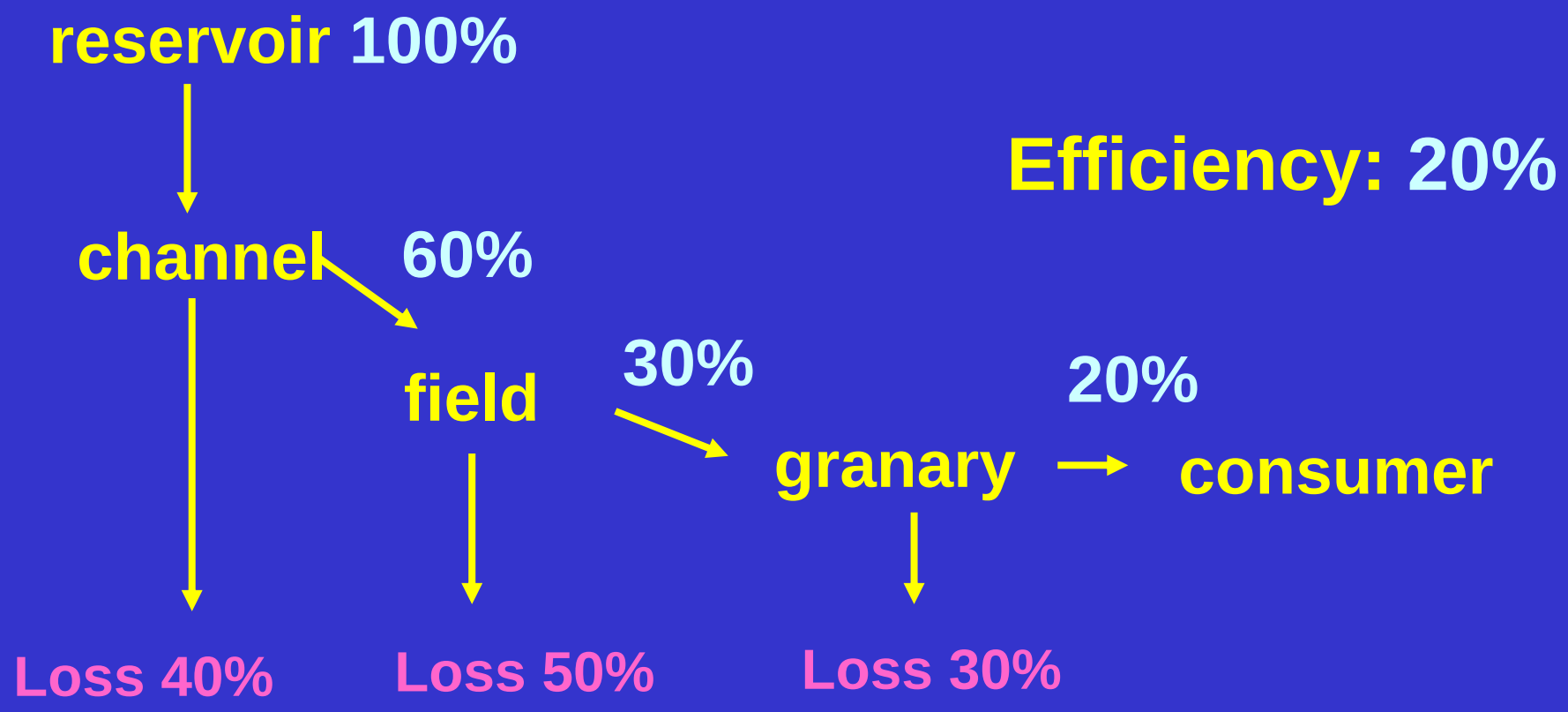
Required: Investments and political will

Some global options (Potential in km^3/a)

- Water saving irrigation (1000)
- Rain water harvesting (100)
- Change of diet (100)
- Change of economic activities and import of „virtual water“ (presently 500)
- Sea water desalination (presently 20)
- Interbasin transfers (100)
- Resettlement of people and birth control (presently 20)

For comparison: Additional demand till 2050: 1000 km^3/a

Typical water efficiency of irrigated agriculture in developing countries



Some further requirements

- Strong water institutions
- Political responsibility
- Implementation
- Demand management via price
- Acknowledgment of global value of ecological services

Conclusions

- Serious regional water problems exist already today and increase in intensity.
- Global water crisis is possible, but in principle avoidable.
- Many regions are not sustainably supplied with water.
- The part of water resources remaining for the environment will further decrease.
- The solution of water problems requires the application of a very wide spectrum of methods.
- Generelly mankind will have to pay in future a larger portion of its income for food and water.
- The socio-economic obstacles to problem solving are as a rule more important the the technical obstacles.

Two examples from our research work

- The Okavango Delta, Botswana
- The Yanqi Basin, China

The Yanqi Basin and its problems

(due to doubling of population over the last 50 years)

Huang Shui River

Qing Shui River

Groundwater table rise due to irrigation

Soil salinization

Control Point

Kaidu River

Bostan Lake

Decline of water level in lake

Second Control Point

Increase of salinity in lake

Die-off of fish

Kongque River

Drying up of „green corridor“

Possible measures to improve situation in Yanqi

- Reduction of irrigated area
- Alternative crops
- Improvement of water efficiency of irrigation
- Deep drains and other drainage measures
- Increased proportion of groundwater for irrigation
- Lowering of lake water level

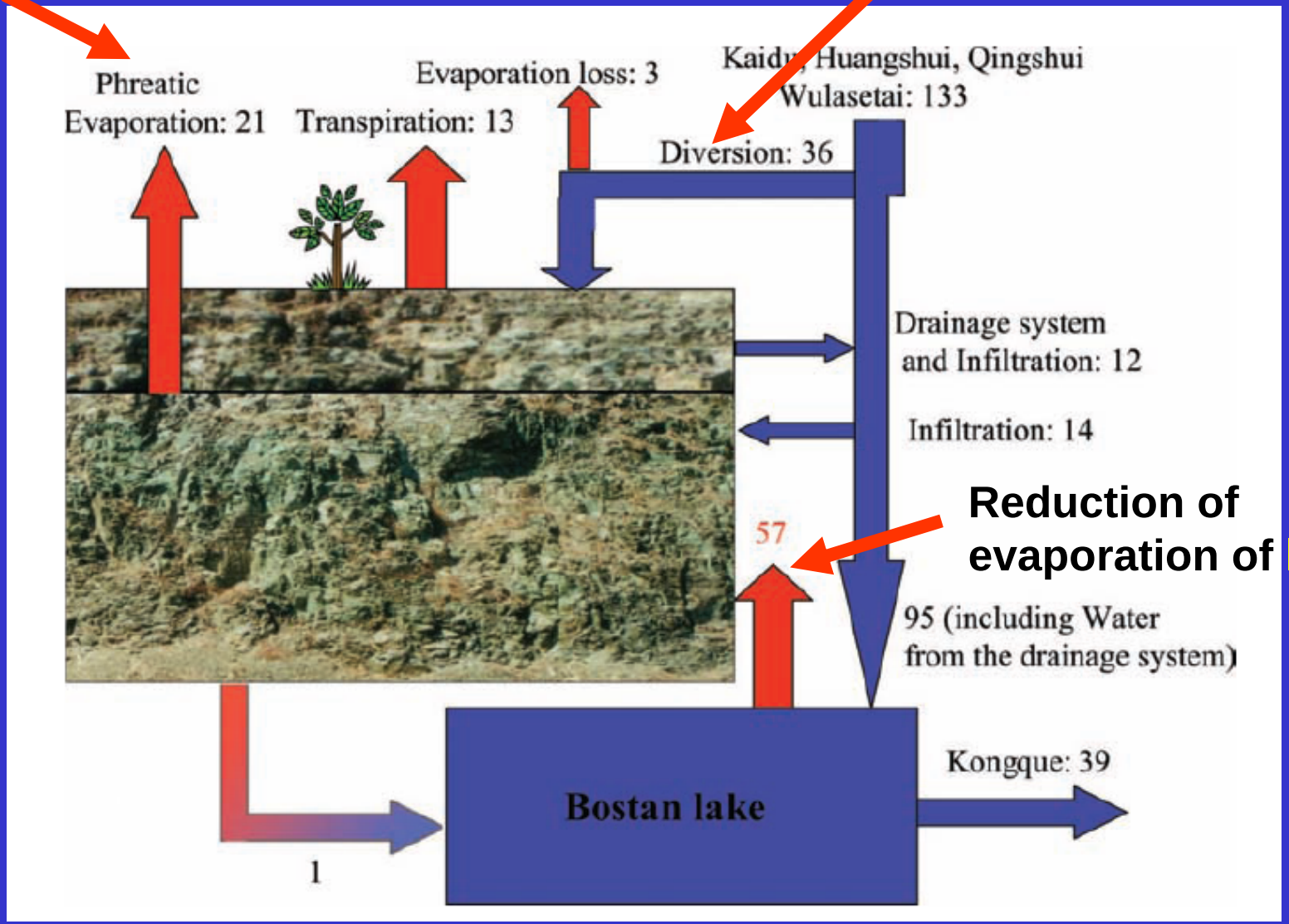
Government directive

Restore downstream flows for nature of 1985

Water balance Units: m^3/s

Resources to be harnessed:
Unproductive evaporation

Savings in irrigation water



Results of scenarios computed with a coupled surface-groundwater model

(at steady state)

	No irrigation	Present	Pumping	P + water saving
Total salinized area (s-h < 2m) (km^2)	846	1720	1232	1036
Phreatic evaporation m^3/s	10.3	22.5	15.3	12.3
Irr. water diverted m^3/s pumped m^3/s	- -	36.2 2.6	26.6 12.6	22.9 12.1
Flow to green corridor m^3/s	69.1	38.9	46.1	53.0
Salinity of outflow g/l	0.8	1.4	1.2	1.0

Cost-benefit analysis

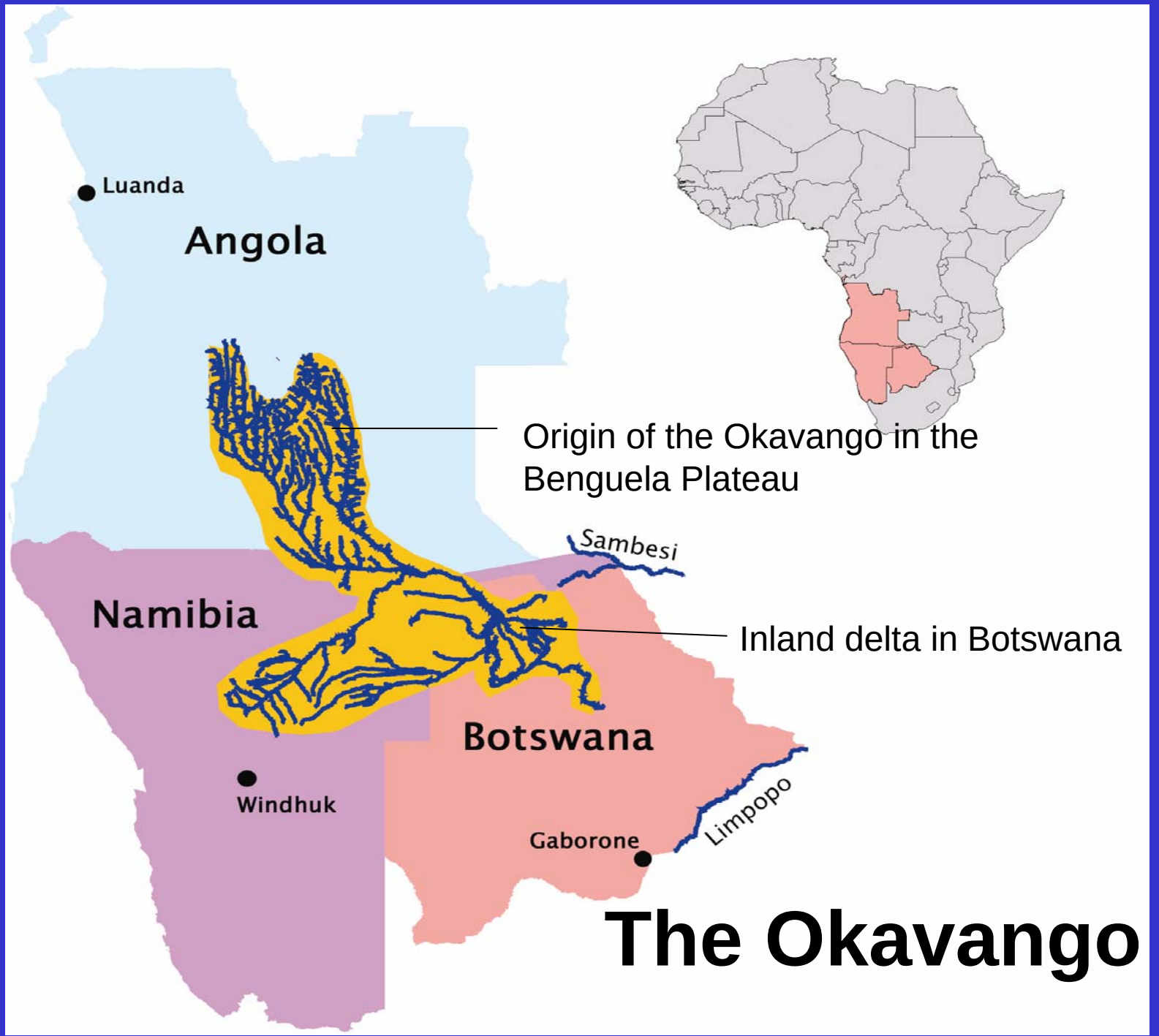
Costs

- Equipment for water saving irrigation
- Electrical energy and equipment for pumping of groundwater

Benefits

- Drip irrigation yields higher productivity for cash crops
- More water for downstream riverine forests
- Less area prone to salinization

Self-propagating practice. Only risk: Too much groundwater abstraction is not sustainable

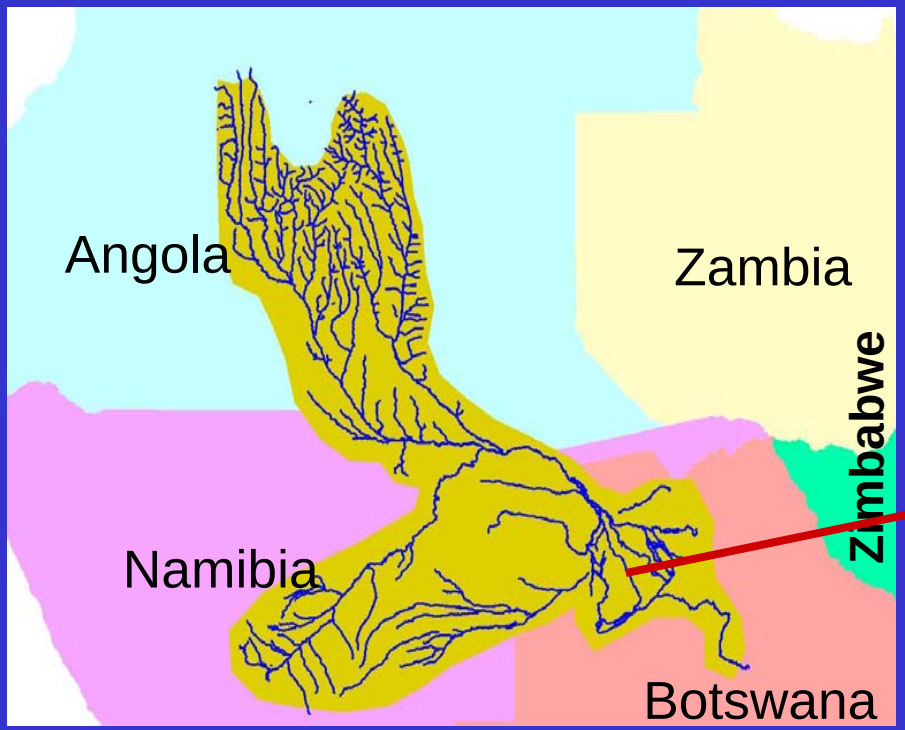


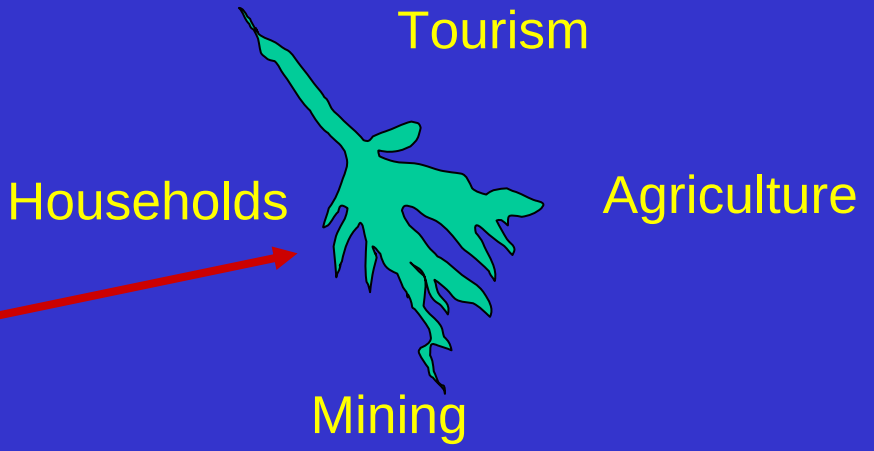
The Okavango River

The Okavango River

The upstream-downstream problem

The local stakeholders In the Delta





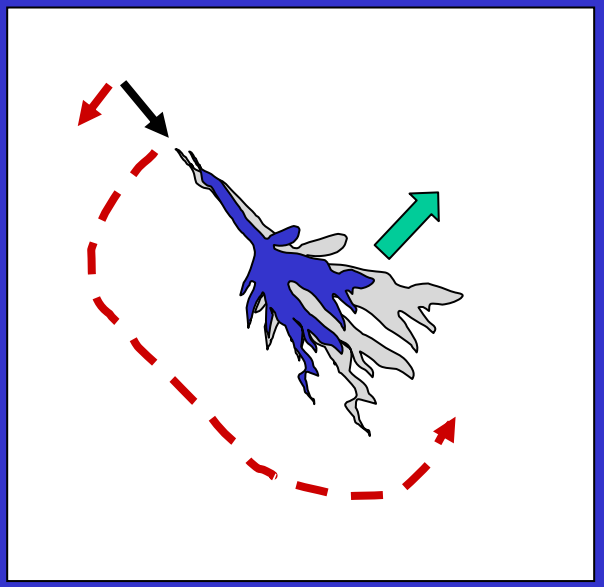
and nature!

The dangers for the Delta

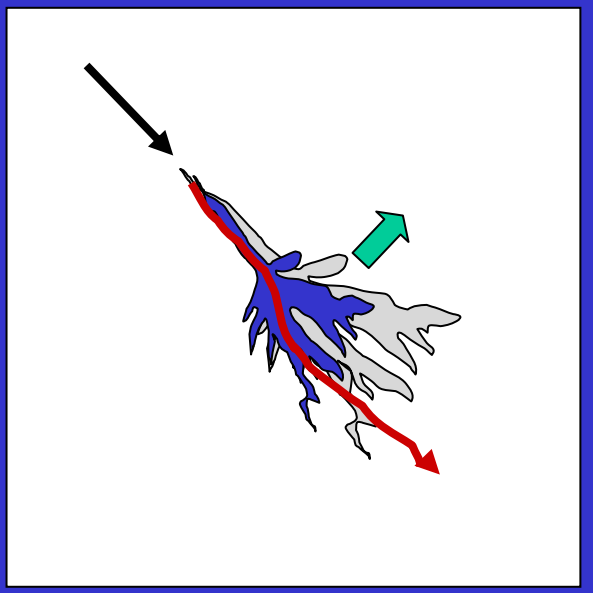
- Water abstraction in the upstream
- Building of dams in the upstream
- Canal through the Delta
- Dredging of sediments
- Cutting of papyrus
- Decreasing water quality in the inflow
- Sediment retention in the inflow

Reactions of the Delta to hydraulic engineering measures

300 km



Reduction of inflow



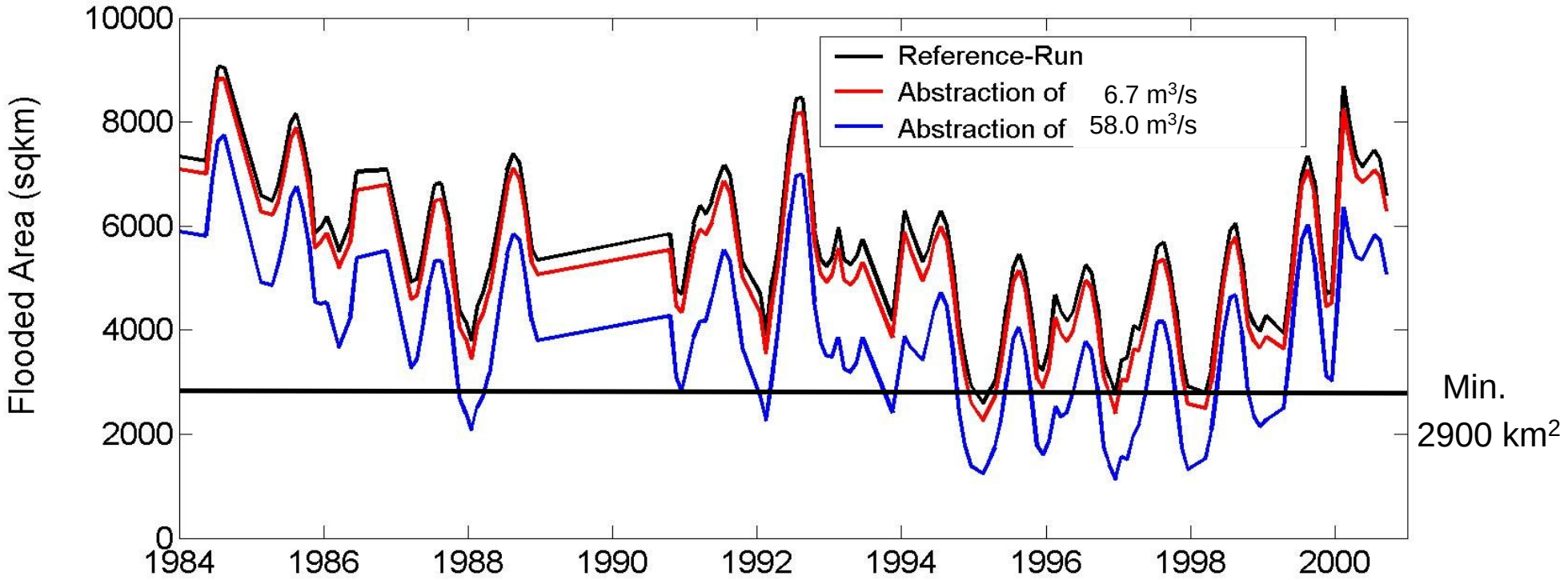
Reduction of retention time

Both lead to a decrease of the seasonally flooded areas

Required: Method to predict the size and shape of the Delta under various management scenarios

Analysis of impact

Observation: Impact smaller than total natural variation
But: Large increase of extreme cases with very small flooded area



Observations

- The impact of abstraction in the upstream shows above all in the increase of critical situations
- As a continued drought in southern Africa is probable, the negative impact of abstractions is enhanced
- Water is sufficient for household demand in the whole basin but not for agriculture
- Development of high-price-low-intensity tourism in a tripartite effort for the whole Okavango basin is wiser than pushing water intensive economic activities
- The permanent political dialogue between all countries should be further promoted. With the OKACOM an adequate platform exists already. The scientific results can flow into this dialogue. Probable result: „Water for money“ agreement between Botswana and Namibia/Angola.