Climate Change Adaptation in India

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Report

Content

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1) Executive summary

Climate variability and change add to the vulnerability, in particular of the poor. With climate change being on its way, even if serious mitigation measures are implemented soon, there will be a need for adapting to the effects, such as higher average temperatures, further aridification of already dry regions and more extreme and frequent floods and droughts.

Experience from around the world shows, that adaptation to current climate variability will also prepare to some degree for future climate change, and can at the same time help to achieve development goals. However, large parts of human population may be facing considerably higher climate risks in the future, for which current coping mechanisms alone are no longer sufficient. The watershed visited in Rajastan clearly has reached the limit of its coping capacity. People are not prepared to cope with any more severe water scarcity or more intense droughts.

When addressing climate change adaptation in India, it will be important to identify hot-spots or critical regions of climate vulnerability. In order to do so, current and future exposure to climate risks as well as adaptive capacity (to cope with changes) need to be mapped out. It is suggested to develop a climate vulnerability index for India, that combines the most relevant bio-physical and socio-economic parameters which determine adaptive capacity. Information is to be drawn from a range of national, state and district sources and also from people in the watersheds. Future exposure is to be derived from climate and climate impact scenarios. This work should take into account and where possible collaborate with past and ongoing activities of similar kind in India and other parts of the world.

After identification of priority areas for intervention, appropriate combinations (portfolios) of adaptation measures are to be agreed upon with people from the respective watersheds. This requires a continued effort of education and awareness raising, given that a long-term pro-active approach is required to build resilience against future climate risks. Selection of appropriate adaptation measures can benefit from current watershed management and development activities as well as from the experience gained and synthesized under the Dialogue on Water and Climate and other national and international climate change adaptation initiatives.

2) Background on water and climate (variability and change)

Climate is changing and always has been changing. In addition to the natural climate variability, anthropogenic changes will become visible over the coming decades. The Intergovernmental Panel on Climate Change (IPCC) reflects the emerging consensus of a wide range of scientists from around the world in its consecutive assessment reports:

1990: "The size of the warming over the last century is broadly consistent with the predictions of climate models...but could largely be due to natural variability."

1996: "...the observed warming trend is unlikely to be entirely natural in origin... The balance of evidence suggests that there is a discernible human influence on global climate."

2001: "...most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations."

The evidence of anthropogenic climate change is no longer deniable. One consequence will be an acceleration of the hydrological cycle with increasing temperatures. But at the same time, a number of **regions will become more water scarce** through decreasing rainfalls and/or increasing temperatures.
The most pronounced decrease in precipitation over the past decades has been observed in the Sahel region – see figure 1.

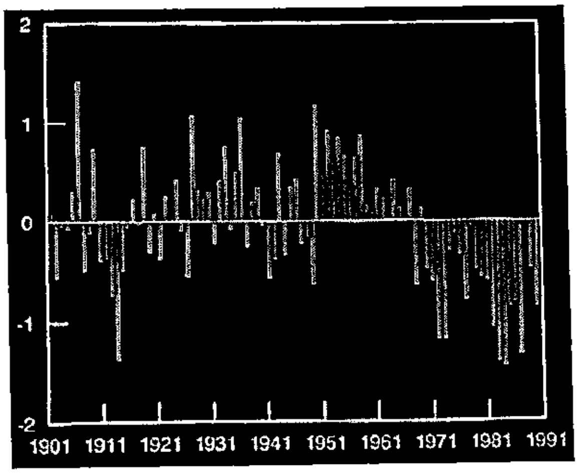


Figure 1: changes in annual precipitation in the Sahel region in the 20th century (DWC 2003)

Non-linear effects in the hydrological cycle can amplify the impacts of climatic changes. Precipitation decreases of 10%, as observed in parts of Tanzania, translate into decreases of 25% in runoff and 40% in groundwater recharge. The example of Lake Chad basin demonstrates that other changes can add to the climate change effects. While the basin experienced a decrease in precipitation of about 25%, inflow into the lake was reduced by 50% and the lake surface shrunk by more than 90% (see figure 2). Coe (2001) estimates that half of the lake's shrinking can be attributed to climate effects, the other half to increasing water withdrawals in the tributaries (of which part is also a response to a more arid climate).

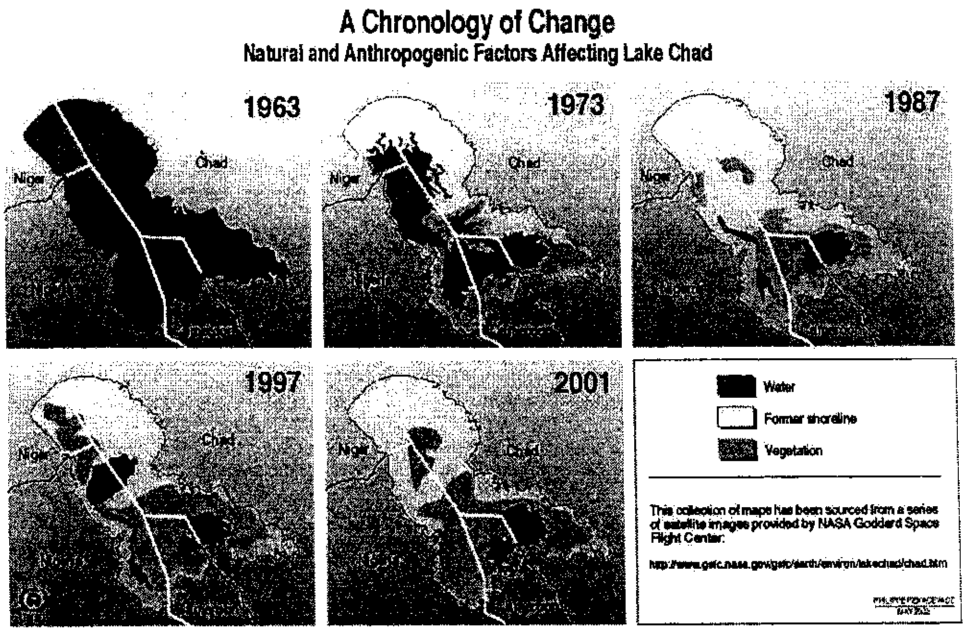


Figure 2: changes in areal extension of Lake Chad, UNEP 2003

Current **climate variability is going to increase**, with more severe and frequent droughts and floods. IPCC (2001) predicts more intense precipitation events to be "very likely" over many areas, and increased summer continental drying and risk being "likely" over most mid-latitude continental interiors in future. IPCC further provides evidence for these effects from current observations already.
The Munich Re database of great natural catastrophes also shows an increase in the number of these events, in particular floods, with strongly increasing economic and insured losses (the losses largely being a function of increasing values exposed to the extreme events) – see figure 3.

Great Natural Catastrophes 1950 – 1999					
	1950 - 59	1960 - 69	1970 - 79	1980 - 89	1990 - 99
Number	13	16	29	44	72
Economic losses	41.2	54.1	79.4	126.1	425.4
Insured losses	-	7.2	11.5	23.0	98.9

Figure 3: Trends in Great Natural Catastrophes, Losses in billion US$ in year 2000 values, Munich Re, NatCat Service, www.munichre.com/publications/302-03901_en.pdf

Climate is not the only driver of water scarcity. Increasing water scarcity, either measured in m^3 of water available per capita or else as withdrawal to availability ratio, results from a combination of changes in availability (mostly through climate changes) and a changes in demand.
A combination of these changes or trends will determine future hot-spots of critical regions – see figure 4.

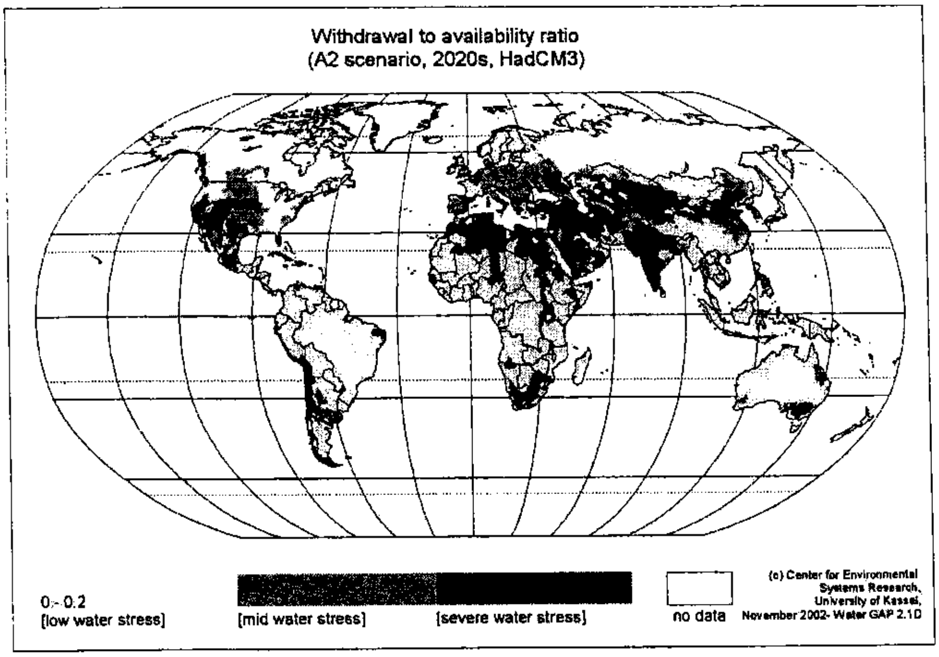


Figure 4: global mapping of water criticality for 2020, using thresholds of 0.2 and 0.4 for the ratio of water demand / availability (DWC 2003)

While it may take decades for some of the climate change effects to become critical in water supply and agriculture, current changes in land and water use, related e.g. to population and economic growth and changes to more water intensive diets (in particular increased per capita meat consumption), etc. have much more immediate effects.
For different temporal (and spatial) scales of climate related effects on water resources see figure 5.

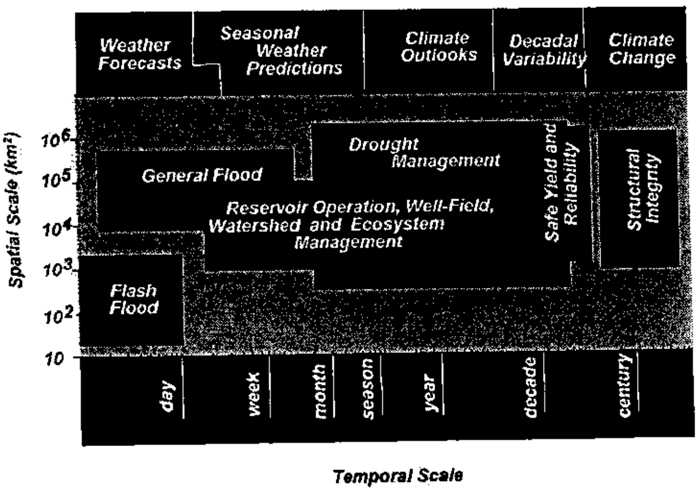


Figure 5: different temporal and spatial scales of weather and climate phenomena and adaptation (Sorooshian 2002)

Water and agriculture will be among the sectors most strongly affected by climate change.

With agriculture being the major user of water world wide (70% of all water is used in agriculture), food production is likely to be hit hard by increasing aridity and/or increasing climate variability in many regions of the world.

With any temperature increase, even without change in precipitation, plants will require more water to maintain biomass production at a constant level – see figure 6.

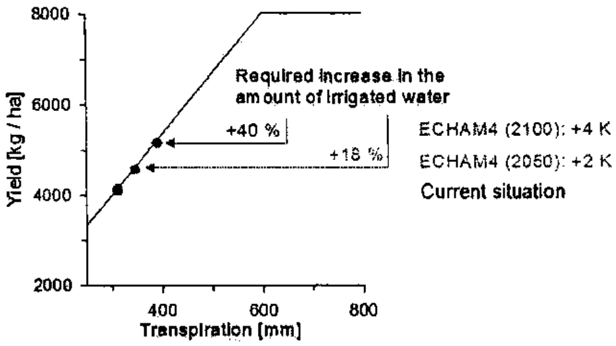
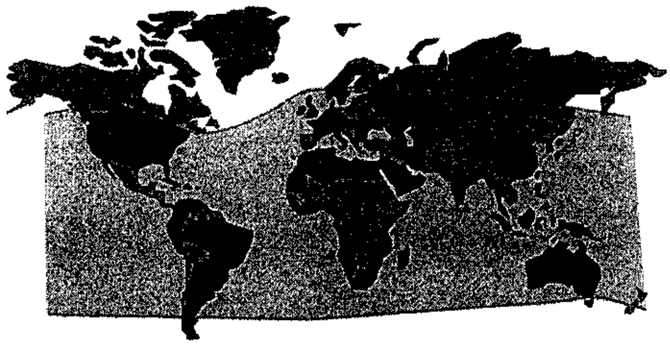
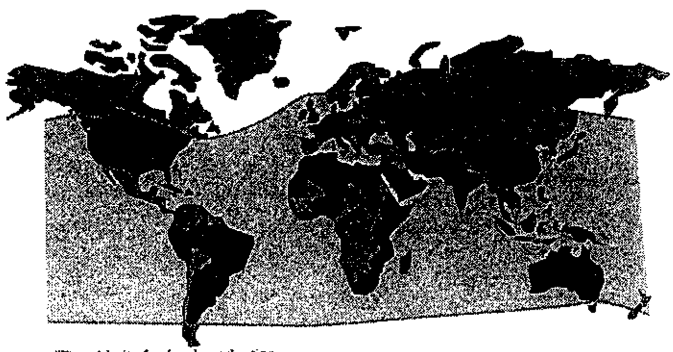


Figure 6 simulation of increasing crop water demand / transpiration with higher temperature – black dot: current temperature, orange dot: 2 degrees warming, purple dot: 4 degrees warming); the increase in crop water demand is much higher than the increase in yield, example from Israel (Menzel 2004)

Situation 2000



Situation 2025



Limits for food production
Lack of water for sufficient food production
Water, soil and climatic conditions allow substantial food production for export
Enough water for food self sufficiency only if all rivers are dammed

Figure 7: water limitations to food production in 2025 compared to 2000. Countries shown in red don't have or will not have enough water to produce all the food required for feeding their population (Zehnder 2002)

Given the close link of water and food production and their vulnerability to climate change, more and more countries, in particular in the developing world, will no longer be able to maintain food self sufficiency. Increasing water scarcity will force them to switch to food imports – see figure 7.

Temperature increases alone, without any water related effects, can also reduce agricultural yields severely or even exceed the tolerance limits of plants, so they cannot be grown any more (possible critical threshold) – see table 1.

Crops	Optimum range	Lower range	Upper range
Wheat	17-23	0	30-35
Rice	25-30	7-12	35-38
Maize	25-30	8-13	32-37
Potato	15-20	5-10	25
Soybean	15-20	0	35

Table 1: Upper and lower temperature limits for the production of certain crops (DWC 2003)

Further, climate change can impact food production, when the length of the growing season changes. In arid to semi-arid climates the number of rainy days or the onset of the rainy season may provide critical thresholds for success or complete failure of any farming efforts.

3) Vulnerability and adaptation to climate risks – examples from around the world

largely based on results from Dialogue on Water and Climate

Vulnerability

Vulnerability of people and ecosystems to climate variability and change results from a combination of external pressures, internal pressures, sensitivity to changes, and coping capacity.
Climate is one additional stress, in particular for the **poor who will be affected most** by the adverse effects. Climate change has the potential to exacerbate inequities, e.g. in health status or access to food and water (IPCC 2001).
The number of people affected by climate extremes, i.e. droughts and floods, including the number of casualties from these extremes, has been and will continue to be much larger in developing than in industrialized countries.

There are a number of reasons for the high vulnerability of the poor and the developing countries:

- Many of the poorer countries are located in semi-arid regions with **high climate variability** that is likely to increase further.

- The **strong role of the agricultural sector** in employment, income generation and GDP leaves the economies of these countries very vulnerable to climate effects – figure 8 shows the close correlation of Zimbabwe's GDP and fluctuations of total annual rainfall. Similarly, floods and droughts have reduced the GDP of Kenya by 22% in the years 1997-2000 (Grey 2004). Figure 9 shows how Ecuador's economic growth suffers during extreme events or natural catastrophes. India's finance minister is quoted with the statement "Every one of my budgets was largely a gamble on rain." (Grey 2004)
ISDR (2002) estimates that El Nino related events may have increased the incidence of poverty in affected areas of Ecuador by more than 10 percentage points.

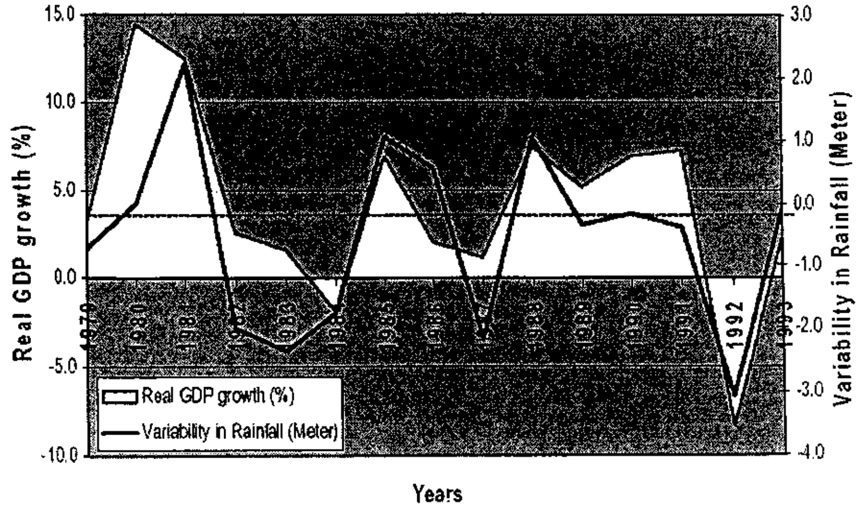


Figure 8: Correlation between annual GDP growth and annual rainfall for Zimbabwe (Grey 2004)

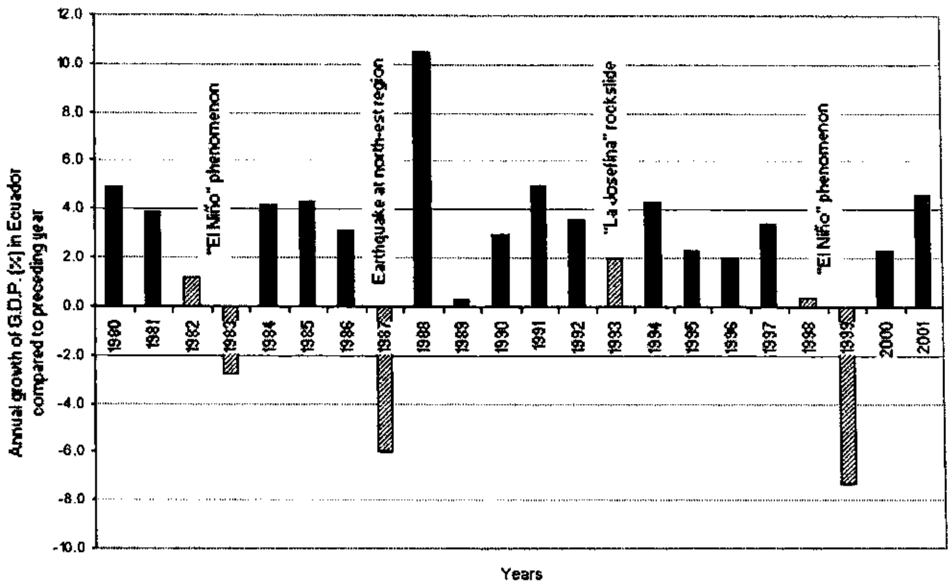


Figure 9: Setback of GDP growth in Ecuador during extreme events and natural disasters (ISDR 2002)

- Developing countries don't have the **financial, technological and institutional capacity** to adapt. An illustration for that is the per-capita storage capacity for water, (mostly reservoirs), which is usually an order of magnitude smaller than in industrialized countries with similar climatic conditions.

- Levels of **investment** in the water and agricultural sector, including foreign direct investment, are usually **very low**. Similarly, private sector engagement in risk spreading, in particular insurance penetration, is almost negligible compared to industrialized countries.

- **Urbanization** and in particular growth rates of urban slums are very high. About half of the world's population now lives in cities and half of the city population in developing countries lives in slums. A lack of infrastructure for water and sanitation in these slums leaves the population very vulnerable to any kind of additional pressures, including climate change, droughts and floods.

For the poorer countries and the poorer populations, climate change means an additional risk to achieving environmental and development goals, such as the Millennium Development Goals.

Adaptation

A wide range of adaptation measures exists. Generally speaking,

- adaptation to current climate variability also prepares for future climate change;
- adaptation to climate variability and change also supports sustainable development;
- with climate change being a long term process, the need for adaptation will increase with time, and at some point, no-regret-measures will no longer be sufficient for dynamic adaptation to increasing climate risks;
- climate change may cause human-environment systems to pass critical thresholds, beyond which unexpected, non-linear or non-reversible responses occur (example changing monsoon system);

- early, pro-active adaptation to coming changes is more cost-effective than re-active, short term emergency measures.

There may be exceptions to these general rules, e.g. afforestation or reforestation, as accepted practice for sustainable watershed development, may not prepare the region well for increasing water scarcity, because many tree species will increase transpiration losses compared to other vegetation: these trees pump water more strongly and from greater depth into the atmosphere than grasses or shrubs do - also during dry periods; additionally, trees do not observe fallow periods without transpiration, like agricultural vegetation does.

Adaptive measures can be grouped according to the following categories:

a) policy measures
b) technological and structural measures
c) change of use, activity or location
d) monitoring and forecasting
e) risk sharing and spreading

Examples for each of these five categories are provided from the Dialogue on Water and Climate (DWC) from around the world – see figure 10 for DWC dialogues.

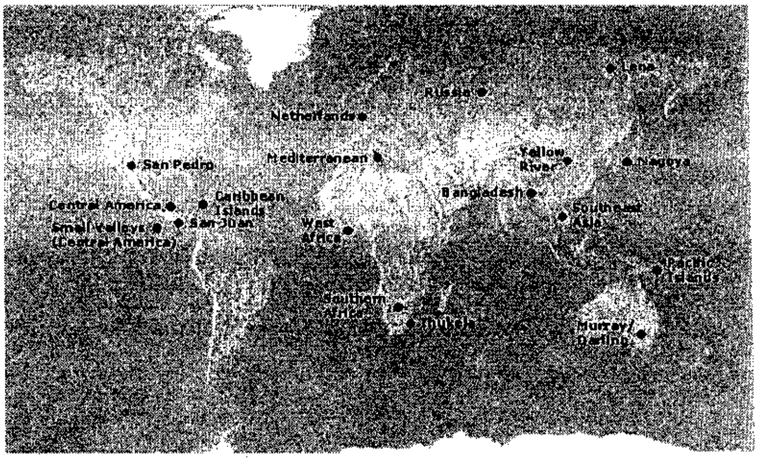


Figure 10: National, regional and basin-level dialogues from the Dialogue on Water and Climate (see www.waterandclimate.org)

A. Policy measures

In South Africa, "Work for Water" programmes provide income to the poor and at the same time help to improve the water balance in the watersheds. By working to clear watersheds of highly water demanding invasive alien vegetation, non-productive transpiration losses to the atmosphere can be reduced and runoff characteristics can be improved.

In the semi-arid northeast of Brazil, Work Front Programmes (Frente de Trabalho) provide employment opportunities to the poor in periods of droughts.

In Bangladesh, microfinance programmes provide loans to the poor, supporting the construction of disaster-proof houses.

Jordan and other Middle East and Mediterranean countries have reduced their agricultural water demand by substituting local production with imports. Some of these imports may be interpreted as active adaptation to increasing water scarcity. Currently, the amount of water required to produce Jordan's total food imports, or the amount of virtual water[1] associated with the food imports, is about three times higher than Jordan's internal water withdrawals – see figure 11.

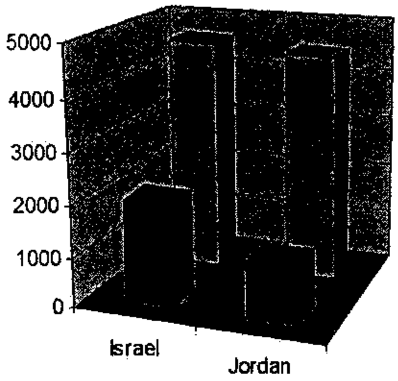


Figure 11: real water use in Israel and Jordan (blue) vs. imports of virtual water (purple) in MCM per year, end of 1990s, numbers from GTZ 1998 and Hoekstra 2002

B. Technological and structural measures

Agriculture as the most water intensive sector, requires measures to increase water productivity, i.e. to produce more food with less water – more crop per drop.
Many examples of changes in agricultural land management and irrigation practices, use of new crop varieties etc. are in place to cope with today's water scarcity and variability. Basically all of these also increase the resilience to climate change. An example from Syria shows how the application of less water in irrigation can substantially increase water productivity – measured in kg biomass production per liter of water applied – see figure 12.

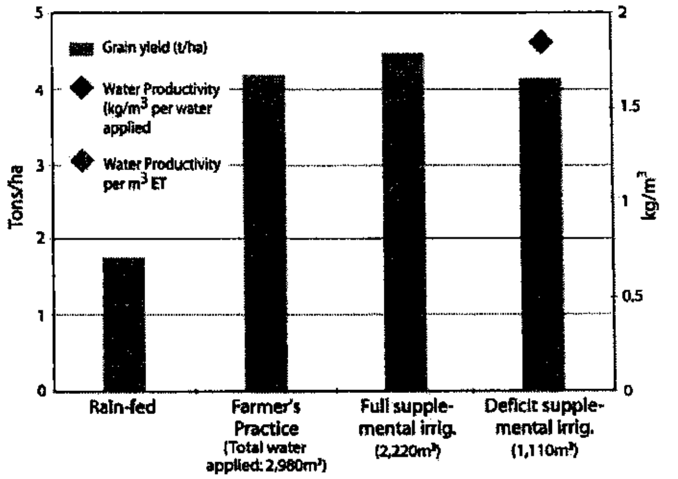


Figure 12: water productivities (in kg yield per liter of water applied in irrigation) for standard farmer's practices vs. full supplemental irrigation (applying water when the plant requires it) vs. deficit irrigation (applying less water than the plant requires), Oweis 2002

[1] **Virtual Water**: the amount of water required to produce a unit of biomass or agricultural yield (e.g. about 1000 liters of water are required to grow 1 kg of wheat, about 10,000 liters for 1 kg of meat). Any virtual water associated with food imports, can save the same amount of real water in the importing country, by not having to produce this amount of food.

The Pacific Islands largely depend on surface water resources. Rainwater harvested from large surfaces, such as airport runways, contributes significant amounts to the total water supply.

Namibia is taking measures to reduce the evaporative losses from open water bodies, i.e. storage reservoirs, by artificially enhancing groundwater recharge, e.g. through injection wells. Water is filtered before injection, in order to avoid groundwater contamination.

Vietnam has an extensive programme of planting mangroves along the coast for protection from typhoons. This measure turns out to be more cost-effective than building and maintaining dikes for coastal protection.

C. Change of use, activity or location

An example for people to change activities and location in response to climatic (and hydrological) changes can be seen along Lake Chad. In response to the shrinking of the lake, over the past four decades – see figure 2, people followed the reclining shoreline and many switched from fishing to farming.

D. Monitoring and forecasting

Short term forecasting systems for floods have been very successfully established in some small watersheds in Central America, where people living in the headwaters report the exceedance of certain rainfall or runoff values, e.g. by phone or radio, to downstream nodes. The combined information from several upstream stations is used to provide early warning and to trigger emergency responses downstream.

In the Pacific Islands, a telemetric warning system has been linked to information from rainfall radar and rainfall-runoff models, to improve the prediction of critical runoff events.

In Bangladesh, a Cyclone Preparedness Programme achieved an impressive reduction of flood-related deaths over the past decades, largely due to early warning and construction of shelters. This program can now alert about 8 million people in the coastal regions, through radio warnings relayed by volunteers, using megaphones and sirens.

In the Pacific Islands, longer term forecasting / seasonal outlooks for droughts (droughts being slow onset events, compared to floods which build up faster), are being based on the Southern Oscillation Index, i.e. on routine measures of meteorological parameters such as temperature and pressure. These improvements in forecasting of droughts are jointly implemented by the meteorological service and weather dependent industries, such as Fiji Sugar Corporation.

In West Africa, improvements of seasonal rainfall predictions, and with that famine early warning system networks, are based upon routine measurements of sea-surface temperatures.

The Dialogue on Water and Climate (DWC) concluded that "the capacity for seasonal forecasting has increased significantly over the past decade, but this is not fully recognized in water management."

However, the DWC also recognizes that "long-term climate scenarios cannot yet meet the operational needs of today's water managers."

E. Risk sharing

Insurance provides a generally underutilized tool to spread climate risks over a larger population group or larger geographical area or a wider range of economic sectors.

In Mexico a natural disaster fund (FONDEN) provides insurance to farmers against crop failures due to droughts, floods and other risks.

In India federations of self-helped groups such as *Vaigai Vattara Kalangiyam* operate disaster insurance funds, which are linked to the insurance schemes operated by state insurance companies.

AOSIS, the Alliance of Small Island States, is developing an international insurance pool to spread hydrometeorological risks.

Insurance can provide incentives for active risk reduction, e.g. through appropriately designed premiums and/or deductibles, and also by encouraging precautionary measures: the Fiji National Building Code provides minimum standards and guidelines for enhancing disaster resistance of buildings. Upgraded homes are inspected and issued a certificate, which is required to obtain cyclone insurance cover and mortgages.

In order to prepare for climate change, each region will require a specific **mix (portfolio) of adaptation measures**, addressing the various scales of intervention and vulnerable groups.

Also **new partnerships** will be required to meet the additional challenges of climate change, e.g. when setting up viable insurance schemes for the poor. The World Bank supports such new partnerships, e.g. in Cambodia, to investigate how private insurance together with government-supported insurance pools, local catastrophe funds and savings and credit schemes, can provide relief from disasters to poor farmers.

Risk spreading institutions themselves, such as the Grameen Bank in Bangladesh, also need to be protected against failure in case of great disasters, e.g. through emergency reserves, risk spreading to other geographic areas or economic sectors, and/or access to international reinsurance.

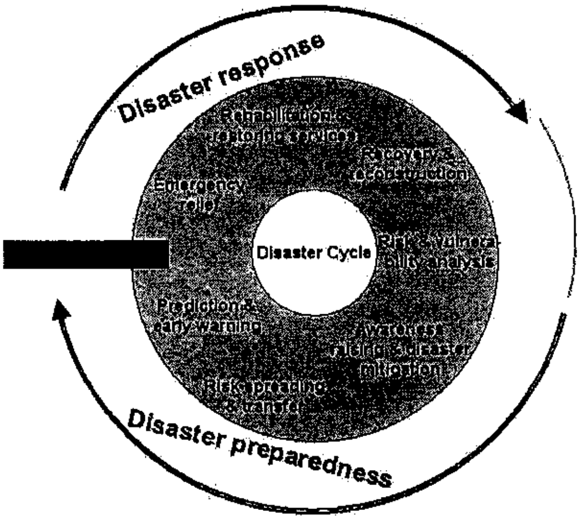


Figure 13: phases of the disaster cycle from emergency measures right after disaster via reconstruction and rehabilitation towards preparedness for the next disaster (DWC 2003)

The disaster cycle – see figure 13 – illustrates the different phases of disaster response and disaster preparedness, most of which are currently addressed by separate institutions, e.g. from disaster management, development cooperation, environmental protection, insurance sector, climate science etc.
Adaptation to climate risks and resilience could be facilitated if these institutions created new partnerships.
Bringing information and tools from science into these new partnerships can be facilitated through institutions that have institutionalised the bridging between science and application, e.g. the CGIAR system (www.cgiar.org), the Co-operative Programme on Water and Climate www.waterandclimate.org (under the Global Water Partnership), the UNESCO HELP programme (Hydrology for Environment, Life and Policy, www.unesco.org/water/ihp/help) etc.

4) Vulnerability and adaptation to climate risks in India, Rajastan, and the Jaunla-Rajwas Representative Watershed

Vulnerability

Vulnerability to climate variability is high in large parts of India, with its dependency on agriculture (2/3 of the employment) and rainfed agriculture (2/3 of all agricultural area), increasing population pressure, proneness to frequent floods and droughts (2/3 of total sown area are drought prone) and current level of water scarcity.
While the green revolution has turned India into a large exporter of food and associated virtual water (India being the 5th largest net exporter of virtual water in the world), there are still about 200 million people, among them 50% of India's children, undernourished (WFP 2002). The rapid agricultural expansion and intensification has resulted in enormous amounts of water being allocated for irrigation, often with low efficiency, at the expense of surface and groundwater resources. Groundwater pumping has boomed, due to mechanisation and subsidised electricity. IAHS (2003) estimates that India pumps about 240 km^3 of groundwater for irrigation annually. Groundwater levels have been dropping in many parts of India accordingly. Surface and groundwater quality have deteriorated (not only due to agriculture).

Migration from the rural areas to cities or other regions during droughts is the most obvious symptom of high climate vulnerability and resulting water and food scarcity.
The cities themselves are also very vulnerable to climate variability for a number of reasons: their sheer size makes water supply difficult, infrastructure development cannot keep up with growth rates, water losses are high, and water and sanitation coverage in informal settlements is very limited. Hence the city population – again in particular the poor - is very vulnerable to situations of water shortage or also floods.
Any further population growth will aggravate the cities' climate vulnerability.

Climate scenarios for India indicate ....– fill in downscaling results from Hadley model[2] and available scenarios of future water scarcity, droughts, floods etc.

Furthermore, additional vulnerability of India's coastal zones to climate change results from the expected sea level rise. Current problems of salt water intrusions into groundwater (mostly due to overpumping) are likely to get worse. More extensive or frequent flooding from the sea could displace large populations.

Rajastan and Jaunla-Rajwas RWS:

Rajastan has 60% desert area, is strongly water stressed and is frequently experiencing droughts. A farmer in the RWS estimated every 4th year to be a drought year, with an increasing trend over the past decade or so.
Population increases at 2.3% per year.
Vulnerability to climate variability, in particular to water scarcity during drought, frequently forces parts of the population to migrate temporarily to cities or to other regions.
In particular the poor and tribal people are highly vulnerable (J. Singh, Aravali).
Child work in Rajastan correlates with droughts, food insecurity and environmental degradation, all of which then negatively affect school attendance (WFP 2002).
It seems that in the driest parts of Rajastan, people are adapted best (least vulnerable) to climate variability (J. Singh, Aravali).

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[2] Hadley Centre collaborates with the Indian Institute of Tropical Meteorology (IITM) on the application of the downscaled HadRM2 for India.

A persistent climate change towards more frequent and more intense droughts might force larger portions of rural population to abandon their land and move permanently to other locations.

The Government of India has launched a number of initiatives that implicitly also address climate vulnerability, such as programmes on:

- desert development,
- droughtprone areas,
- integrated wasteland development,
- forestry development, and the
- National Watershed Development Project in Rainfed Areas

Existing criteria for prioritizing watersheds for these programmes seem to be applied very flexible and to be affected by the states' tendency to overestimate vulnerable areas in order to maximize funding requests to the national government.

The perception of people in the RWS is that the drought in 2002 was the most severe on record, especially since it was the third consecutive drought year after 2000 and 2001. They also expressed that they couldn't cope autonomously (without external food aid) with droughts of that intensity or even more consecutive drought years than that. Storage of staple food within the villages would last one year at maximum.

Comparing the 2002 drought with that of 1987, vulnerability seems to have decreased (J. Singh, Aravali). This effect could be due to the prolonged period of drought from 2000-2002 which forced new adaptation measures such as check-dams, increasing recharge etc, which somewhat mitigated drought effects in 2002.

Adaptation

People in Rajastan and in the RWS are adapted to current climate variability and associated water scarcity in many ways.

Irrigation itself is an adaptation measure to water scarcity. Canal areas of Rajastan for example are able to cope with drought periods better than other areas. However, an integrated approach of mainstreaming climate adaptation into overall sustainable development will have to look also into the sustainability of water extractions at the source of these canals, including scenarios of climate change.

The **storage of food** is a good practice for bridging drought periods. One kg of rice for examples is the equivalent of about 2000 liters of water (the amount used for production) that do not need to be available or stored.

Rainwater harvesting, either for direct use of the water or for recharging groundwater, does not seem to be a common practise in the watershed we visited. In preparation for climate change, the measures recently or currently taken, e.g. building of small dams or deepening and desilting of ponds could be expanded and complemented by measures to increase natural or **artificial recharge**, e.g. installing tubes or infiltration wells that conduct surface water down to the aquifers. This would reduce the evaporative losses from open water bodies (up to 15mm per day). At the same time, underground storage also avoids competition of new reservoirs for land e.g. with agricultural uses (and resulting displacement of population).

Improving irrigation efficiency can help to produce "more crop per drop". For example the warabandi system of allocating water for certain pre-defined times, rather then according to plant water demand, is contraproductive in this respect (Narain 2003). An example for possible improvements in water productivity with changes in irrigation practices is provided in figure 12.

Traditional knowledge on prediction of droughts seems to exist but not to be used much in watershed management. There may be potential to better utilize this knowledge, in combination with modern techniques for seasonal rainfall predictions, to be able to prepare early when a drought season is approaching.

Given the expected changes in climate, in particular projected increases in monsoon variability, it will be important to **prepare for more severe water scarcity and droughts. Current adaptation measures have reached their limit.** This was clearly stated by the village people in the RWS, when they said that they would not be able to cope (autonomously) with any more severe water scarcity or more frequent or intense droughts. When asked for possible additional measures beyond current adaptation for climate variability, they didn't come up with any ideas and didn't seem to have put much thought into possible further degradation of the water and food situation.

Hence, beyond further drought-proofing by current measures and offering concrete adaptation practices and technologies, it would also be important to **raise awareness** for climate change and the concrete impacts in the watersheds. Only if the people saw the need for precautionary measures, changes in current practices would become acceptable, or at least those measures implemented during drought periods could be maintained throughout better years in preparation for more difficult years to come. The Dialogue on Water and Climate concluded that "science can identify hotspots, but local action strongly depends on perceived vulnerability." Witnessing the lively debate we stimulated in one of the villages of the RWS, when suggesting that the future might hold more severe droughts, it seems to be worthwhile to translate scientific findings on climate change and associated risks into the people's language.

Adaptation measures in the agricultural sector alone (such as introduction of more drought resistant crops, integrated crop management, diversification through new medicinal plants or increasing efficiency in irrigation) **will not be sufficient** to meet the challenge of climate change, because all agricultural activities strongly depend on water.
This point is also emphasized by the fact that some of the intended benefits of measures implemented in the IGBP project could not be realized due to the recent intensive drought.

Given also the expressed preference of people to stay in the area rather than looking for **income alternatives** elsewhere, additional employment / livelihood diversification needs to be created within the villages of the RWS.
The example of handicrafts such as the necklace production we saw, may be pointing in the right direction.
Income generating alternatives would either have to be sustainable throughout drought periods, or else they would have to produce surplus that can be stored as a backup for income losses during the drought periods.
The importance of income alternatives for rural population is also emphasized by the fact that cities and in particular poor areas, in which the "refugees" from the rural areas tend to live, are very vulnerable to climate variability and change themselves. Hence rural livelihoods and income of rural population need to be improved in order to enable them to live in the watersheds.

Given that India has a wide range of climates, agro-ecological zones, exposures to climate risks, and expected hydrological responses to climate change (A.K. Gosain at the IGBP workshop on climate adaptation), it should be possible to spread drought (and flood) risks geographically, to cope with the adverse effects of these events. Likely, any type of insurance, e.g. **crop insurance**, that attempts this type of risk spreading, would have to be supported by the government and could benefit from an initial involvement of international donors. Ideally, the private insurance sector would be a partner in this, to provide expertise e.g. with respect to policies, incentives for risk reduction, technical implementation etc.

While the Dialogue on Water and Climate showed that locally planned and managed climate adaptation is most practical, beneficial and cost effective, adaptation has to take place at all levels, up to **macro-level**. The need for income alternatives that was identified for individual watersheds, can also be stated for India as a whole: under a changing climate, India may have to **reduce its dependency on the agricultural sector** which consumes over 80% of all water (that is irrigated agriculture only; the amount of water consumed by rainfed agriculture is several times larger). If India, currently a net exporter of "virtual water"[3], was able to satisfy more of its food demand on the world market, it could re-allocate water to other sectors with higher water productivity – see table 2 – and subsequently reduce overexploitation of water resources and rehabilitate natural ecosystems.
Note, that there are many political and social implications to this suggestion, such as stronger dependency on exporting nations such as US, Canada and Australia and the need to generate enough income to buy on the world markets. But given the competitive advantage India has, e.g. in the IT sector, it seems possible to generate the required income with much lower water consumption.

Table 2, water productivity of the different sectors in Australia (Foran 2002)

Liters of water required to generate 1 Aus $	
Sugarcane	1239
Beef cattle	812
Bauxite mining	366
Accommodation, restaurants	75
Pharmaceuticals, agric chemicals	24
Banking	9

Also the issue of equal access to food for all has to be addressed more rigorously under climate change conditions.

Another adaptation measure to be addressed at macro-scale is that of **electricity subsidies**, which in combination with tube-wells have led to a change from less water-intensive to more water intensive crops and overexploitation of groundwater. This overexploitation, be it under current or future climate, may not be controllable without changes of these subsidies.

Also at macro-scale, **land use planning** will have to take into account climate change and the resulting impacts on agro-ecological zones and potentials. A starting point (also for the new German programme on climate change and agriculture) could be the work by the International Institute for Applied System Analysis (IIASA) e.g. Fischer 2002, which assesses the effects of climate change on agro-ecological zones and the possible shifts of growing belts for certain crops (http://sheba.geo.vu.lh/users/ivmadapt/downloads/climate-agri.pdf).

[3] India's gross exports of **virtual water** associated with food exports in 1996 were about 85 km^3 or 85,000 MCM (Hoekstra 2002). In other words, India's water resources were depleted by this amount, in order to satisfy food demands of other countries. This compares to about 20 km^3 of virtual water associated with the food distributed through India's public food distribution system annually and 0.08 km^3 of virtual water associated with the food distributed by the World Food Programme in India annually (WFP 2002).

5) Recommendations for climate adaptation and prioritisation of watersheds

Many of the IGBP activities have implicitly addressed climate risks and vulnerability of the people and adaptation. By strengthening resilience against climate variability, the activities in the watershed also prepare to some degree for climate change effects. Any new activities to build adaptive capacity for future climate change, should draw from the experience that has been gained in IGBP so far.

In order to specifically address climate change, additional pressures and impacts have to be identified first, that do not occur under current climate variability. New measures for adaptation to climate change will not necessarily be no-regret measures only, different from most conventional measures that are have been implemented so far to adapt to current climate variability. Hence it will be difficult to introduce these new measures so that they are acceptable to the people in the affected watersheds. For that, awareness needs to be raised for the additional risks from climate change that can be expect in the future. The slow process of education and awareness raising may be complemented by a clever coupling of old with new measures. That is to say that "regret-measures", i.e. those measures that have a price, but may yield the full benefit only in the future under a changing climate, may be offered to the people as a package-deal with the more conventional measures.

A tool to raise people's interest in their future, including climate change, are **scenario exercises** which are done jointly with experts and stakeholders. The goal of these exercises, which follow certain rules (Schwartz 1991), is to identify important impacts and possible responses, and cast them in a very limited number (no more than 2-3) credible scenarios. These scenarios, which are basically "storylines" or "images of alternative futures", express consistent trends and future states of key variables. Participants of such scenario exercises gain a much better understanding of their environment and the effects of external changes as well as adaptation options. As part of such exercises, participants identify vulnerable components of their livelihoods and environment.

In order to maximize the contribution of future projects to climate adaptation, it will be important to **prioritise watersheds** for interventions according to their vulnerability to climate change. This needs to be done jointly by experts that provide expertise on climate change and its effects, and the local people who know best in which respect they are most vulnerable to climate risks. The following two suggested approaches can benefit from the experience gained in IGBP:

Approach A) is to develop a **climate vulnerability index** (CVI) for India, which is an overlay - using GIS - of different biophysical and socio-economic parameters. The CVI would quantify -geographically explicit- the exposure to climate stress and the adaptive capacity to change.
This approach is largely top-down, although it has to integrate information available at different scales, including local knowledge from within the watersheds.

Approach B) is a bottom-up, **reverse approach** that inverts the conventional cause-effect chain, which usually starts from climate change and subsequently calculates changes in hydrology, effects on water resources and eventually on water and food security and health etc.
The reverse approach instead starts from people's knowledge of their own vulnerability and **important thresholds** of stability of their livelihoods and environment, and from that defines maximum acceptable climate change effects for the respective watershed, so that these thresholds are not exceeded and drastic or non-reversible changes are avoided. In a next step, climate predictions (from regional climate models) will be used, so that watersheds can be identified, which under future climate are threatened to exceed these thresholds.

Approach A) Climate vulnerability index

The Dialogue on Water and Climate concluded that "the development of indicators for comparing vulnerabilities will be important for prioritizing interventions". Similarly IPCC (2001) called for "greater emphasis on the development of methods for assessing vulnerability...especially at national and sub-national scales".

A (scalable) climate vulnerability index could be developed for India for prioritising watersheds, based e.g. on the work initiated by the Centre for Ecology and Hydrology (CEH) in Wallingford, UK (Sullivan 2003), www.nwl.ac.uk/research/WPI/images/WaterPovertyIndexPaper.pdf and/or by TERI, www.teriin.org in Delhi (TERI 2003). Parameters of the vulnerability index, e.g. on water and food security, adaptive capacity and environmental conditions, would be selected according to their relevance, but also pragmatically according to data availability at national, state and smaller scale. Useful sources in the case of Rajastan could include for example the Watershed Atlas of Rajastan, Basic Statistics of Rajastan, data from the Rajastan State Remote Sensing Application Centre, Jodhpur, and data from national sources such as India's Food Insecurity Atlas etc. It would be important to integrate this top-down approach with a bottom up collection of information from stakeholders in the watershed etc.

Table 3 compares parameters of the CEH Climate Vulnerability Index (CVI) to

a) elements from TERI's profile for India's vulnerability to climate and globalization;
b) indicators of the Food Insecurity Atlas of Rural India (WFP 2002);
c) the IGBP GTZ indicators for evaluating watershed projects (Bollom 1998);
d) criteria for priorities from the Watershed Atlas for Rajastan.

Table 3, possible parameters for a climate vulnerability index for India, taken from different sources

CEH climate vulnerab. index	**TERI climate vulnerability**	**WFP Food Insecurity Atlas**	**IGBP watershed management**	**Wateratlas for Rajastan**
Resource	soil degradation groundwater availability		soil loss groundwater level	vegetation cover soil type & erosion land degradation drainage density
Access				
Capacity	agricult. workers literacy gender discrimin. child mortality / fertility	deficit in food production % population below poverty line % scheduled cast or tribe	height for age ownership of consumerdurables social capital	
Use	irrigation			land use
Environment	infrastructure	% drought prone area		
Geospatial				

The comparison of these different indicator exercises, that were initiated with very different objectives, reveals the importance of a "capacity component" in any climate vulnerability index, in order to take into account the capacity of the local population to cope with changes. Examples given by CEH for parameters that contribute to the adaptive capacity are:

- under-five mortality rate
- availability of disaster warning systems
- educational level

- level of informal housing
- strength of municipal institutions
- investment in the water sector

A methodological challenge will be the combination of the different components into one aggregate index and the assignments of a weight to each component (equal weighting?). Possibly local population can also be consulted for this.

B) "Reverse approach" to climate change adaptation:

This approach starts from the definition of critical thresholds of people's livelihoods and ecosystem integrity, that should not be exceeded, in order to avoid unexpected, non-linear or even non-reversible[4] responses.
Such thresholds – again defined jointly with local people - could be for example the number of consecutive drought years, changes in the spatial and/or temporal monsoon patterns (e.g. delays in the onset of the monsoon, minimum number of rain days etc), groundwater levels dropping permanently below pumpable level, complete failure of rainfed agriculture, loss of rural income options etc.

Once the critical thresholds, e.g. with respect to agriculture, water resources and climate extremes, are defined for a number of watersheds, these will be compared / overlayed with regional climate model results for the region in which the respective watershed is located. The result would be a list of watersheds in which the acceptable agro-ecological or hydrological effects of climatic changes are likely to be exceeded and from that a vulnerability ranking of watersheds with respect to climate change could be derived.

Either of these two approaches may help to identify critical , high-priority watersheds for future climate change adaptation project.
Both of the proposed approaches would require a certain level of supporting research for method development and adaptation. Given that several donors (and Indian institutions) have expressed an interest to engage in climate adaptation activities, it may be worthwhile to approach them for possible collaborations.

An initial list of **potential partners for collaboration on climate change adaptation** from India, but also international partners is provided below. Funding opportunities will vary between these different institutions:

a) TERI, The Energy Research Institute in Delhi (www.teriin.org), has initiated vulnerability mapping for India with a focus on agricultural productivity (TERI 2003). TERI will now focus on climate vulnerability with respect to water resources and water management;

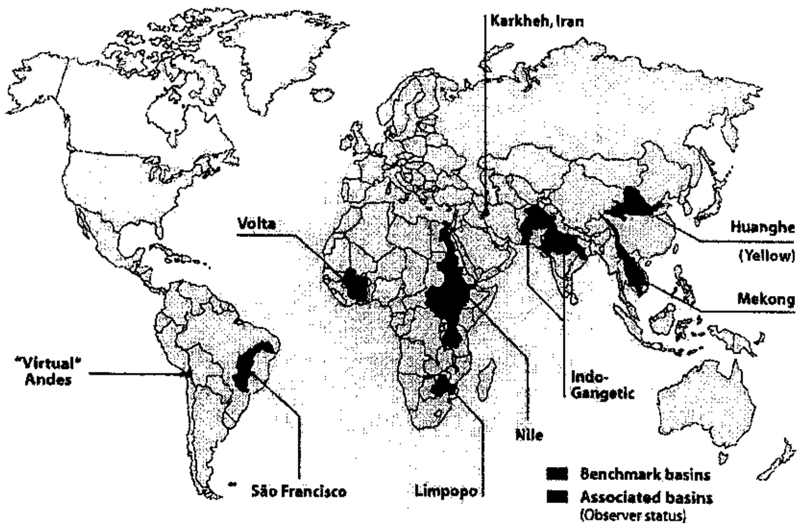
b) the British High Commission in India will soon have a call for supporting research for climate adaptation;

c) the Swiss Agency for Development and Cooperation stated that it seeks co-ordination with other agencies in specific areas like in watershed development with Germany;

[4] An example for irreversible change in livelihood was provided by TERI for some coastal regions of India, where people have adapted by switching from agricultural land use to prawn cultivation. Once land is dedicated to prawn cultivation, it cannot be returned to agriculture any more.

d) the Challenge Programme (CP) on Water and Food (www.waterforfood.org) which is a key activity of the CGIAR system and is led by the International Water Management Institute (IWMI) in Sri Lanka. The CPs objective is to "increase the productivity of water for food and livelihoods, in a manner that is environmentally sustainable and socially acceptable." The Indo-Gangetic region is one of 6 key regions world-wide addressed by the CP – see map of CP benchmark basins, figure 14. The CP should have a new round of calls for proposals in 2005.

Figure 14, global map of benchmark basins of the Challenge Programme on Water and Food



e) The Co-operative Programme on Water and Climate, which is a continuation of the Dialogue on Water and Climate, www.waterandclimate.org

f) The UNESCO HELP programme (www.unesco.org/water/ihp/help) aims at bridging between science, water management and policy making. It currently has only one active basin in India, the Subernarekha (Jharkand). For the next phase of HELP, additional candidate basins are Brahmani-Baitarani (basin size 50,000 km^2) and Gagas (Uttaranchal, basin size 1500 km^2).

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Annex 1) Itinerary

9 May, departure from Germany

10 May: arrival in Delhi (delayed due to aircraft malfunction) and introduction to IGBP, tasks etc by Guy Honore and Norbert Hagen

11 May, Delhi: preparation of presentations for IGBP workshop, jointly with Guy Honore, Norbert Hagen and Shashikant Chopde

12 May, Delhi: keynote at IGBP Workshop on Climate Change Adaptation in India

13 May: travel to Jaipur, visits to Ministry of Water Resources (cancelled), Jaipal Singh – Aravali, Association for Rural Advancement Through Voluntary Action and Local Involvement, and M.S. Rathore – Institute of Development Studies for information about the current situation in Rajastan with respect to climate vulnerability and adaptation, jointly with Shashikant Chopde, Puja Gour, Norbert Hagen

14 May: field visits in Jaunla-Rajwas RWS, discussions with farmers / village people, information about water supply improvements, check dams, rainwater harvesting, groundwater recharge, medicinal plants, income alternatives, vermicomposting, biogas production, smoke free stoves, village councils and other watershed management measures, jointly with jointly with Shashikant Chopde, Puja Gour, Norbert Hagen, Ernst Tideman, Kasturi Basu and GO and NGO representatives

15 May: return to Delhi, preparation of draft report

16 May, Delhi: preparation of draft report

17 May, Delhi: visit to Swiss Agency for Development and Cooperation (SDC) and preparation of draft report

18 May, Delhi: visit to Tata Energy Research Institute (TATA) discussing their activities with Suruchi Bhadwal, Sudip Mitra, Vivek Kumar and Kapil Narula

19 May, Delhi: revision of the report, based upon suggestions by Guy Honore, Norbert Hagen and Shashikant Chopde

20 May, departure to Germany

Annex 2) Coping Compendium from the Dialogue on Water and Climate

Separate pdf file

ADAPTATION OPTIONS	DRAWN FROM DIALOGUE(S)
POLICY INSTRUMENTS	
International	
International Conventions on Climate Change	Caribbean, Pacific Islands, Mediterranean, Southern Africa, West Africa, Central America, Netherlands, Bangladesh
International policy - to mitigate or to adapt?	Netherlands
International Trade (particularly WTO)	Mediterranean, Bangladesh
Polluter-pays principle influences ODA/Funds	Southern Africa
Regional	
Regional Adaptation Plans of Action	Southern Africa, West Africa, Caribbean, Central America, Mediterranean
Regional Strategic Action Plans for IWRM	Southern Africa, West Africa, Pacific
Transboundary plans and interstate cooperation	San Juan, Aral Sea, West Africa,
Informal bi-national cooperation	San Pedro
Regional institutions	Caribbean, Small Valleys Programme
National	
National Poverty Reduction Strategies	Thukela, West Africa, Southern Africa
National strategic interests	Lena
National Water Policies and Laws	Thukela, Lena, Yellow River, Bangladesh, Netherlands
National Adaptation Plans of Action	Bangladesh
Disaster Management Policies	Bangladesh
National Drought Action Plans	Murray Darling
Economic instruments and water markets	Murray Darling, Yellow River, Aral Sea
Risk management cross-cutting in development plans	San Juan, Bangladesh, Pacific, West Africa, Netherlands
Strengthened functions of River Basin Authorities	San Juan, Thukela, West Africa
Integrated catchment management	Murray Darling, Yellow River
Water management strategy under climate change	Lena
Non-water planning, eg urban areas, refuges	Nagoya
TECHNOLOGICAL AND STRUCTURAL INSTRUMENTS	
Storage and Reticulation	
Surface water	
Large Reservoirs	Nagoya
Small Reservoirs	*
Groundwater	
Artificial Recharge	*
Borehole Drilling	*
Sand Dams	*
Scavenger/Gallery Wells	*
Related options	
System Maintenance	
Supply Leakage Control	*
Irrigation equipment maintenance	*
Irrigation Canal Leakage	*
Rainwater Harvesting	Nagoya, Caribbean
Water Re-use/Recycling	Mediterranean, Bangladesh, Yellow River, Nagoya, Aral Sea
Desalination	Caribbean
Flood/Storm Surge Control	
Structures (Levees, Dykes)	Netherlands, Bangladesh, Nagoya
Preventative operations	Lena
Early Warning Systems	
Near Real Time (Hours to Days)	Bangladesh, Small Valleys Programme, Nagoya, West Africa
Short-Term (Days to Weeks)	Bangladesh
Medium-Term (Month to Season)	West Africa, Southern Africa, Pacific
Long-Term (Years to Decades)	Caribbean, Pacific
Communicate Forecasts to End-Users	Mediterranean, Netherlands, Thukela, Bangladesh, Nagoya
Operations/System Improvements	
Reservoir Operations Rules	Nagoya
Integrated, optimised reservoir systems	Nagoya
Retrofitting Existing Structures	*
Irrigation scheduling	Murray-Darling
Water Demand Management	Mediterranean, Bangladesh, Yellow River, Nagoya, Aral Sea
Indigenous Coping Strategies	*
Precipitation Enhancement	*

ADAPTATION OPTIONS	DRAWN FROM DIALOGUE(S)
RISK SHARING AND SPREADING	
Insurance	
Primary Insurers	Caribbean
Re-Insurance	*
Micro-Insurance	*
Finance	
Development Banks	*
Private	*
Micro-Lenders	*
CHANGE OF USE, ACTIVITY OR LOCATION	
Land Use Measures	
Conservation Structures	
Adaptive Spatial Planning	Nagoya
Tillage Practices	
Crop varieties	San Juan
Resettlement	

ADAPTATIVE CAPACITY	DRAWN FROM DIALOGUE(S)
KNOWLEDGE, SKILLS AND PARTICIPATION	
Participatory Approaches in Decision-Making	
Stakeholder Dialogues	All
Awareness raising	San Pedro, Lena, Nagoya
Stakeholder surveys	Bangladesh, San Pedro, San Juan
Networks of action	Small Valleys Programme
Advocacy through stakeholder River Basin Committees	Thukela, San Pedro
Knowledge Consolidation	
Common adaptation frameworks	Mediterranean
Piloting adaptation options	West Africa
Baseline studies	Nagoya
International information sharing	Bangladesh, Pacific, Caribbean
Integrated information systems	Yellow River, Aral Sea
Research and Development	
Improved climate modelling	Yellow River
Integrated science programmes	Murray Darling, Yellow River
Integrated management tools with climate embedded	Murray Darling, Aral Sea
Risk mapping	Netherlands, Mediterranean, Caribbean
Observation of basic data	
More intensive observation systems	Nagoya, Lena
Skills	
Technical and operational capacity	Southern Africa, West Africa
Forecasting	Small Valleys Programme
Drought Resistant Crops	Mediterranean
Specific skill needs	Caribbean, Small Valleys Programme

MITIGATION OPTIONS
REDUCING EMISSIONS OF GREENHOUSE GASES
Energy
Energy mix
New sources of energy, (low-carbon and renewables)
Energy conversion technologies
Energy demand management
Technological
Improved efficiency of end-use devices
Reduction of industrial by-products
Reduced process-gas emissions
ENHANCING CARBON SINKS
Conserving the existing carbon pools
Increased sequestration through new carbon pools
Substitution of sustainably-produced biological products

*denotes options originating from sources other than the 18 Dialogues.

***Table 4.1** Compendium of Coping Options*