Issues Paper

For discussion in developing a DFID research programme on

Water ecosystem services and poverty reduction under climate change

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Prepared by

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Executive Summary

IIED is steering a team, working to the end of June 2007, to scope a possible DFID research programme on freshwater ecosystem services and poverty reduction in the context of climate change and other drivers of change. The work will identify key research areas and delivery mechanisms. It will do this by: seeking views from stakeholders internationally; drawing key lessons from the literature; carrying out policy and practice analyses in key developing countries; and capturing the results in a report to DFID. This Issues Paper seeks to present some initial thinking on key areas that need to be considered, and it highlights some initial questions.

The challenge addressed by this work is a daunting one. Freshwater ecosystem services – the benefits obtained by people from freshwater ecosystems like rivers, swamps, floodplains and groundwater systems - are central to human well-being. But ecosystems are in trouble and the Millennium Ecosystem Assessment showed that freshwater ecosystem services are particularly in trouble. Ecosystem degradation increases water problems and these problems hit the poor hardest. The multiple and often conflicting uses of water pose huge difficulties for any system of management. Global climate change looks certain to exacerbate water problems. The impacts will vary greatly by region – and Africa will be hard hit. Yet despite the gloomy prognosis, many promising solutions to the problems exist. The key to unlock these solutions in many contexts appears to be governance – the range of issues associated with how decisions are made about water ecosystem services.

So how can research help? Below we pose a set of questions whose answers could usefully shape a programme of research and delivery that is well-targeted to achieve optimum impact:

1. ***Water ecosystem services.*** *Which water ecosystem services need to be better understood in the context of poverty reduction and climate change?*
2. ***Poverty-water ecosystem direct links.*** *What are the research priorities in the direct links between poverty and water ecosystem services under climate change?*
3. ***Changes and transitions****. Which other changes affecting water ecosystem-poverty links will need to be better understood as the global climate continues to change?*
4. ***Technology.*** *What are the research priorities amongst the existing or promising technological solutions to water ecosystem service problems under climate change?*
5. ***Institutions and integration.*** *Which policy, legal, organisational and integrative approaches affecting water ecosystem services need to be better understood?*
6. ***Economic instruments****. What are the research priorities in enabling economic instruments to help tackle water ecosystem service problems under climate change?*
7. ***Research organisation.*** *Which are the key organisational characteristics of effective research and delivery on water ecosystem services and poverty reduction under climate change?*
8. ***Research and delivery mechanisms****. What research and delivery mechanisms will work best?*

Readers of this Issues Paper are encouraged to respond to the above questions or any other aspect of the paper. Contact: James.Mayers@iied.org, Ivan.Bond@iied.org or Elaine.Morrison@iied.org
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1. Introduction and objectives

The International Institute for Environment and Development (IIED) is undertaking a research scoping study on "water ecosystem services and poverty reduction under climate change" for the UK's Department for International Development (DFID). There are two **objectives**:

- Identify the **key research areas and knowledge gaps** for improving the sustainability and equity of water provision and water ecosystem services management in the context of climate change in developing countries of Africa and Asia. This will include, *inter alia*, assessment of the extent to which research on integrated water resources management, payments for ecosystems services and the impacts of climate change are being integrated, and the prospects for policy coherence across these areas.

- Identify the **most effective means** by which research can contribute to achieving more sustainable and equitable water services and ecosystems management in these countries.

The remainder of this Issues Paper presents some initial thinking on key areas that need to be considered. It summarises the approach we are taking and highlights some initial questions to which we seek responses. Reactions to any aspect of this paper in addition to the questions are welcome.

2. The challenge

Despite huge problems for people in different places and times, much progress in human well-being has been achieved over the last hundred years. While the world's population has tripled, average food consumption has been maintained and average life expectancy increased. Many other major development hurdles have been overcome. Whether the Earth's ecosystems can sustain this progress is a key question for the next hundred years.

Freshwater ecosystem services are central to human well-being

- Each person needs over 4,000 litres of water each day to produce enough food for a healthy diet. A calorie of food takes a litre of water to produce. A kilo of grain takes 500-4,000 litres, a kilo of industrially produced meat 10,000 litres.
- People in Cambodia obtain about 60-80% of their total animal protein from the inland fishery in Tonle Sap and associated floodplains
- Intact mangroves in Thailand have a total net present economic value (marketed products such as fish and non-marketed services such as protection from storm damage) of at least $1,000 per hectare (and possibly up to $36,000 per hectare) compared with about $200 per hectare when converted to shrimp farms
- Over 60% of the world's food is produced from green water (mostly soil moisture from rainwater, rather than irrigation). In sub-Saharan Africa this figure reaches 95%.
- Fresh water is crucial to climate stability. For example, although covering only an estimated 3-4% of the world's land area, wet peatlands are estimated to hold 540 gigatons of carbon, representing 25-30% of global carbon contained in terrestrial vegetation and soils.

Sources: CAA (2006), Falkenmark and Rockstrom (2005), MAW&W (2005), UNDP (2006)

Freshwater ecosystem services are central to human well-being

Fresh water is fundamental to life and contributes to all the major benefits provided to people, both directly and indirectly, from ecosystems. The Millennium Ecosystem Assessment, delivered in 2005, installs a wide definition of these 'ecosystem services':

- *Provisioning* services like food, fresh water and fibre
- *Regulating* services like climate and flood regulation
- *Supporting* services like soil formation and nutrient cycling
- *Cultural* services like spirituality, aesthetics, education and recreation

Fresh water is a provisioning service as it provides for human use of water for domestic use, irrigation, power generation and transportation. Fresh water and the hydrological cycle also sustain inland water ecosystems, including rivers, lakes and wetlands. These ecosystems provide cultural, regulating and supporting services that contribute directly and indirectly to human well-being through recreation, scenic values and maintenance of fisheries. Fresh water also plays a role in sustaining freshwater-dependent ecosystems such as mangroves, inter-tidal zones, and estuaries, which provide another set of services to local communities and tourists alike (see Table 1). The trade offs and balances between these different uses of fresh water in the midst of increasing demand for all types of human benefit derived from fresh water – are, to say the least, major challenges.

Some of the key types of freshwater ecosystems are:

- Permanent and temporary rivers and streams
- Permanent lakes, reservoirs
- Seasonal lakes, marshes and swamps, including floodplains
- Forested wetlands, marshes and swamps, including floodplains
- Alpine and tundra wetlands
- Springs and oases
- Geothermal wetlands
- Underground caves and groundwater systems

Table 1. Ecosystem services provided by fresh water and the hydrological cycle

Provisioning services	Regulatory services	Cultural services
• Water quantity and quality for consumptive use (for drinking, domestic use, and agriculture and industrial use • Water for non-consumptive use (for generating power and transport/ navigation) • Aquatic organisms for food and medicines	• Maintenance of water quality (natural filtration and water treatment) • Buffering of flood flows, erosion control through water-land interactions and flood control infrastructure • Climate regulation (source and sink for greenhouse gases, and influence temperature and precipitation)	• Recreation (river rafting etc and fishing as a sport) • Tourism (river viewing) • Existence values (personal satisfaction from free-flowing rivers)
Supporting services		
• Nutrient cycling (role in maintenance of floodplain fertility) • Ecosystem resilience • Mitigation of climate change (mangroves and floodplains providing physical buffering)		

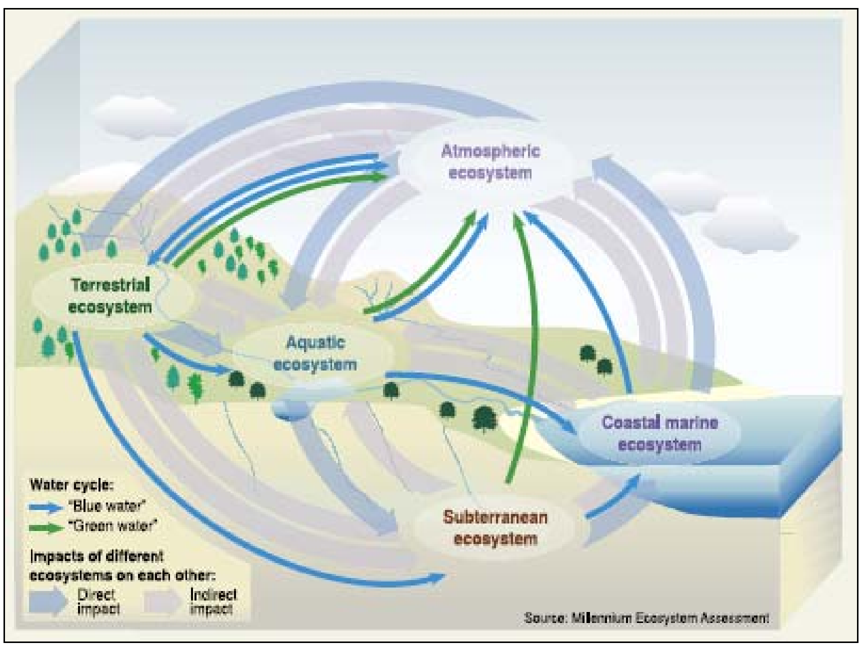
Source: adapted from MAR7 (2005)

In addition to the climate regulating services provided by water bodies - sequestering and releasing a major proportion of fixed carbon in the biosphere – some water ecosystem services support mitigation of climate change. Sea level rise and increases in storm surges associated with climate change will result in the erosion of shores and habitat, increased salinity of estuaries and freshwater aquifers, altered tidal ranges in rivers and bays, changes in sediment and nutrient transport, and increased coastal flooding and, in turn could increase the vulnerability of some coastal populations. Wetlands such as mangroves and floodplains, can play a key role in the physical buffering of climate change impacts.

Rain and snow are the ultimate sources of water supporting ecosystems. Ecosystems, and the extent to which they are managed by people, in turn control the character of renewable freshwater resources for human well-being by regulating how rain and snow are partitioned into evaporative, recharge and runoff processes. Together with energy and nutrients, water is arguably the centrepiece for the delivery of ecosystem services to humankind.

The water cycle is the movement of water between all parts of Earth in its different forms (vapour, liquid and solid) and throughout the broader biophysical environment (atmospheric, marine, terrestrial, aquatic and subterranean). A simplification of the water cycle in two components is considered useful by some: 'blue water' is all the water in rivers, lakes and aquifers and is controlled by physical processes, including evaporation; and 'green water' is water that is influenced by biological processes, for example naturally infiltrated rainwater accessible as soil moisture.

Figure 1. Interrelationships among environmental components of global water cycle



Source: MAW&W 2005: 35

But ecosystems are in trouble

The Millennium Ecosystem Assessment (MA) is an international wake up call. It represents a damning indictment of the failure of policy and practice to look after ecosystems worldwide. The work of some 1,360 experts from 95 countries, the four major findings of the MA are as follows (our synthesis):

- ***We have irreversibly degraded our planet***. Over the past 50 years, humans have changed ecosystems more extensively than in any comparable period of time in human history. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.

- ***Our well-being has improved but at the expense of future generations***. The changes that have been made to ecosystems have contributed to substantial gains in human well-being, but at growing costs - degradation of many ecosystem services and the exacerbation of poverty for some groups of people. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems. Already some 2 billion people living in dry regions are intensely vulnerable to the loss of ecosystems services, including water supply.

- ***Ecosystem degradation is worsening and prevents development***. The degradation of ecosystem services could grow significantly worse during the first half of this century and is a barrier to achieving the Millennium Development Goals (MDGs). This is compounded in particular by the growing threat to ecosystems from climate change and nutrient pollution.

- ***Effective responses are partially known***. The challenge of reversing the degradation of ecosystems while meeting increasing demands for their services can be partially met with significant changes in policies, institutions, and practices that are not currently under way. Many options exist to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.

Freshwater ecosystem services are particularly in trouble

The MA demonstrated that freshwater ecosystem services are in trouble particularly. It found that the degradation of lakes, rivers, marshes and groundwater systems is more rapid than that of other ecosystems. Similarly it found that the status of freshwater species is deteriorating faster than those of other ecosystems. The loss of species and genetic diversity decreases the resilience of ecosystems – their ability to maintain particular ecosystem services as conditions change.

Primary direct drivers of degradation of freshwater ecosystem services include infrastructure development, land conversion, water withdrawal, eutrophication and pollution, overexploitation, and the introduction of invasive alien species. Agricultural systems and practices have exerted a wide range of mostly adverse impacts on inland freshwater ecosystems. Both the extensive use of water for irrigation (some 70% of blue water use globally is for irrigation) and excessive nutrient loading associated with the use of nitrogen and phosphorous in fertilisers have, despite their major contributions to global food production and employment, resulted in a decline in the delivery of services such as fresh water and some fish species.

Problems for freshwater ecosystem services

- Lake Chad shrank over 35 years from about 2.5 million hectares in surface area to only one twentieth of that size at the end of the twentieth century as a consequence of, at first, low rainfall, then a poor understanding of the climate and badly planned irrigation projects - with the subsequent loss of many species and ecosystem services
- The surface area of the Mesopotamian marshes (located between the Tigris and Euphrates Rivers in southern Iraq) decreased from an area of 15,000-20,000 square kilometres in the 1950s to less than 400 square kilometres today due to excessive water withdrawals, dams and industrial development
- The volume of water in the Aral Sea basin has been reduced by 75% since 1960 due mainly to large-scale upstream diversions of the Amu Darya and Syr Darya river flow for irrigation of close to 7 million hectares
- Of the 1,138 waterbird biogeographic populations whose trends are known, 41% are in decline. Of the 964 bird species that are predominantly wetland-dependent, 203 (21% of total) are extinct or globally threatened.
- Approximately 20% of the world's 10,000 described freshwater fish species have been listed as threatened, endangered, or extinct in the last few decades
- 40% of irrigation withdrawals in the driest regions of Africa are estimated to be non-sustainable
- According to the World Water Commission, more than half of the major rivers of the world are seriously polluted (WWC 1999 cited in MAR7).
- With a global population of 8 billion people—a 2 billion increase—and a business-as-usual scenario, an overall increase in water withdrawals of 22% over 1995 levels is expected by 2025 by the International Water Management Institute (Rosegrant 1999 cited in MAR7)

Sources: MAC7 (2005), MAC20 (2005), MAW&W (2005), MAR7 (2005), UNDP 2006

Ecosystem degradation hits the poor hardest

Degradation of ecosystem services hits the poor disproportionately. It is also sometimes the principal factor causing poverty, often contributes to the growing inequities and disparities across groups, and increasingly fuels social conflict. This is because poor people rely heavily on ecosystem services and, with limited other resources, they are more vulnerable to ecosystem change. Modification of ecosystems to enhance one service generally comes at a cost to other services and these costs are often borne by the poorest. Richer people's greater access to many ecosystem services, their over-consumption and waste, and prevailing resource-intensive development patterns are the flip-side of the same coin and require equal efforts to redress. The absence of clean water is a major cause of poverty and malnutrition. Mounting pressure to reallocate water from agriculture to industry threatens to increase rural poverty.

Poor people are hit hardest by degraded freshwater ecosystem services

- 1.6 million children under 5 years of age die each year because of unclean water and poor sanitation
- One in five people in the developing world - 1.1 billion in all - lacks access to an improved water source. The Millennium Development Goal of halving by 2015 the proportion of people without sustainable access to safe drinking water will be missed on current trends by 235 million people. To meet the MDG, 300,000 people need to be served each day, every day from now until 2015.
- Most of these 1.1 billion people use about 5 litres of water a day – one quarter of the 20 litres now considered a minimum threshold and, increasingly, a basic human right, and one tenth of the average daily amount used in rich countries to flush toilets
- Diseases and productivity losses linked to water and sanitation in developing countries amount to 2% of GDP, rising to 5% in Sub-Saharan Africa—more than the region gets in aid.
- In many of the poorest countries the poorest households pay as much as 10 times more for water as wealthy households.
- Africa and Asia account for 80% of people currently unserved by an improved water source, of whom rural people are 5 times less likely to be served than urban dwellers
- Within the household the gender division of labour means that women and girls shoulder a greater burden of disadvantage than do men because they are responsible for collecting water, cooking and caring for young, elderly and sick family members
- Water is a vital productive input for the smallholder farmers who account for more than half of the world's population living on less than $1 a day.
- The number of people living in water-stressed countries will increase from about 700 million today to more than 3 billion by 2025.
- Over 1.4 billion people currently live in river basins where the use of water exceeds minimum recharge levels, leading to the desiccation of rivers and depletion of groundwater.
- In water-stressed parts of India irrigation pumps extract water from aquifers 24 hours a day for wealthy farmers, while neighbouring smallholders depend on the vagaries of rain. In parts of India, groundwater tables are falling by more than 1 metre a year
- Groundwater depletion poses a grave threat to agricultural systems, food security and livelihoods across Asia and the Middle East.
- In Ethiopia the military budget is 10 times the water and sanitation budget – in Pakistan, 47 times
- The US stores about 6,000 cubic metres of water per person compared to 43 cubic meters in Ethiopia

Sources: MAC7 (2005), UNDP (2006), WHO and UNICEF (2006)

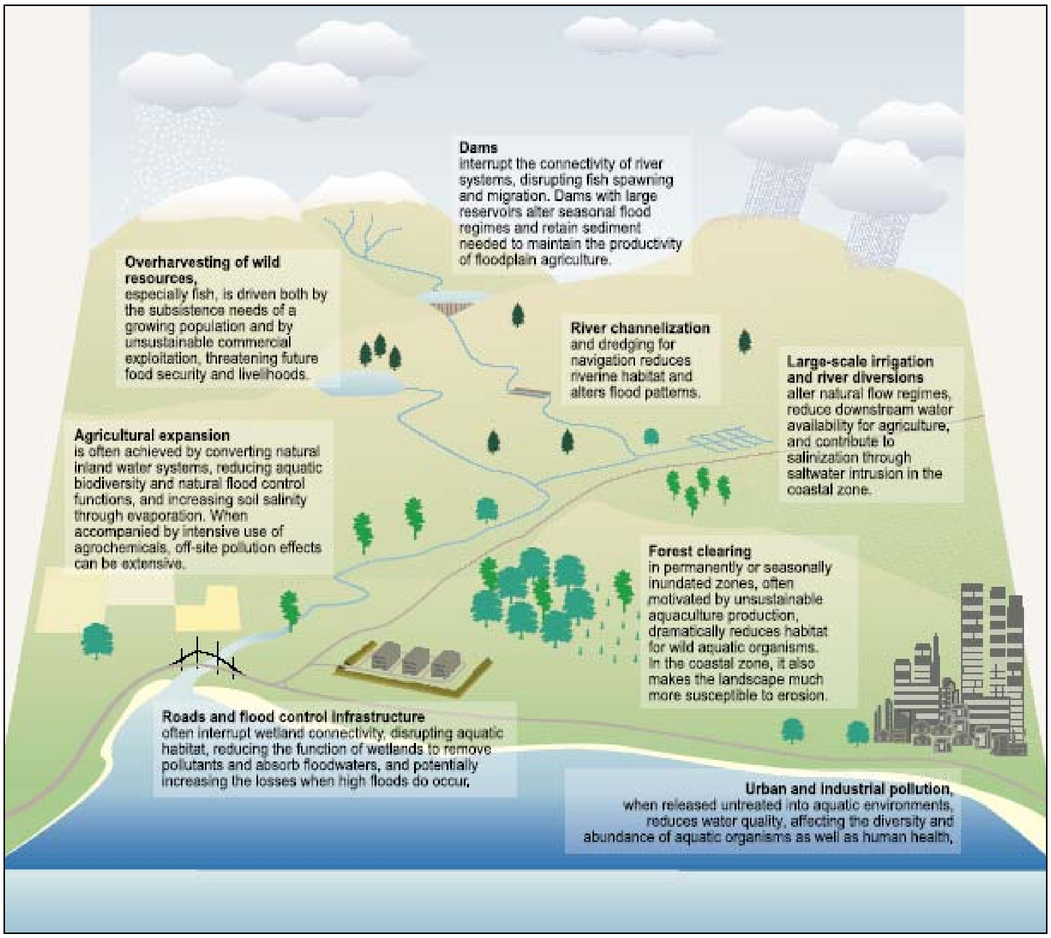
Water problems are increased by ecosystem degradation

Huge gains have been made in meeting human needs through water resources development – the construction of dams and irrigation channels, the construction of river embankments to improve navigation, drainage of wetlands for flood control, and the establishment of inter-basin connections and water transfers. Some of these structural and capital-intensive approaches – particularly large dams - have greatly augmented the natural availability of freshwater provisioning services. Between 1990 and 2000, 1.2 billion people have been supplied with both improved water and improved sanitation, although population growth has diminished the impact of this significant effort (WHO and UNICEF, 2006).

At the same time, these approaches have themselves become direct drivers of ecosystem degradation. The impacts of water resource development are two-fold:

less water remains in the ecosystem and the distribution and availability of the remaining water often has a different pattern from that present under natural conditions. It is estimated that the amount of water withdrawn from inland water systems has increased by at least 15 times over the past two centuries. As a result, humans now control and use more than half of the continental runoff to which they have access. The impact of withdrawals, though, is not evenly spread and it is estimated that about 80% of the global population is living downstream of only 50% of Earth's renewable water supplies (MAC7, 2005).

Figure 2. Pictorial representation of some direct drivers of change in inland and coastal wetlands



Source: MAW&W 2005: 39

Water quality has also been reduced by water resource development through the pollution of in-land water ecosystems. The major pollutants affecting water quality include nutrients, which drive eutrophication; heavy metals; nitrogen and sulphur based compounds, which cause acidification of freshwater ecosystems; organic compounds; suspended particles, both organic and inorganic; contaminants such as bacteria, protists, or amoebae; and salinity.

Changes in the condition of freshwater and associated inland water ecosystems have also occurred at the hands of other direct drivers such as species introductions and land use change (Table 2).

Table 2. Impacts of human activity on freshwater ecosystems

Human Activity	Impact on Ecosystems
Dam construction	Alters timing and quantity of river flows. Water temperature, nutrient and sediment transport, delta replenishment, blocks fish migrations
Dike and levee construction	Destroys hydrologic connection between river and floodplain habitat
Diversions	Depletes stream flow
Draining of wetlands	Eliminates key component of aquatic ecosystem
Deforestation/land use change	Alters runoff patterns, inhibits groundwater recharge, fills water bodies with silt
Release of polluted water effluents	Diminishes water quality
Overharvesting	Depletes species populations
Introduction of exotic species	Eliminates native species, alters production and nutrient cycling
Release of metals and acid forming pollutants into the atmosphere	Alters chemistry of rivers and lakes
Emission of climate altering air pollutants	Potential for changes in runoff patterns from increase in temperature and changes in rainfall

Source: MAR7 (2005)

Multiple uses of water create multiple management challenges

Since most freshwater ecosystems have multiple uses, some of which are private goods and others of which are public goods, and since the hydrological cycle is so dynamic, huge management challenges are created. These suggest the need for institutional arrangements that can define, and adaptively manage, the level of provision and allocation of these goods and services that is desired by society. Governance is thus critical to balancing competing demands for freshwater. The inadequate governance associated with water resource development, particularly a single-minded, engineering-economic approach to the ecosystems services that inland water systems provide, has led to significant social and environmental impacts - impacts that have disproportionately affected the rural poor that rely on the natural functioning of water ecosystems (MAR7, 2005).

Increasing attention has been paid over recent years to considering water as an economic commodity. This has provoked considerable controversy with respect to financing water infrastructure and water pricing, notably privatisation of municipal water supplies, as well as with the application of market approaches, particularly the development of water markets and the use of payment systems for watershed services (see below).

Thus the multifunctional nature of water defies simple classification as either a public good or a private good. While water may sometimes be managed more successfully when its ‘‘economic’’ characteristics are recognized, due to its public good attributes, it cannot be treated as a one-dimensional commodity. Conversely, simply assuming fresh water is a public good in all contexts is equally wrong. Rather, as the MA notes ‘there is a need to respond to the inherent complexity of fresh water and work in an adaptable fashion toward site-specific solutions that accommodate the attributes and uses of fresh water in the local context’ (MAR7, 2005).

In less politically anodyne terms it should be added that water is frequently a contested resource and that water management institutions and policies are effects of political practices (Mehta, 1999; Mollinga, 2001). Thus, such processes as the above-mentioned trend to treat water as an economic commodity and the kind of site-specific negotiation of multiple water use urged by the MA need to be assessed in the their political context – there are winners and losers, powers gained and powers undermined.

Climate change will exacerbate water problems

One of the greatest impacts of climate change will be on water cycles. A changing climate can modify all elements of the water cycle, including precipitation, evaporation, soil moisture, groundwater recharge, and runoff. It can also change both the timing and intensity of precipitation, snowmelt and runoff.

Modelling exercises point to complex and uncertain outcomes that will be shaped by micro-climates. But the weight of evidence suggests that many of the world's most water-stressed areas will get less water, and water flows will become less predictable and more subject to extreme events.

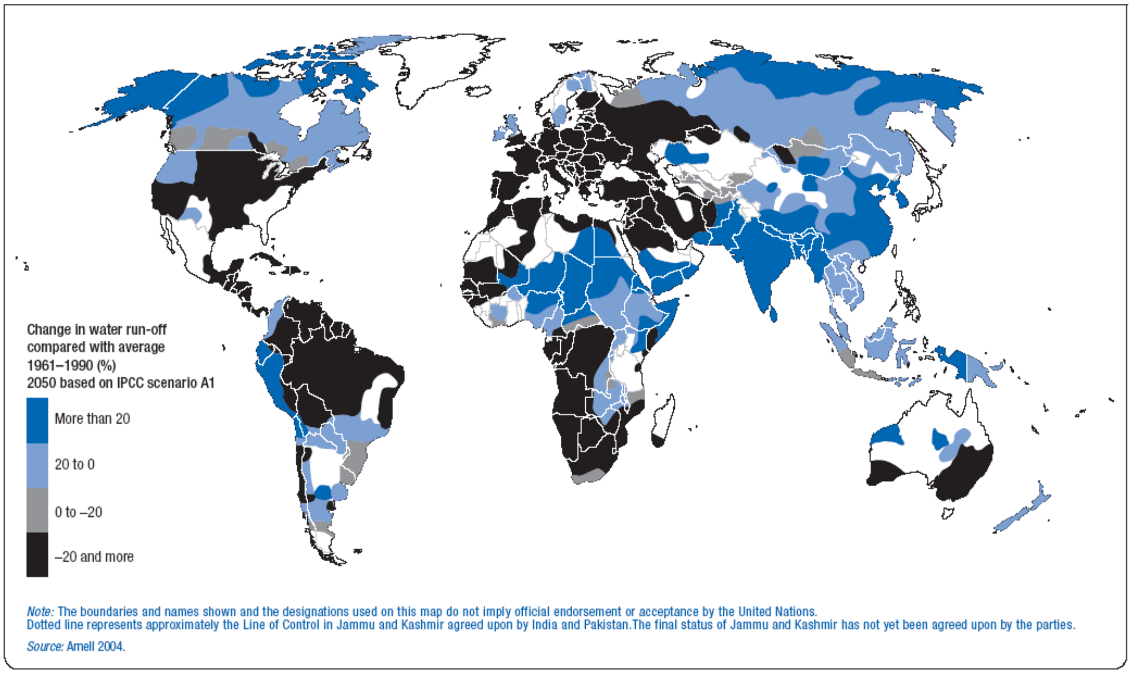
Climate change will intensify water problems for the poor

- The Intergovernmental Panel on Climate Change predict that the global temperature will rise by up to 6.4 degrees C by the end of this century, with their "best guess" scenario putting the range at between 1.8 and 4 degrees C.
- Water insecurity linked to climate change threatens to increase malnutrition by 75–125 million people by 2080, with staple food production in many Sub-Saharan African countries falling by more than 25%.
- Marked reductions in water availability in East Africa, the Sahel and Southern Africa are predicted as rainfall declines and temperature rises, with large productivity losses in basic food staples. Projections for rainfed areas in East Africa point to potential productivity losses of up to 33% in maize and more than 20% for sorghum and 18% for millet.
- Disruption of food production systems has been predicted, exposing an additional 75–125 million people to the threat of hunger.
- Accelerated glacial melt is expected, leading to medium term reductions in water availability across a large group of countries in East Asia, Latin America and South Asia.
- Models suggest disruptions to monsoon patterns in South Asia, with the potential for more rain but also fewer rainy days and more people affected by drought.
- Rising sea levels are likely, resulting in freshwater losses in river delta systems in countries such as Bangladesh, Egypt and Thailand.
- Some 150,000 people a year are now dying as a result of climate change, as diseases spread faster at higher temperatures (this is with the current rise of 0.6 degrees C)
- The 'Stern Review' carried out by the UK government on the economics of climate change calculated that the dangers of unabated climate change would be equivalent to at least 5% of global GDP each year for a narrow range of direct effects, and about 20% of global GDP if a wider range of impacts on the environment and poor people are taken into account.

Sources: DWC (2003), IPCC (2007), Scholze *et al* (2006), UK-Treasury (2006), UNDP (2006), WHO (2003)

The Intergovernmental Panel on Climate Change (IPCC) forecasts that rainfall will become less predictable over time – particularly in parts of Asia, sub-Saharan Africa and Latin America. Greater variations in rainfall, combined with rising sea levels and higher sea temperatures, are likely to lead to more frequent and more extreme weather events – such as storms, floods and droughts. These circumstances put great stress on the institutional, governance and market-related processes for fresh water and watershed management and use.

Figure 3. Climate change will cause decline in water runoff in many regions



Source: Arnell 2004 cited in UNDP 2006: 162[1]

The MA concluded that global climate change is expected to exacerbate the loss and degradation of many freshwater ecosystems and the loss or decline of their species and to increase the incidence of vector-borne diseases such as malaria and dengue and of waterborne diseases such as cholera in many regions. Excessive nutrient loading is expected to become a growing threat to rivers, lakes and marshes (as well as coastal zones and coral reefs). The MA further concludes that growing pressures from multiple direct drivers increase the likelihood of potentially abrupt changes in freshwater ecosystems, which can be large in magnitude and difficult, expensive, or impossible to reverse

Indirect impacts of climate change on the physical, chemical and biological characteristics of wet ecosystems include (DWC, 2003):

- Disruption of flowering phenology and shifts in vegetative season
- Species invasions
- Range extensions of contractions
- Distances between refuges (e.g. water oases)
- Change in productivity of ecosystems
- Shifts in nutrient cycles related to fluctuations in water levels
- Changes or declines in hydrological connectivity leading to loss of fish habitat
- Shifts in intensity and frequency of structuring processes (fire, flood, pests)

The MA proposes that removing the existing pressures on freshwater ecosystem services and improving their resiliency is the most effective method of coping with the adverse effects of climate change and a key element in the mitigation of climate

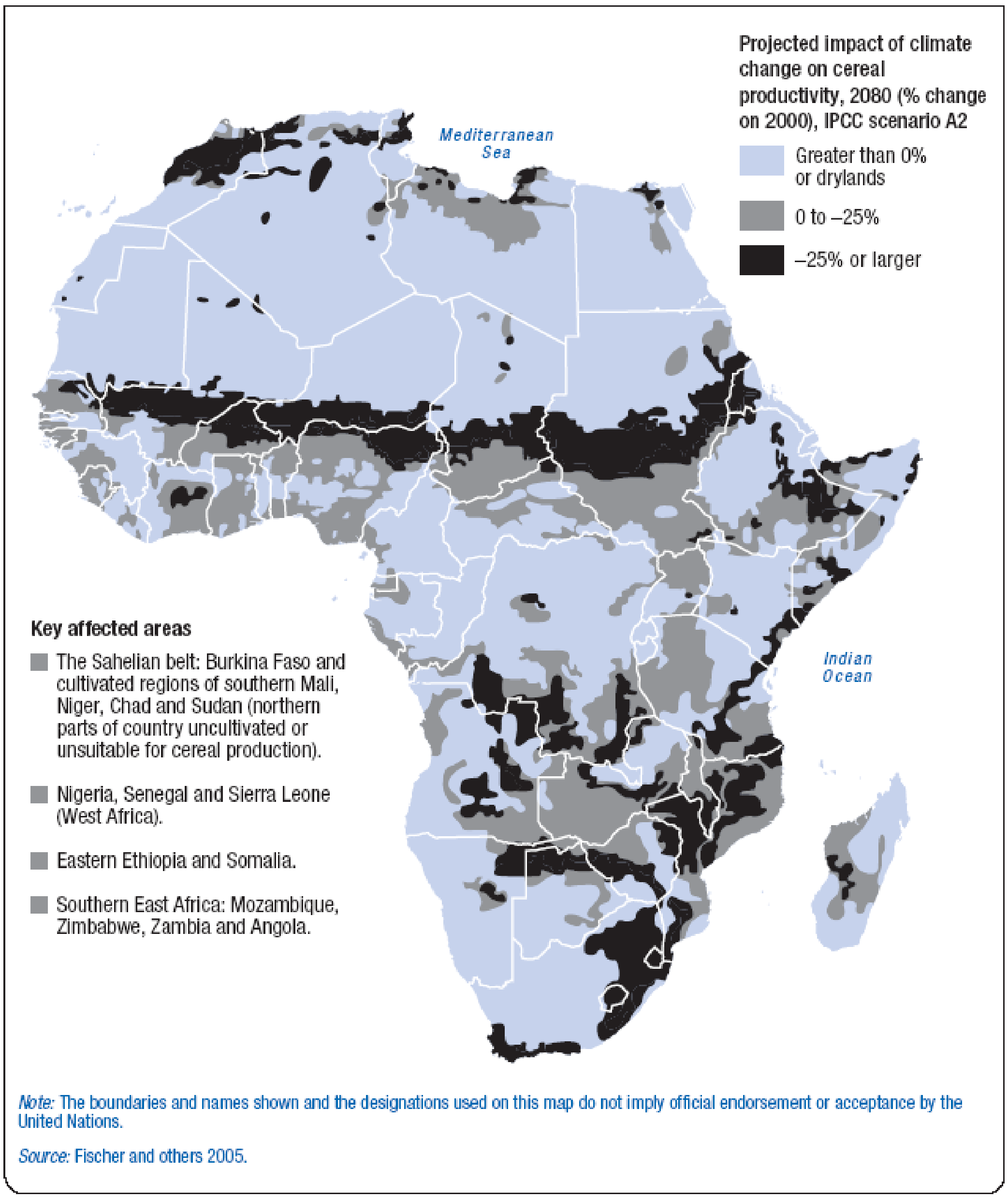
[1] Figures 3, 4 and 5: Copyright material UNDP. Human Development Report 2006. Beyond Scarcity: Power, poverty and the global water crisis. 2006. Reproduced with permission of Palgrave Macmillan.

change mitigation. A key question then is whether practical strategies for supporting and developing such resilience can be found and implemented.

Climate change impacts will vary greatly by region – Africa will be hard hit

Whilst the modelling of the impact of climate change on crop yields and output is an evolving field, not an exact science – recent work provides important indications that should stimulate further analysis and preparedness (e.g. figure below)

Figure 4. Climate change threatens to reduce cereal productivity across much of Sub-Saharan Africa



Source: Fisher *et al.* 2005 cited in UNDP 2006: 164

The Sahel. Under intermediate IPCC global warming scenarios, the Sahel will warm by between 0.2 degrees C and 0.5 degrees C per decade, with 10% less rainfall in interior regions and water losses increased by rising temperatures. In the Sahel persistent rainfall deficits could entrench desertification through a critical loss of water recycling between land and atmosphere, exacerbated by reduced soil infiltration when so-called hydrophobic soils are created in arid environments, and by soil compaction over poorly managed lands. Such rainfall deficits also reduce replenishment of the groundwater resource, exacerbated by the decreased permeability of soils that favour storm runoff and flooding, even in the context of lower overall precipitation (MAC7, 2005).

In the past quarter century the Sahel has experienced the most substantial and sustained decline in rainfall recorded anywhere, punctuated by recent droughts in Burkina Faso, Mali and Niger. In West Africa river discharge has fallen by more than 40% since the 1970s. Looking to the future, the Niger River, which provides water for 10 poor and arid countries, could lose a third of its flow. Simulations based on work in Sudan point to reduced production potential of 20%-76% for sorghum and 18%-82% for millet (MAC7, 2005).

While climate already produces chronic water stress, episodic droughts greatly increase the number of people at risk. Once each generation, the major sub-regions of the western Sahel, Horn of Africa, and SADCC region sees a tripling in the number of people at risk from severe water stress (MAC7, 2005). With climate change large parts of the region will become drier, increasing the number of people at risk of hunger and poverty by the tens of millions. A highly variable and unpredictable climate also makes the region acutely vulnerable to floods.

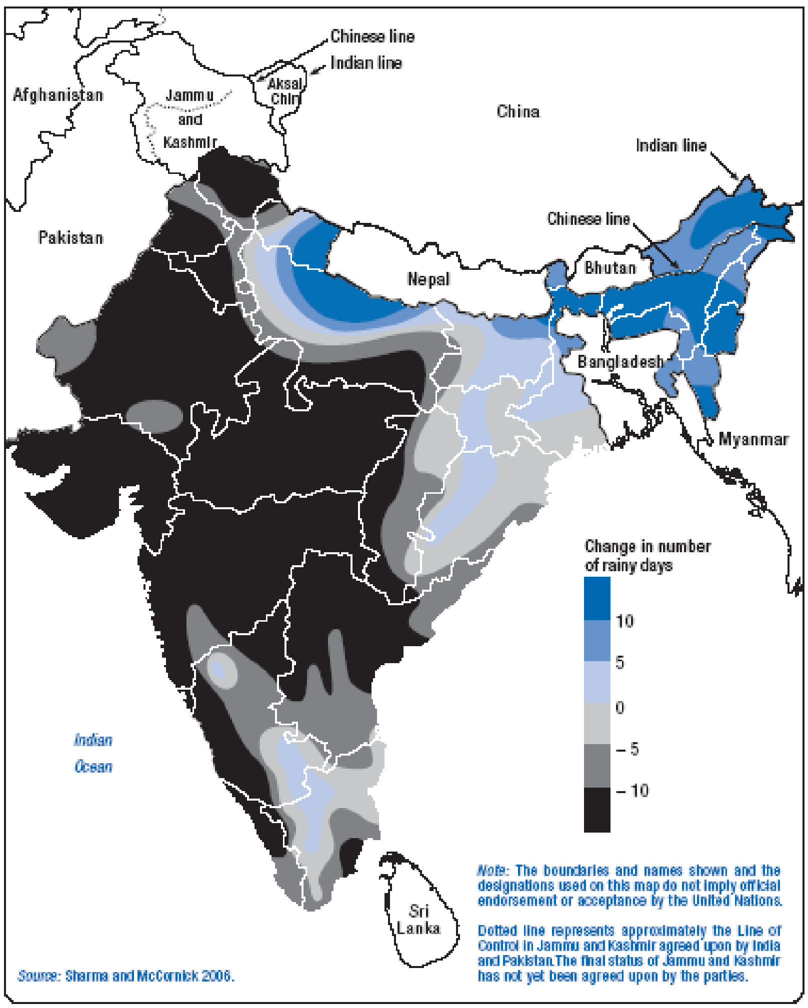
East Africa. Projections to 2030 indicate that the region will get more rain but become drier as temperatures rise. For Tanzania the predicted increase in temperature is between 2.5 degrees C and 4.0 degrees C. Parts of the country are projected to receive more rainfall, while the rest of the country – including the drought prone southern areas – will receive less. Maize productivity is projected to fall on some simulations by 33%. Rainfall in Kenya is projected to increase on average but decline in semi-arid areas. Crop production in both countries will suffer. Yields of basic food crops, coffee and tea could fall by a third because of climatic shifts according to some IPCC scenario projections (UNDP, 2006).

Southern Africa. Average regional temperature is projected to register a 1.5-3.0 degrees C increase for intermediate global warming scenarios, with a 10%-15% decline in average annual rainfall, much of it in the growing season. The Zambezi river faces a projected drop in run-off of about a third by 2050, rising to 40% or more in the Zambezi basin. The chronic food emergencies that have afflicted Malawi, Mozambique, Zambia and Zimbabwe are set to become more frequent. Yields for maize will fall sharply with a 1-2 degrees C rise in temperature and less water (UNDP, 2006).

Across large areas of **Central and South Asia** rural livelihoods depend on glaciers. The glaciers of the Himalayas and Tibet alone feed seven of the world's greatest rivers - Brahmaputra, the Ganges, Indus, Irrawady, Mekong, Salween and Yangtze – that provide water supplies for more than 2 billion people. With global warming glaciers are melting more rapidly, increasing the risk of flooding in spring, followed by water shortages in summer. Over the next 50 years glacial melt could emerge as one of the gravest threats to human progress and food security

India. Projections for India highlight the complexity of climate change patterns (see Figure 5). Most modelling exercises point to an increase in rainfall for the country as a whole. However, an increased proportion of rain will fall during intensive monsoon episodes in parts of the country that are already well endowed with rainfall. Meanwhile, two-thirds of the country - including semi-arid areas in Andhra Pradesh, Gujarat, Madhya Pradesh, Maharashtra and Rajasthan - will have fewer rainy days. This will translate into a net loss for water security, placing a premium on water harvesting and storage. One factor that will shape the profile of winners and losers is adaptive capacity. Irrigation systems will offer some protection, and large-scale commercial farmers are well placed to invest in technologies that raise water productivity. Risk will be skewed towards producers who depend on rainfall and lack the assets to adapt through investment (UNDP, 2006).

Figure 5. Climate change will leave India with fewer rainy days



Source: Sharna and McCornick 2006 cited in UNDP 2006: 167

The Amazon. The way in which the impacts of climate change on some ecosystem services is interrelated with its impacts on other services (and the way climate change begets climate change) is illustrated by modelling of the Amazon forest done by the University College London and the UK Met Office. The Amazon produces the rain which sustains much of South America and parts of the Amazon forest are responsible for as much as 74% of local rainfall. As they start to die as the temperature rises, less water is released into the air by the forest. This has three effects: less rainfall to sustain the remaining trees, more sunlight reaches the forest floor (drying it and making the forest more susceptible to fires), and less heat is lost through evaporation. The rising temperature and decreasing rainfall kill more trees, and the chain reaction continues. The researchers conclude that this threshold exists very near to current climatic conditions (Cowling et al 2004).

Rising sea levels will be among the most powerful determinants of water security for a large share of the world's population in the 21st century. Increased **salinisation** could dramatically reduce freshwater availability for many countries, while coastal flooding threatens millions of livelihoods. There is a substantial group of countries that stand to be affected. Bangladesh, Egypt, Nigeria and Thailand have large populations living in delta areas threatened by saline intrusion.

The low-lying regions of Bangladesh support more than 110 million people in one of the most densely populated regions of the world, and more than half of Bangladesh lies at less than 5 metres above sea level. The World Bank has estimated that by the end of the 21st century sea levels for the country could rise by as much as 1.8 metres, with worst case scenarios predicting land losses of 16%. The area affected supports 13% of the population and produces 12% of GDP. Similarly, in Egypt rising sea levels would weaken the Nile Delta's protective sand belt, with serious consequences for essential groundwater, inland freshwater fisheries and swathes of intensively cultivated agricultural land.

Many promising solutions to the problems exist

Much is known about how water resources can be managed under conditions of change. Indeed the MA itself reviewed a wide catalogue of 'response options', and highlighted many viable ways forward. Key fields in which good work lies include poverty-oriented surface and groundwater management and provision, integrated water resource management and payments and negotiation for watershed services.

Prospects for freshwater ecosystem services

- Investments in water and sanitation have the potential to generate a high return – a World Health Organisation study calculated that every $1 spent in the sector creates on average another $8 in costs averted and productivity gained (WDR, 2006)
- In Vietnam, a programme by the Red Cross to protect country's coastal inhabitants from typhoons concludes, "the planting and protection of 12,000 hectares of mangroves has cost around S1.1 million, but has helped reduce the cost of dyke maintenance by $7.3 million per year
- The price tag in terms of aid for achieving the MDG on water and sanitation has been estimated at $10 billion and the total economic benefits estimated at about $38 billion annually.
- There are 23 UN agencies dealing with water and sanitation. This flowering of institutions is mirrored at other levels – the state of Andhra Pradesh in India has over 30 government departments that have an interest in water management. Such institutional proliferation may of course prove a huge challenge for coordination.
- Trans-boundary conflict over water has been the exception not the rule: over the past 50 years, there have been some 37 cases of reported violence, mostly minor skirmishes, between states over water, whilst there have been more than 200 water treaties negotiated.
- Under programmes of integrated watershed management a survey of 27 US water suppliers found that the cost of water treatment in watersheds forested 60% or more was only half that of systems with 30% forest cover

Sources: DWC (2003), IWMI (2006), MAC7 (2005), UNDP (2006)

Some of the possible responses to problems faced by freshwater ecosystem services and poverty under climate change in different contexts include:

Governance interventions include:
- Determining ecosystem water requirements
- Rights to freshwater services and responsibilities for their provision
- Increasing the effectiveness of public participation in decision-making (for example, watershed/catchment councils and farmer-based irrigation management systems)
- Legal agreements and organisations for river basin management (international or regional scale)
- Integrated water resource management
- Private sector participation
- Institutional capacity building (for example, for regulatory agencies)
- Regulation of: ecosystems, species conservation and preservation; pollution; environmental flows; and artificial flood releases

Economic interventions include:
- Markets and trading systems for flow restoration and water quality improvements (such as water markets, and cap and trade systems)
- Point source pollution standards and fines/fees, taxes
- Partnerships and financing
- Payments for ecosystem rehabilitation
- Payments for watershed services
- Demand management through water pricing, payments and subsidies for on-farm and household water conservation

Technological interventions include:

- Water infrastructure projects (such as dams, dikes, canals, water treatment and sanitation plants, desalinisation)
- Soil and water conservation technologies (such as physical and vegetative measures for soil and water conservation)
- Rainwater harvesting
- End-use and transmission efficiency options (such as drip irrigation and canal lining/piping)
- Wetland restoration
- Demand management/technologies for higher end-use efficiency, (such as low-flow showerheads, energy conservation programmes/ incentives)

Social, cultural, and educational interventions include:

- Environmental education and awareness
- Making explicit the value of non-provisioning water ecosystem services
- Research into the conditions, trends and above responses in freshwater ecosystem services

In theory, cross-sectoral and 'integrated' approaches that consider the trade-offs between different freshwater ecosystem services are more likely to contribute to sustainable development than many existing sectoral approaches. For example, strategies to increase food production and reduce poverty quite commonly propose the conversion of marshes to agriculture and significant increases in the use of fertilisers to increase crop production. This approach will reduce habitat area, increase the input of water pollutants and remove the natural water filtering service provided by wetlands. This will make development goals for water and sanitation more difficult to achieve, whilst a development strategy that aims to safeguard the full range of benefits provided by these ecosystems might better achieve development goals while minimizing future harm to wetlands (MAR7, 2005).

Integrated water resources management is the current paradigm for sustainable water use and conservation. It was adopted by the World Summit on Sustainable development in Johannesburg in 2002 as part of the wider international strategy for the MDGs. The starting point for integrated water resources management is that all water should be treated as a single environmental resource and allocated within a coherent public policy framework among the main groups of water users: agriculture, industry and households. By factoring in sustainability, the model also recognises that there are ecological limits to water use and that the environment has to be treated as a user in its own right (UNDP, 2006).

Experience with integrated water resources management has been mixed. In many cases it has a narrow technical focus. Most of the understanding of watershed dynamics and management principles comes from hydrological research on small watersheds and from studies at the local scale (MAC7, 2005). And more integration *per se* does not guarantee better outcomes. Adopting an incremental approach – focusing on a few issues initially then gradually addressing additional ones as capacity increases – is often more feasible and effective. In addition these approaches can only succeed if the authority and resources of the management mechanisms are consistent with their responsibilities. Integrated water resources management requires institutions that take several years to develop, even with strong political commitment, and attention to the equity and social justice issues that are central to long term sustainability and poverty reduction (UNDP, 2006). These are issues of governance.

Governance is the key to making most promising solutions work

A target of halving the number of people who cannot access safe drinking water by 2015 is the only explicit water-related MDG. However, the full range of freshwater ecosystem services will come into play, directly or indirectly, in most actions aimed at achieving the many other ambitious MDG targets on poverty reduction, human nutrition, education, health and environment. Governance frameworks need to recognise this.

An increasing body of research shows that there is not enough 'blue water' left to meet competing food water and environmental needs. It also shows that a high proportion of food in developing countries, some 95% in Africa, is produced from 'green' rather than 'blue' water. Reducing the loss of green water through non-productive evaporation and making it accessible to plants as productive transpiration (so called vapour shift) has the potential to supply large amounts of water for forestry products, grain farming and market food needs. This implies a substantial shift in governance focus to recognise green water issues and land use issues in water resources management (Falkenmark and Rockstrom, 2005).

Similarly, the 'comprehensive assessment of water management in agriculture', which involved 700 experts over 5 years led by the International Water Management Institute reported in 2006 and called for radical governance changes to squeeze 'more crop per drop' from water in land use (IWMI, 2006). The assessment concluded that low-cost technologies, such as treadle pumps and micro-drip kits, combined with micro-credit and access to markets, could increase poor farmer's access to water, efficiency of its use and income. Urban wastewater could be a productive resource if health risks linked to its use are addressed. The report calls for reform of the governance of water and - while governments need to leave farm water management to farmers and local communities – governments have a critical role. For example, the assessment, concludes that governments need to (IWMI, 2006):

- Enable water to be re-allocated from lower- to higher-value uses including transfers from agriculture to cities and industry (clearly a particularly controversial recommendation)
- Provide incentives for water conservation including rewards for saving water
- Set and enforce water quality standards
- Establish and implement systems of water use rights and entitlements

Ultimately, any development of water resources will involve a trade-off between provisioning, and the cultural, regulating and supporting services. Current trends to continue favouring provisioning services should reduce poverty. But due to the linkage between ecosystems and their cultural, regulatory, and supporting services, it is expected that poverty can only be reduced so far before feedback loops from ecosystem degradation will cascade back through these services, thereby reducing well-being, particularly for the poorest members of society.

Full protection of ecosystems is a theoretical alternative – through full implementation of many conventions, laws, and rules that could radically reverse ecosystem degradation and biodiversity loss. However, such full protection would greatly limit opportunities for meeting the growing needs for freshwater provisioning services with the probable consequence that poverty would increase. Balancing freshwater ecosystem services, optimising them across their full range, is clearly the approach to strive for. Whilst optimisation is unlikely in the real world, keeping the idea of balance in mind is surely vital in work to achieve improvement and increase in the overall productivity of freshwater ecosystem services (MAR7, 2005).

Many of the responses designed with a primary focus on freshwater ecosystem services and water resources will not be sustainable or sufficient unless other indirect and direct drivers of change are addressed. These include, for example, actions to sustainably intensify agriculture, slow nutrient loading, internalise environmental externalities, encourage stakeholder participation, and increase transparency and accountability of government and private sector decision-making.

Initiatives to establish payments for watershed services have received particular attention recently. The assumption behind such initiatives is that a payment or compensation by downstream beneficiaries of changes in quantity or quality of water will provide an incentive for upstream land users to adopt conservation and sustainable land management practices that guarantee these changes. Although existing more in theory than in practice to date, analysis of experience suggests that such initiatives can play a useful role – where bio-physical, social and governance conditions are right.

The evaluation of costs and benefits in the use of water ecosystem services depends on a thorough understanding of the causal relationship between land uses and hydrological variables. Evidence is often not clear and, as a result, unwarranted conversions of land use have been in part justified by erroneous assumptions about hydrological benefits, e.g. forests converted to cropland; mixed farmland converted to tree plantation.

Ecosystem services are also persistently under-valued and environmental flows are frequently omitted from the decision making process. A common perception is that valuation of ecosystem services and quantification of environmental flows are too complex and too uncertain to be included in decision-making. In some contexts, this is changing. Techniques are improving – the critical factor now is recognition of their results in governance such that the market and non-market values of services sustained by ecosystems are internalised in water resources management.

Alongside the practical challenge of appropriate valuation is that of more effective priority setting and monitoring. The need for indicators at the national or regional scale to help governance decision-makers and donors establish priorities in water resource management is widely acknowledged. Such metrics can also assist in monitoring progress toward sustainable development goals in a systematic manner. An important indicator that combines physical, environmental, economic, and social information related to water availability and use is the Water Poverty Index (MAC7, 2005). The Index has five components: water resources; access to water; water use; capacity to manage water; environmental integrity. Development of this Index to incorporate measures of the integrity and change in freshwater ecosystem services, and to make it more effectively and widely used, may be a key priority.

How can research help?

Do we need more research on freshwater ecosystem services and poverty, or do we just need to put more existing research into practice? The answer is almost certainly that we need both – and we need them together. And it is likely that some of the most important understanding needed is on exactly *how* more research can be converted into practice.

Research on integrated water resources management, payments for ecosystem services and the impacts of climate volatility and change on water cycles are each large and in the latter two cases relatively new areas. Concerted implementation and integration in these fields, aimed at improving the welfare of the poor especially in semi-arid areas, is sorely needed. Yet it looks elusive in practice until a range of governance constraints are recognised and tackled. Research on how this can best be done is thus also needed.

Multi-functional freshwater ecosystem services - and their problems, prospects and trade-offs - exemplify the need for a type of research which can meet the challenges of sustainability. This means research that can bridge the divide between disciplines and analyse the dynamics of ecosystems, economics and social interactions. The type of cutting edge research that is needed will be set in local contexts and applied in ways that recognize the special circumstances of the poor - particularly as regards risk, dependency, and long-term productive potential and environmental externalities. Sayer and Campbell (2004) identify seven conditions needed for this type of research:

- Acknowledge and analyze the complexity of natural resource systems
- Use action research—become actors in the system
- Consider effects at higher and lower scales
- Use models to build shared understandings and as negotiating tools
- Be realistic about the potential for dissemination and uptake
- Use performance indicators for learning and adaptation
- Break down the barriers between science and resource users

DFID is well-placed to support those tackling the problems of governance that constrain the potential for wise use of ecosystem services. In its 2006 White Paper DFID brings a major new focus on this potential. More specifically, the White Paper commits DFID to help partner countries develop sustainable and equitable ways of managing their fresh water resources. DFID recognises a key role for research in this effort and now seeks to set the scope of an appropriate research programme to be run by its Central Research Department. This programme will only work if it is shaped by the demands and views of those it seeks to help, if it finds a niche that complements the work of others, if it builds effectively on the strengths of DFID supported past and current research and existing experience, and if it is focused both on spreading understanding of the problems and getting solutions actually into use.

A range of tried-and-tested approaches and more experimental and innovative mechanisms for research and delivery may need to be considered. More developing country input in defining areas of need is likely to be central, as is more involvement of local institutions, federations of the poor and new social movements in the governance of the whole research cycle. In some of this work, methodologies that recognise and build on the value of plural stocks of knowledge (e.g. western science and indigenous knowledge) may prove important.

How DFID might best support developing country-run research consortia, and how to run competitive grant facilities in closely-defined areas of need, are key questions needing attention. Longer timeframes than has been the norm are likely to be needed – to allow for more in-depth analysis, adaptation to changing circumstances and greater use of action-research approaches. Significant flexibility and responsiveness may need to be built into management, so that small and micro-grants, key meetings, publications and other communication products can be covered. Funding that remains available 'between' projects to maintain networks and avoid the feast/famine effect for priority research needs might be an important innovation.

A greater focus on research methods that engage with enabling environments may need to be considered, with capacity and uptake elevated from assumption level to objective level – e.g. work on governance, policies, institutions, property rights and market access. Better assessment methods may be needed especially for policy and poverty impact work. Efforts to ensure that robust evaluations of research and delivery programmes become routine would also be useful.

Finally, a key set of mechanisms, in which experience is fast developing with promising results, is learning groups, communities of practice and networks that explicitly set out to develop and effect practical systems and capacity for re-orienting institutions and professional practice. Deriving the conditions under which such mechanisms are most effective might prove very useful in designing research organisation for water ecosystem services and poverty reduction.

3. The Approach

The approach of this scoping study has the following main elements:

- **Core team** and **Specialist team** (specific shorter-term inputs) with experience in key subject areas: natural resource governance; analysis and support for improved livelihoods and reducing poverty; policy analysis; research-into-use approaches; surface and groundwater management and provision; water governance; integrated water resource management; payments and negotiation for watershed services; and climate change mitigation and adaptation.
- **Learning from past DFID-supported work**. Our approach aims to draw on key lessons from relevant past DFID-supported research initiatives, notably: the Renewable Natural Resources Research Strategy (RNRRS) and Engineering KAR programme water theme, and their respective evaluations programmes; the OASIS resource centre's scoping study for possible DFID funding of research into water for development; the WELL resource centre for water, sanitation and environmental health; other research scoping processes such as on the Sustainable Agriculture Research Strategy, Climate Change Adaptation in Africa programme and current work on energy; other Development Research Centre programmes.
- **Concerted exploration of the gaps and links**. We think it likely that the current level of integration of key research areas such as integrated water resource management, payments for watershed services and climate change will be weak. We will make particular efforts to unearth work that sheds light on these links, why there are gaps, and what opportunities/constraints exist for integration and improved policy.
- We will aim to present **research priorities and mechanisms based on clear criteria** for their suitability. Key criteria are likely to include: quality of research, governance of research, and impact on poverty and environment.

There are four main tasks that we expect to undertake:

(a) Evidence from stakeholders: seeking views internationally

We will collect and analyse relevant evidence from key stakeholders in water provision and water ecosystem services management and their impacts on poverty reduction in the context of climate change. The scope will be international – consulting with key individuals and institutions in developing countries and in agencies in developed countries connected to these issues. A particular emphasis will be placed on African and Asian contexts, and on what can be learned and transferred from Latin American contexts. Ideas and priorities emerging from the work will be debated with relevant representatives of research, policy and practice communities. This issues paper will be used to stimulate these consultations and an on-line survey instrument will be developed around the key questions (see section 4 below). Annex 1 (available on request) gives a little more detail on the consultation methodology. A workshop will be held with a sub-set of those consulted once preliminary findings have been generated.

(b) Literature review: drawing key lessons from major bodies of work and less well-known material

A review of existing literature in relevant fields will be conducted. These fields include: integrated water resources management; use of other ecosystem services that affect water; payments for ecosystems services; and climate change impacts on water cycles. The review will make particular efforts to access grey literature as well as web-based and published literature. Special efforts will also be made to uncover material that explores the links and integration among the above fields, and between these fields and the main approaches used in practice for poverty reduction, development cooperation, water supply and sanitation. The Millennium Ecosystem Assessment will be used as a key framework (whilst also recognising that some bodies of relevant knowledge do not fit well within the structure and approach of the MA, e.g. indigenous knowledge systems with alternative cosmologies). The team will identify bodies of work that offer lessons on what and how research can enlighten and influence practice more on water ecosystem situations, scenarios and responses. Annex 2 (available on request) gives a little more detail on the literature review methodology.

(c) Policy and practice analysis: identifying influences on water delivery in key developing countries

Water and ecosystem services policy and planning, and their impacts on practice, will be analysed for key developing countries. The emphasis here will be less on policy and planning influences on delivery of water, and more on their influence over practices that affect the quantity and quality of water available. The status and impact of climate change thinking and evidence on these policies and practices will also be analysed. The analysis will explore the relationships between policy and planning priorities, temporally and spatially. It will also explore the impact of research in these fields and draw findings on where research is most needed and how its impact might be optimised. The analytical framework will draw on approaches such as IIED's *Policy That Works* analyses in different fields of environment and development, livelihoods analysis, and drivers of change analysis. Analyses will be conducted in Kenya, India and South Africa. Annex 3 (available on request) gives a little more detail on the policy and practice analysis methodology.

(d) Ways forward: identifying key research areas and approaches

With the findings from the previous tasks the team will debate and identify the key research areas and research-to-policy entry points for DFID funded research on water ecosystem services and poverty reduction under climate change. These key research priorities and delivery mechanisms will be captured in a final study report along with the syntheses of the consultation, the literature review and the country policy and practice analyses.

4. Key questions

Our aim in this work is to discover: [A] the ***key research areas and knowledge gaps*** for improving the sustainability and equity of water provision and water ecosystem services management in the context of climate change in developing countries; and, [B] the ***most effective means*** by which research and its delivery can contribute to achieving more sustainable and equitable water services and ecosystems management.

This aim is addressed through eight main questions below. Each question will be asked directly of respondents to (a) interview, and (b) an on-line survey. A set of elements - options and issues - is listed under each question. In the case of interview they will be used to provoke context- and experience-specific responses. In the case of the on-line survey, respondents will be asked to give a score from 1 to 10 to each element – with 1 being the lowest priority, and 10 being the highest priority.

It should be noted that for each question we are asking for the respondent's own judgement of the state and quality of existing research and understanding, and the extent to which it is acted upon, in assessing future priorities.

In the case of both interviewees and on-line respondents we would aim to collect basic information on their: profession/main interest; current employment; years of experience; region of interest and expertise.

1. Water ecosystem services. *Which water ecosystem services need to be better understood in the context of poverty reduction and climate change?*

- ❑ Water quantity and quality for drinking and domestic use
- ❑ Water for agriculture and industrial use
- ❑ Water for non-consumptive use (e.g. hydro-electric power, transport)
- ❑ Food and medicines from aquatic organisms
- ❑ Natural filtration for water quality, buffering and mitigation of floods and sources/sinks for greenhouse gases (regulatory services)
- ❑ Recreation, option values and existence use values
- ❑ Nutrient cycling and ecosystem resilience (supporting services)
- ❑ Other (please specify) ……………………………………………………….

2. Poverty-water ecosystem direct links. *What are the research priorities in the direct links between poverty and water ecosystem services under climate change?*

- ❑ Equity in access to water for basic human needs (e.g. drinking, bathing, laundry)
- ❑ Increasing demand and competition for water
- ❑ Women's ability to shape water decisions at local, regional and national levels
- ❑ Land use change, including forest cover change and draining of wetlands
- ❑ Extreme events – storms, floods and droughts – impacts and adaptation
- ❑ Nutrient loading, salinisation and polluted water,
- ❑ Incidence of vector-borne and water-borne diseases
- ❑ Variability of rainfall and water supply
- ❑ Water ecosystem degradation and species loss, and resilience
- ❑ Farming systems adaptive capacity and resilience
- ❑ Social systems coping strategies, adaptive capacity and resilience
- ❑ Other (please specify)……………………………………………………………….

3. Changes and transitions*. Which other changes affecting water ecosystem-poverty links will need to be better understood as the global climate continues to change?*

- ❑ Social change e.g. changes in inequality, security and conflict

- ❑ Population growth, migration, urbanisation
- ❑ Energy change e.g. fuel prices/access and fuel production including biofuels
- ❑ Market and demand shifts e.g. consumption changes and the rise of the BRICs
- ❑ Information and technology developments e.g. new crops, usable information
- ❑ Changes in ill-health and disease burdens
- ❑ Macro-policy shifts, e.g. influence of international initiatives, more local control
- ❑ Other (please specify)…………………………………………………………….

*4. **Technology.** What are the research priorities amongst the existing or promising technological solutions to water ecosystem service problems under climate change?*
- ❑ Water infrastructure projects (such as dams, dikes, canals, water treatment and sanitation plants, desalinisation)
- ❑ Soil and water conservation technologies (such as physical and vegetative measures for soil and water conservation, including rainwater harvesting)
- ❑ End-use and transmission efficiency options (such as irrigation innovations and canal lining/piping)
- ❑ Adaptive crop management technologies
- ❑ Sustainable groundwater use
- ❑ Wetland restoration and wise-use
- ❑ Other (please specify)…………………………………………………………….

***5. Institutions and integration.** Which policy, legal, organisational and integrative approaches affecting water ecosystem services need to be better understood?*
- ❑ Institutions, norms, rules and rights that influence productive water use (e.g. land tenure, infrastructure, user groups, rules on ecosystem water requirements)
- ❑ Increasing the effectiveness of participation in water decision-making (e.g. citizens' action, irrigation management transfer, private sector participation)
- ❑ Building capacity of local water user groups, national institutions responsible for water ecosystem services and catchment or basin management agencies
- ❑ Negotiating rights to freshwater ecosystem services and responsibilities for their provision
- ❑ Maintaining rights and responsibilities under increased variability of water supply
- ❑ Water legislation and regulation enforcement
- ❑ Legislation and regulation of: ecosystems, species conservation and preservation; pollution; environmental flows; and artificial flood releases
- ❑ Legal agreements for river basin management (international or regional scale)
- ❑ Regulating investment decisions for sustainable water provision to the poor
- ❑ Mechanisms and tactics for making integrated water resource management work
- ❑ Other (please specify)…………………………………………………………….

***6. Economic instruments**. What are the research priorities in enabling economic instruments to help tackle water ecosystem service problems under climate change?*
- ❑ Demand management through market-based approaches, such as payments for watershed services
- ❑ Regulatory mechanisms (such as fines, fees or taxes)
- ❑ Pricing water fairly and efficiently across user groups
- ❑ Insuring against risk under increasing uncertainty
- ❑ Social impacts of water as an economic good
- ❑ Valuing water ecosystem services
- ❑ Water trading mechanisms
- ❑ Generation and use of finance to drive effective action
- ❑ Other (please specify)…………………………………………………………….

7. Research organisation. *Which are the key organisational characteristics of effective research and delivery on water ecosystem services and poverty reduction under climate change?*

- Start with an assumption that much is known and can be uncovered; learn lessons on methods that work
- Shape research by the demands and views of those it seeks to help
- Recognise different stocks of knowledge (e.g. 'western' science and indigenous knowledge)
- Acknowledge and analyse the complexity of, and trade offs within and between, water ecosystem services, economics and social interactions
- More involvement of local institutions in the governance of the research cycle
- More action research – researchers as actors in the system
- Longer timeframes to enable research to be adaptive and responsive
- Work in cognisance of existing potential capacity and uptake throughout
- Recognise that evidence is only one basis for policy decisions
- Tailor the delivery mechanism to the context, and follow up
- Pay attention to potential up-scaling and resistance to change through the research cycle
- Other (please specify)……………………………………………………………….

8. Research and delivery mechanisms*. What research and delivery mechanisms will work best?*

- Inception periods to learn from past work
- Context-specific and process analysis on how policy and practice responds best to evidence on water ecosystem services, climate change and social vulnerability
- Research consortia run by developing country institutions
- Competitive grant facilities in closely defined areas of need
- Learning groups and learning networks
- Funding available between projects to maintain networks in priority research areas
- Time and resources to get products of research tailored to context, then to disseminate and use them
- Strategies for communications, policy uptake and for impact evaluation built in to research
- Peer review, and methods for distinguishing good and bad research
- Performance indicators for learning and adaptation

Other (please specify)……………………………………………………………….

5. Study team

The following people are involved in the study. Please contact members of the core team with responses on this issues paper or other comments – emails are listed below.

Core team

- James Mayers - IIED, UK. Project manager. James.mayers@iied.org
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Specialist team

- Saleemul Huq - IIED, UK

- Ashvin Gosain - Indian Institute of Technology, India
- Cynthia Awuor - African Centre for Technology Studies, Kenya
- Gavin Quibell - Freelance consultant, South Africa
- Mike Mortimore - Drylands Research Ltd, UK
- Jim Sumberg - New Economics Foundation, UK
- Plus several other researchers in IIED and other institutions

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