WATER POLICY BRIEF

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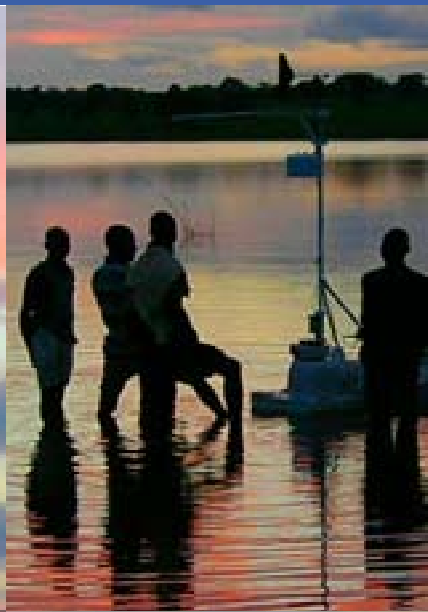
Putting Research Knowledge into Action



Flexible Water Storage Options
and Adaptation to Climate Change

Water storage has a vital role to play in improving global food security and building resilience for adaptation to climate change. A wide range of storage options are available, each with strengths and weaknesses. Because of the uncertainty associated with climate change, planners need to focus on flexibility in storage systems and give careful consideration to the effectiveness and suitability of different storage types.

Key findings

- Water storage should be just one component of a multi-pronged approach to adapting agriculture to climate change.
- In adapting to climate change, careful attention must be given to the full continuum of physical water storage from groundwater, through soil moisture, small tanks and ponds to small and large reservoirs.
- Appropriate water storage for agriculture can contribute to both poverty alleviation and climate change adaptation.

International Water Management Institute

Agriculture is by far the largest human use of water. It uses 70% of global freshwater withdrawals, mainly for irrigation to supplement water for rainfed crops and for livestock. 'Natural' variability in rainfall and temperature mean that in many places access to freshwater is already unpredictable. How climate change will alter this 'natural' variability is the subject of considerable study.

For many millions of smallholder farmers, reliable access to water is the difference between plenty and famine. The classic response is to store water behind dams or in tanks or ponds when it is abundant and where it can be conserved for times of shortage. Water storage spurs economic growth and helps alleviate poverty by making water available when and where it is needed. Today, many developing countries, even those with abundant water, have limited water storage capacity.

Limited storage options leave farmers vulnerable to the vagaries of climate. Ethiopia is one such example. Ethiopian farmers are heavily reliant on rainfed subsistence agriculture. The lack of storage infrastructure means farmers have limited ability to cope with droughts and floods. These limitations are estimated to cost the economy one-third of its growth potential. The Ethiopian case is a good illustration of the urgent need for appropriate investments in water storage to increase agricultural productivity and to ensure that farmers have options for adjusting to the coming climate changes.

Storing water

Physical water storage is one component of a range of adaptation strategies; other options include food storage and management strategies. These are complementary, not mutually exclusive approaches and the best results are obtained when there is a harmony among all three aspects. Figure 1 illustrates potential water storage options.

Natural streams and ponds have traditionally been a low cost, reliable storage option

Small Reservoirs Project:

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Small multi-purpose reservoirs are an age-old adaptation to living in dry areas with highly variable rainfall and where droughts or seasonal floods are common. Small reservoirs supply water for domestic use, livestock and small-scale irrigation and help reduce some of the risk in precarious livelihoods.

All these small, seemingly isolated reservoirs are in fact linked by small rivers and streams that have been dammed to create them or by the aquifers that feed them. Taken as a whole, these reservoirs store a huge quantity of water and while they can have a significant effect on downstream flows, they are rarely considered as systems.

See also the GTZ project Rethinking Water Storage for Climate Adaptation in Sub-Saharan Africa http://africastorage-cc.iwmi.org/Default.aspx

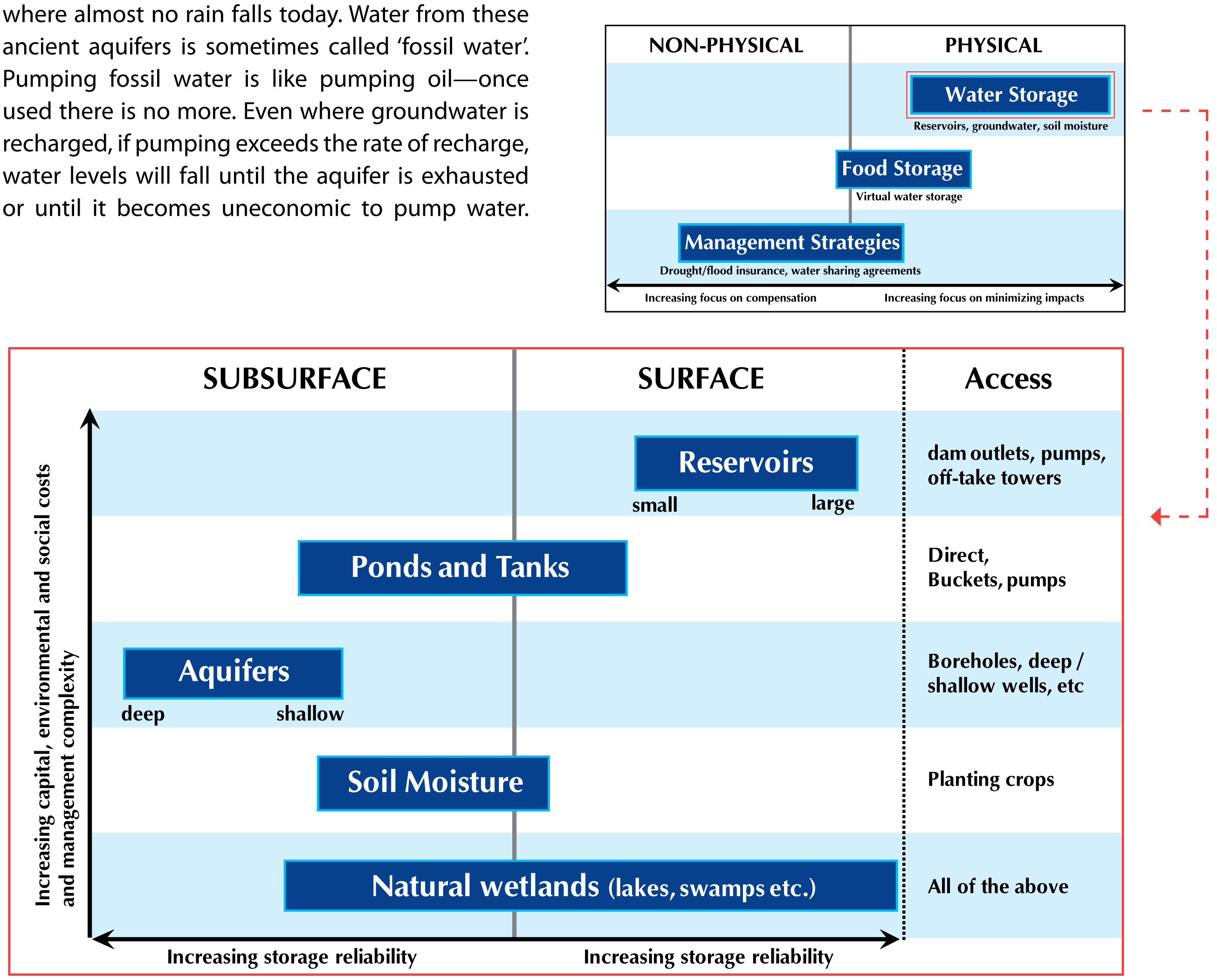
When most people think about water storage, the first thing that comes to mind is large dams. More than 45,000 large dams (more than 15 m high) have been built throughout the world. The majority of these are in North America, China and Europe. About 40% are used solely or partially for irrigation.

Dams are one of the many surface and below-surface water storage options for agriculture. Others include natural wetlands, water stored in the soil and rainwater harvesting ponds. Historically, irrigation depended heavily on water in rivers or naturally stored in lakes, floodplains and wetlands. Groundwater provides much of the water used for irrigation. In India, more than 19 million pumps withdraw 230 cubic kilometers of groundwater annually. In Spain, northern China and California, crop production is almost entirely dependent on groundwater. All groundwater originates as rainfall that percolates down through the soil into aquifers. In some places, the groundwater in these aquifers came from rains that fell many thousands of years ago when rainfall patterns were very different. Libya, for example, is currently exploiting vast reserves of water stored beneath the Sahara Desert, where almost no rain falls today. Water from these ancient aquifers is sometimes called 'fossil water'. Pumping fossil water is like pumping oil—once used there is no more. Even where groundwater is recharged, if pumping exceeds the rate of recharge, water levels will fall until the aquifer is exhausted or until it becomes uneconomic to pump water.

This is already happening in a number of regions, for example, in Gaza, northern China and California, where demand exceeds recharge. Artificial recharge of groundwater aquifers is an important element of water storage and should not be forgotten.

Some effective methods for storing water are also relatively simple and cheap, bearing in mind that in some regions such as Ethiopia, even simple ponds and tanks are beyond the financial means of the poorest. Ponds and tanks built by individual households or communities can store water collected from micro-catchments and rooftops. Individual ponds and tanks may be small in volume, but in some places this water is vital to supplement domestic water supplies, household gardens, rainfed crops and livestock. Thousands of small community dams have been constructed in northern Ghana and in Burkina Faso for just such purposes.

Figure 1: Potential water storage options.



Natural wetlands provide vital environmental services.

A surprising amount of water is stored in the soil. Soil moisture conservation techniques such as bunding, terracing and mulching keep moisture in the soil longer than it would under natural conditions and so increase the water available for crops. These and similar inexpensive measures play a vital role in supporting crop production in arid and semi-arid environments.

Water storage and the environment

Of all the choices available for water storage, large-scale dams are the most controversial. Many large-scale dams contribute significantly to economic development. It is also true that inappropriate construction and operation have been the cause of significant social and environmental costs and have adversely affected poor people. For most of the world's large dams, downstream economic and environmental consequences have been given little attention in design and operation. Most dams were constructed with the emphasis on maximizing the economic returns from the dam itself, with little understanding of the long-term consequences of changing river flow patterns downstream.

Effective food storage begins with harvesting and post-harvest processing.

Over the last 40 years, there has been an increasing understanding of how dams modify riparian ecosystems. Using dams to regulate flow has been found to cause serious degradation of ecosystems and the natural resources and services upon which many people living downstream of the dam depend. Concerns about the negative social and environmental impacts led to reduced investment in large dams in the 1990s. More recently, there has been a re-evaluation of the role of dams and while the controversy continues, investment in large dams in Africa and Asia is increasing again.

Engaging women in management strategies remains a priority.

Other forms of water storage and water use can also have negative environmental impacts. Use of water in agriculture can change river flow patterns and wetlands. Excessive pumping lowers the water table and can reduce dry season spring flows and cause wetlands to dry up. Even storage in small tanks and in the soil can modify flow regimes if scaled-up over large areas.

A vast amount of water is stored in the soil.

The importance of ecosystem services are now widely recognized. Providing water to support those services is increasingly viewed as an essential use of water, along with water for agriculture, industry and domestic use. In many countries, national legislation now makes explicit provisions to safeguard flows in rivers to protect the environment and support basic human needs.

Planning, designing and operating water storage schemes must take into account the externalities created by different storage types, especially those likely to be affected by climate change. For example, water storage tanks and ponds also create breeding grounds for mosquitoes and can lead to an increase in outbreaks of malaria and other water-borne diseases. The higher temperatures expected with climate change is expected to worsen the situation.

Different types of water storage also have a unique carbon footprint. Tropical hydropower reservoirs produce greenhouse gas emissions (GHG) from the decomposition of flooded vegetation and primary production. Under certain circumstances, these GHGs may exceed that of comparable fossil fuel power stations. Pumping from deep groundwater aquifers takes a lot of energy, usually in the form of electricity or diesel fuel. IWMI partners and research collaborators estimate that the groundwater irrigation in India accounts for about 4% of the country's total GHG emissions.

Population growth, rising incomes and urbanization are just some of the drivers increasing the demand for water in cities and industry. Part of the problem in supplying these needs is that the pattern of demand is seldom the same for all users. For example, hydropower demand is more or less constant through the year with diurnal variations, whereas irrigation water is needed only at specific times of the year. For flood control, water levels in a reservoir need to be lowered, while irrigation requires a reservoir be kept as full as possible. These differences are often a source of competition for and conflict over stored water.

The impact of climate change on water storage options

Climate change will increase rainfall variability and increase average temperatures, affecting both the supply and the demand side of the irrigation equation. In some areas of the world, annual precipitation will decline, decreasing river flows and groundwater recharge. In other places, total precipitation may increase but it will fall over shorter periods with greater intensity so that dry spells are longer. Higher temperatures will increase evaporation so that crops will use more water. Although the effects will vary from place to place, farmers will generally need to adapt to less soil moisture and higher evaporation. This means larger volumes and more frequent use of supplemental water.

Small reservoirs can make a big difference to the lives of poor farmers.

All storage options are potentially vulnerable to the impacts of climate change. For example, less rainfall and longer dry periods mean that soil water conservation measures may fail to increase soil moisture availability for crops. Groundwater recharge may be reduced if infiltration decreases, although methods for increasing recharge are available. Many near-coast aquifers will be at risk from salt water intrusion as a result of sea level rise. Ponds, tanks and reservoirs may not fill up enough to support agriculture, or may be at risk of damage from more extreme floods. Larger, more intense floods could also cause catastrophic large dam failures.

The role of water storage in climate change adaptation

With increased uncertainty, higher demand and greater competition, water storage is only one component of a multi-pronged approach for adapting agriculture to climate change. Future water resource management must also include re-allocation of water between users and increasing water productivity in all sectors. There is no doubt that providing more and diverse physical storage infrastructure is imperative for securing reliable supplies of water for agriculture and other uses.

Each type of storage has its own niche in terms of technical feasibility, socioeconomic sustainability, impact on health and environment and institutional requirements. Each needs to be considered carefully within the context of its geographic, cultural and political location. With so much uncertainty in climate change scenarios, the best option is to focus on flexibility in storage systems, possibly combining a variety of types to take advantage of their unique characteristics.

Poor farmers already struggle to cope with changing and unpredictable weather patterns and this will be worsened by climate change. As climate change becomes a greater threat to water systems and agriculture, variety in the types of water storage systems use will provide an important mechanism for adaptation. However, the type of storage will have to be tailored to the specific needs and socioeconomic conditions of each area. Planners need to start taking climate change into account when they design and manage integrated storage systems.

Storage Type	Possible biophysical risks associated with climate change
Reservoirs	• Reduced inflow, resulting in longer periods between filling • Higher evaporation, increasing the rate of reservoir depletion • Infrastructure damage as the result of higher flood peaks • Improved habitat for disease vectors (e.g. mosquitoes) • Increased risk of eutrophication and salinization • Increased siltation
Ponds and tanks	• Reduced inflow, resulting in longer periods between filling • Higher evaporation, increasing rates of pond/tank depletion • Infrastructure damage as the result of higher flood peaks • Improved habitat for disease vectors (e.g. mosquitoes) • Increased risk of eutrophication and salinization • Increased siltation
Soil moisture	• Reduced infiltration resulting from modified rainfall intensities • Waterlogging resulting from modified rainfall intensities and duration • Longer dry periods resulting from altered temporal distribution of rain • Depleted soil moisture arising from higher evaporative demand • Soil erosion resulting from modified rainfall intensities and duration • Reduced soil quality (including water holding capacity and nutrient status) resulting from modified rainfall and temperature
Aquifers	• Reduced recharge resulting from modified rainfall intensities • Reduced recharge resulting from land-cover modification and increased soil moisture deficits • Saline intrusion in near-coast aquifers • Increased percolation through frequent flooding
Natural wetlands	• Reduced rainfall and runoff inputs resulting in wetland desiccation • Higher flood peaks resulting in wetland expansion and flooding of fields and homes • Improved habitat for disease vectors (e.g. mosquitoes) • Retreat of glaciers due to higher temperatures and altered precipitation patterns

Gathering data with this evaporation pan in a small reservoir in the Upper East Region, Ghana provides some of the scientific backing needed for sustainable policy and management of water resources.

Related Publications

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Groundwater now supplies much of the water used for irrigation.

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