Drought mitigation

Analysing South Africa's water management options mitigating drought

Introduction

South Africa is a semi-arid to arid country with a highly variable climate and highly constrained freshwater resources which are affected by weather extremes imposed by climate variability and change. Drought is one of the main constraints for crop and livestock production in South Africa. The socio-economic impacts of droughts tend to be severe in regions with an annual rainfall of less than 500 mm, hence, the annual average rainfall of approximately 450 mm makes South Africa prone to recurrent droughts. Indeed, the drought which is currently devastating parts of the country is a recurrent characteristic feature of South Africa's highly variable climate and weather extremes.

Various researchers have examined the occurrences and management of drought in South Africa. This article reviews the available options for mitigating drought through management of water resources in South Africa. It looks at various water resource management measures with emphasis on water storage.

Definition of drought

A drought can be defined as "a decrease of water availability to substantially below the normal condition for a certain place and time", typically associated with a period of below-average rainfall. Drought is unlike other natural hazards (such as floods) in that there is often no well-defined start and end. There are four basic categories of drought, namely meteorological drought, agricultural drought, hydrological drought and socio-economic drought.

Figure 1 shows the interrelationships between initial meteorological drought, followed by the cascade of successive agricultural, hydrological, and socio-economic forms of drought. The sequence of drought occurrence and impacts for the most commonly accepted drought types is presented in Figure 2.

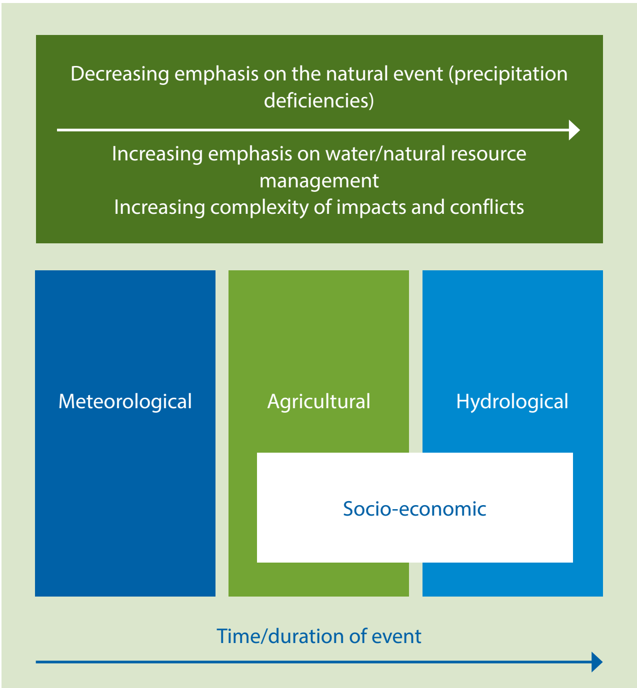

Figure 1: Interrelationships between different forms of drought (Adapted from: National Drought Mitigation Centre, 2006)

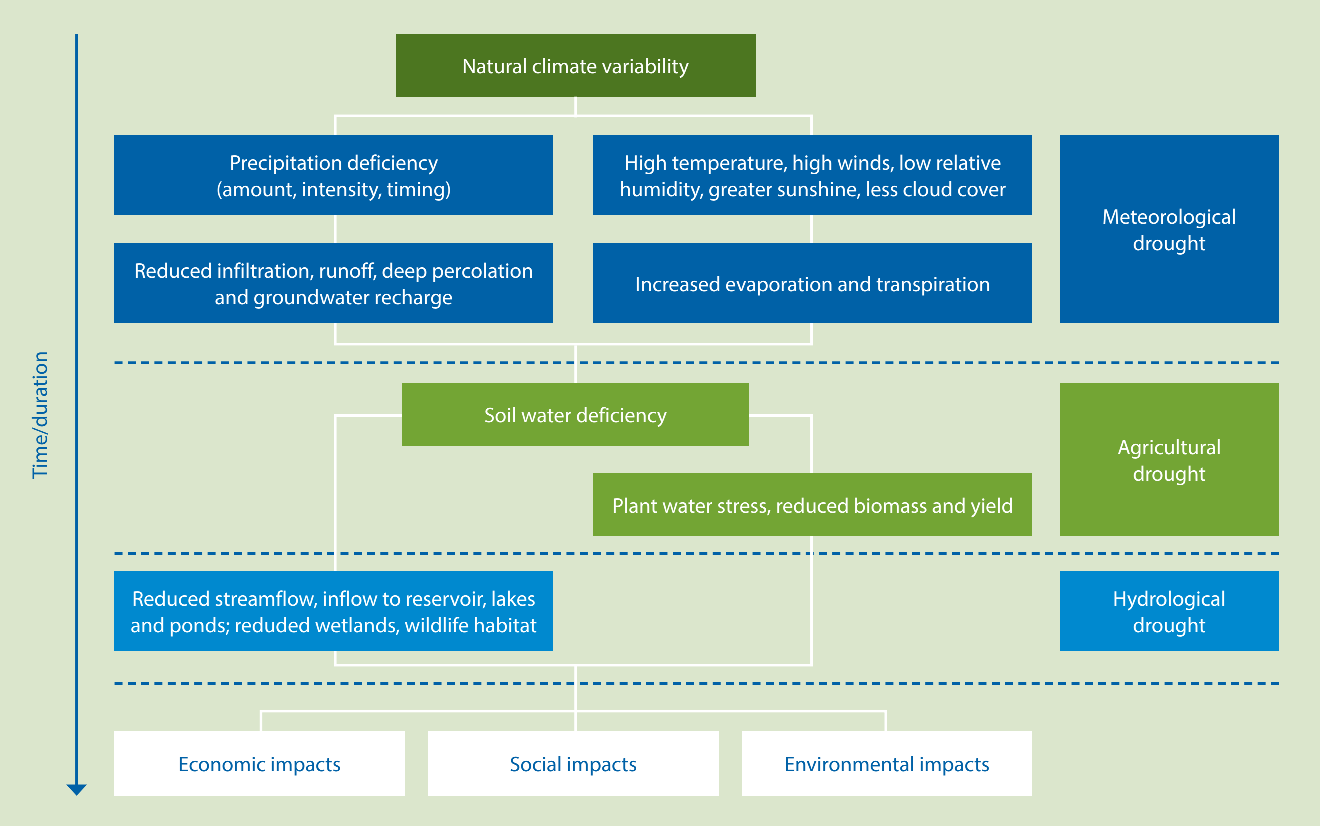

Figure 2: Sequence of drought occurrence and impacts. (Adapted from: National Drought Mitigation Centre, 2006)

Figure 2 also shows the economic, social and environmental impacts which are independent of the time scale, indicating that such impacts can occur at any stage during a drought. Figures 1 and 2 illustrate that all droughts actually originate from the initial deficiency in precipitation, which is known as meteorological drought. The other forms of drought and the resulting impacts cascade through time from the initial deficiency.

Droughts in South Africa

The climate of South Africa exhibits variability in global and hemispheric circulation patterns at intra-seasonal (of the order of one or two months) and inter-annual (year-to-year) time scales. El Niño-Southern Oscillation (ENSO) is recognised as the leading mode of inter-annual variability in the tropics and is driven by variations in sea-surface temperatures (SSTs) in the equatorial Pacific Ocean. There is a link between ENSO and southern Africa's rainfall such that warm ENSO events (El Niño) are commonly associated with below-average summer rainfall over much of southern Africa and cold events (La Niña) are typified by above-average rainfall in this region. It has been observed that summer droughts in southern Africa tend to occur under El Niño conditions.

Water management practices for mitigating drought

Since the primary concern of drought is water shortage, most of the drought mitigation and adaptation activities are aimed at reducing the effect of water shortage through measures that are taken before, during and after drought. The activities comprise a wide range of measures to reduce societal vulnerability that are not necessary linked to water resources.

In addition to planning, effective water resource management in drought prone areas hinges on the institutional and legal set-up established for addressing the interrelated issues of water conservation and planning for drought. Because of the close relationship between water resources and drought, drought management is an essential element of national water resources policy and strategies.

It is argued that drought response problems are water management problems. Hence, from the water resources perspective, a proactive approach to drought is equivalent to strategic planning of water resources management for drought preparation and mitigation. Such planning consists of two categories of measures, both planned in advance:

- long-term actions, oriented to reduce the vulnerability of water-supply systems to drought, i.e. to improve the reliability of each system to meet future demands under drought conditions by a set of appropriate structural and institutional measures; and

- short-term actions, which try to face a particular drought event within the existing framework of infrastructures and management policies.

The overriding objective of the long-term actions is adjustment to drought conditions, even under normal situations, as a proactive and preparatory measure. This includes, for instance, the increase of water storage capacity, the adoption of water saving technology, the recharge of groundwater, etc.

Depending on the severity of drought, long-term actions may or may not eliminate completely the risks associated with it. They are supplemented by short-term measures which correspond to the actions taken during what is called a drought contingency plan. The plan is implemented during drought but the shift to it is usually gradual, reflecting the progressive onset of drought.

An effective water resources plan is one that has an optimal combination of both long and short-term measures.
The measures that can be included in each of the above two categories for alleviating drought impacts can also be grouped into three main types or sub-categories:

- water-supply oriented measures;
- water-demand oriented measures; and
- drought impact minimisation measures.

The measures related to supply management aim at increasing the available water supplies, whereas those pertaining to demand management aim at improving the efficient use of the available resources. These two categories of measures aim to reduce the risk of water shortage due to a drought event, while the third category is oriented to minimize the environmental, economic and social impacts of drought. In practice, the measures are actually interrelated and, at times, even overlapping; but such interrelationships are necessary in order for the plan to achieve its goals. Table 1 gives various drought mitigation measures related to water resources.

Table 1: Drought mitigation measures related to water resources.

Category	Short term	Long term
Supply management	- Mixing fresh and low quality waters - Exploiting high-cost waters - Over-drafting aquifers - Diverting water from given uses - Decreasing transport and distribution losses - Adjust legal and institutional framework	- Increase water collection and storage opportunities (reservoirs) - Desalination of brackish and saline water - Treatment and reuse of wastewater - Water transfers - Artificial precipitation - Locate potential new resources - Groundwater recharge - Adjust legal and institutional framework
Demand management	- Restricting agricultural uses (rationing, subjecting certain crops to stress) - Restricting municipal uses (eg. lawn irrigation) - Review operations of reservoirs - Water metering and pricing - Water rationing - Education and awareness creation - Provide permits to exploit additional resources - Provide drilling equipment - Adjust legal and institutional framework - Negotiate transfer between sectors	- Adopting supplementary and deficit irrigation - Water-saving irrigation techniques (drip, sprinkler, etc.) - Incentives to invest in water saving technology - Water recycling - Dual distribution networks for drinking water supply - Inventory private wells and negotiate their public use - Assess vulnerability and advise water users - Adjust legal and institutional framework
Impact minimisation	- Temporary reallocation of water resources (on the basis of assigned use priority) - Restrict uses - Emergency supplies - Public aid to compensate loss of revenue - Tax relief (reduction or delay of payment deadline) - Rehabilitation programmes - Resolving conflicts - Implement set-aside regulations	- Development of early warning system - Reallocation of water resources on the basis of water quality requirements - Use of drought resistant plants - Development of a drought contingency plan - Mitigation of economic and social impacts through voluntary insurance, pricing and economic incentives - Education activities for improving preparedness to drought - Elaborate set-aside regulations

(Source: Bazza, 2002)

Efficient irrigation techniques, such as drip irrigation, can be effective in combating drought in arid and semi-arid areas. Improved access to water for irrigation or supplemental irrigation can prolong the growing period, avoid false starts, and reduce the risk of impacts from dry spells, both for large-scale as well as smallholder farmers.

Water storage

Currently, agriculture in South Africa is predominantly rainfed. According to FAO estimates of 2012, only about 13% of total cropland is equipped for irrigation, of which an estimated 95% is actually irrigated, and agricultural water withdrawals amount to just 15% of total renewable water resources. The country's rainfall and river flows are variable, erratic and seasonal; droughts occur frequently and agricultural yields are often constrained by insufficient water. Under these circumstances, even relatively small volumes of water storage can, by safeguarding domestic supplies and supporting crops and/or livestock during dry periods, significantly increase agricultural and economic productivity and enhance people's well-being.

Water storage is often associated with large dams mainly because of their considerable financial requirements, as well as the political opportunities that they represent. There is ample evidence of the broad links between high storage capacity constituted by many large dams and increased agricultural productivity and economic growth.

Generally, water storage provides a mechanism for dealing with drought which, if planned and managed correctly, increases water security, agricultural productivity and climate change/variability adaptive capacity. Building dams with large storage capacity is one of the strategies governments use to match water demand with stored supply, and for security against the risk of drought.

Water storage capacity

One of the indicators of water resources deployment is the water storage capacity, which is the amount of water stored in reservoirs per capita. Improved water resource management and water storage capacity make the economy more resilient to external shocks, such as rainfall variability and drought, and thus provide a stable and sustainable base for increased food and industrial productivity and production to maintain economic growth and development.

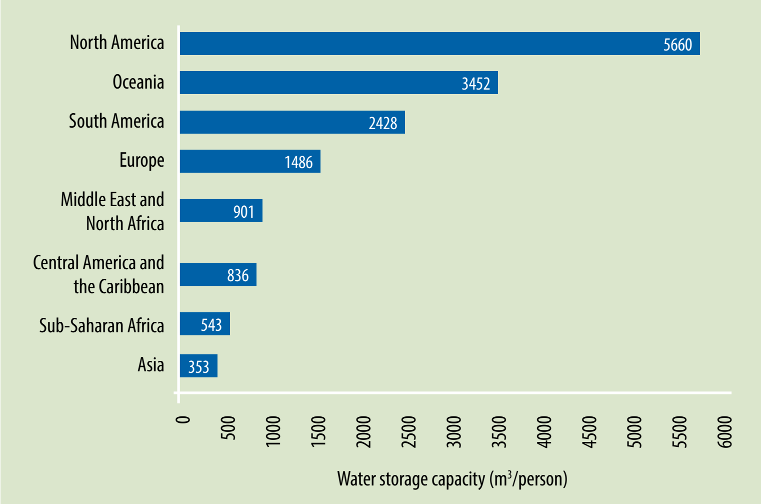

Figure 3: Water storage capacity in m³/person by continent (Source: White, 2005)

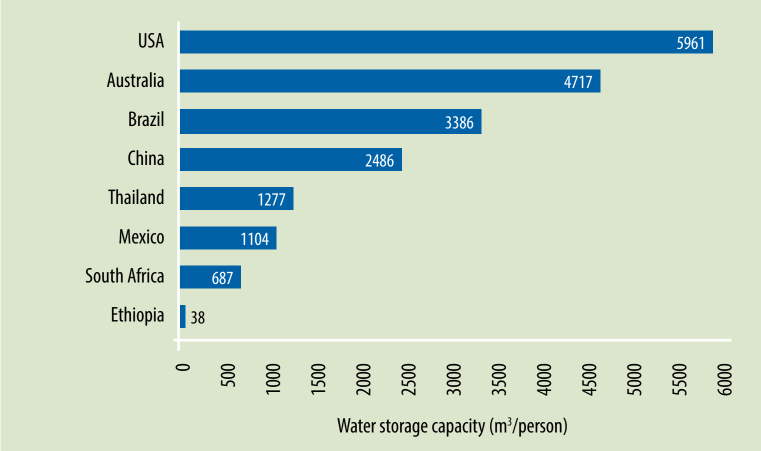

Figure 4: Water storage capacity in m³/person in selected countries, 2003 (Source: Grey and Sadoff, 2006b)

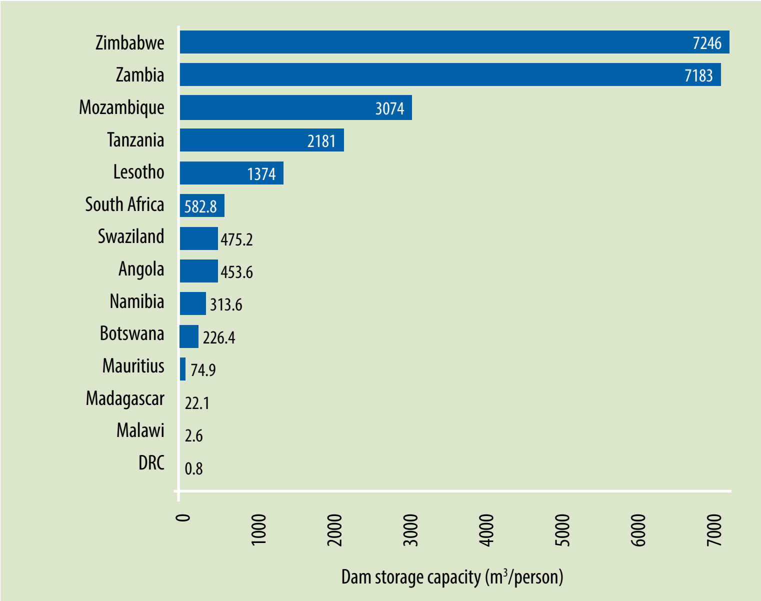

Figure 5: Water storage capacity in m³/person in SADC countries for period of 2008-2012 (Source: FAO, 2015)

Despite the region's vulnerability to frequent droughts and floods, sub-Saharan Africa and Asia have the least-developed water storage infrastructure needed to manage the variability of rainfall and drought (Figure 3).

When compared with other nations on the globe, South Africa has very low water storage capacity (Figure 4).

The average water storage capacity in South Africa is the ninth lowest within the southern African region (Figure 5).

Within the country, the Free State Province has the largest water storage capacity of 5 669.6 m³/capita while Gauteng Province has the lowest water storage capacity of 8.7 m³/capita (Figure 6).

Available water per capita

The indicator 'water resources per capita' is frequently used to show the mismatch between freshwater resources – a renewable but finite resource – and population, and a sense of the level of competition. It indicates a risk of scarcity when a population and its needs are high when compared with the availability of water. A country is said to be rich in water when it has more than 1 700 m³/inhabitant/year, while a water scarce country is below 1 000 m³ (and becomes extremely water scarce when below 500 m³/inhabitant/year).

Figure 7 shows that water availability in South Africa has been declining steadily from 1 329 m³/capita in 1988-1992 to 980 m³/capita in 2008-2012. The projection is that South Africa will remain a water scarce country with water availability of less than 1 000 m³/capita by the end of the 2013-2017 period.

Figure 7 also shows that water storage capacity declined steadily from 776 m³/capita in 1988-1992 to 582 m³/capita in 2008-2012.

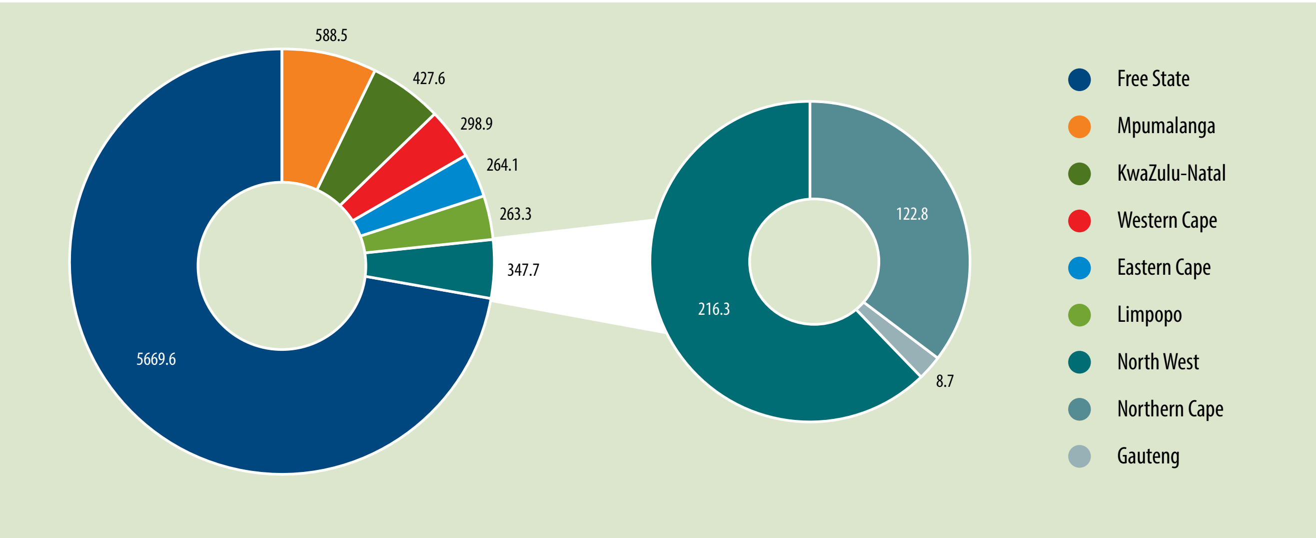

Figure 6: Water storage capacity in m³/person by province in South Africa in 2015 (Data source: DWS, 2015; Statistics South Africa, 2015)

Figure 7: Trend of available water and total storage capacity in South Africa (Source: FAO, 2015)

Water storage options

There are various water storage options for mitigation climate drought. The water storage options include natural wetlands, soil moisture, groundwater, ponds and tanks, and reservoirs. The various storage options and summarised in Table 2.

Natural wetlands, such as lakes, swamps and other wetland types have provided water for agriculture for millennia both directly as sources of surface water and shallow groundwater, and indirectly through soil moisture. Wetlands span the surface/subsurface interface and provide water in many different ways and as a result of their important role in the provision of water, wetlands are increasingly perceived as natural storage infrastructure.

Soils store huge amounts of water. However, such volumes vary from place to place and are quickly depleted through evapotranspiration. Today, there are various in situ rainwater management techniques that enhance infiltration and water retention in the soil profile.

These rainwater harvesting techniques are part of soil and water conservation measures which include deep tillage, reduced tillage, zero tillage and various types of planting basin. The effectiveness of different measures depends a lot on soil characteristics and, particularly, on water holding capacity.

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Water stored beneath the soil surface, groundwater, has the advantage of little or no evaporation and total volumes are often much greater than annual recharge. The amount of water that can be abstracted from groundwater body

Table 2: Water storage options

Storage option	Benefits	Risks
Natural wetlands	• Water storage is provided as an ecosystem service without the need for costly infrastructure; • Water purification; • Regulation of water flows; • Attenuating floods and droughts; • Sediment & nutrient retention and export.	• Excessive utilisation of water in natural wetlands may undermine other ecosystem services.
In-field rainwater harvesting	• Generally, low-cost options that can be implemented by individual farmers and communities.	• Limited storage, will not provide water for more than a few days without rain; • Farmers with small land holdings may be reluctant to give up some land to serve as donor areas.
Groundwater	• Evaporation losses are low or non-existent; • Multiple year storage that is largely decoupled from seasonal variability.	• Requires detailed hydrogeological information to locate wells and estimate yields; • Depending on the geology of the aquifer, the water may contain toxic chemicals (e.g., arsenic).
Ponds and tanks	• Low cost options implementable by communities and non-governmental organizations (NGOs).	• High evaporation losses; • Risk of contamination from surface runoff and livestock; • Risk of siltation; • May provide breeding habitat for disease vectors.
Reservoirs	• Large volume of water which can be used for multiple purposes; • It enables production of electricity; • Can offer protection from floods.	• Requires substantial capital investment; • Displacement of large number of people; • Significant environmental and social impacts arising from changes in river flows; • May provide breeding habitat for disease vectors.

(Source: McCartney and Smakhtin, 2010; SANBI, 2011; Wang et al., 2012; Mussá et al., 2015)

is a function of the characteristics of the aquifer. Groundwater reservoirs can be increased by pumping surface water directly into an aquifer (using injection wells) and/or enhancing infiltration by spreading water in infiltration basins.

Ponds and tanks are often linked with rainwater harvesting and store relatively small volumes of water. Ponds and tanks fill either by surface runoff from a roof or surface catchment or through groundwater and differ from reservoirs by the absence of a dam. While tanks are often covered, ponds are usually shallow, with a relatively large surface area, so that often a significant proportion of the water is lost through evaporation.

Reservoirs are water impounded behind small and large dams constructed across streams and rivers. Small dams store relatively small amounts of water and often empty every year. Large dams (often rock-filled or concrete) store millions, sometimes billions of cubic meters of water. The water may be used for multiple purposes and they are sometimes used for flood control and power generation. Some large reservoirs provide storage that is greater than the mean annual runoff and thus provide multi-year carryover of water.

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Conclusion

Water storage infrastructure is an indispensable tool for mitigation of, and adaptation to, drought and climate change. The review shows that South Africa needs to improve on storage capacity as the country is water scarce.

Apart from large storage reservoirs, there isa need for smaller scale storage which offers the benefit of more local control and less externalities in terms of submerged area.

Improved water control may also be achieved through methods that focus on the control of evaporation, such as conservation farming, drip irrigation, furrowing and levelling of fields.

These methods have also tended to be the most economical and affordable for resource-poor farmers. Water storage can also contribute to power generation and providing water supply for domestic, commercial and industrial uses.

Hence, water storage, in all its forms, has an important role to play in poverty reduction, sustainable development and adaptation to climate change. By providing a buffer, water storage reduces risk and offsets some of the potential negative impacts of droughts, thereby reducing the vulnerability of people. Water storage can, thus, enhance both water security and agricultural productivity.

It is important to treat water conservation (and storage) as a way of life and not just something that has to be done when we are forced to.

References available on request