IMPACT OF CLIMATE CHANGE ON IRRIGATION WATER MANAGEMENT

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1. INTRODUCTION

Scientific observations have shown that the average air temperature of the earth has increased by between 0.3ºC and 0.6ºC during the past 100 years. About two-thirds of this increase has occurred over the past 40 years and there is strong evidence that much of the warming can be attributed to human activities. Modern human society is married to energy sources from fossil fuels, and this, together with the growing population, is changing the atmospheric chemistry.

Although climate change is expected to affect many sectors of the natural and built environments, water is considered to be the most critical. South Africa, because of its general aridity and high variability of rainfall, is especially vulnerable to climate change because of its effect on changes in water availability. Stream flow is relatively low for most of the year, and due to the high water demand by industries, forestation and urban development the requirements for water already exceed the natural availability of water in several of the river basins. Current water requirements for the country is about 13 700 million m^3/a, very close to the about 14 000 million m^3/a usable surface runoff (Frenken, 2005). Water is therefore considered as a limiting resource in Southern Africa and a change in available water supply, together with climate change, could have severe implications on the majority of sectors of the economy, especially on the irrigated agricultural sector.

This paper provides an overview of the impact of climate change on the water situation in South Africa, as well as possible extension strategies to manage this impact whilst maintaining an economically viable irrigation industry.

2. HOW WILL CLIMATE CHANGE IMPACT ON THE WATER SITUATION AND IRRIGATION IN SOUTH AFRICA

The average annual rainfall is 451 mm[1], ranging from less than 100 mm in the western deserts to about 1200 mm/year in the eastern part of the country. The precipitation on 65% of the country is less than 500 mm, which is not enough for successful dry land crop production. Crop production in this area can only be successful if grown under irrigation. Mild to severe frost occurs regularly on the inland plateau where most of the total irrigation area is found. This limits the choice of crops and also results in strong seasonal patterns for most crops grown (Frenken, 2005).

Climate change is expected to alter the present hydrological resources in South Africa and add pressure on the adaptability of future water resources (Schultz & Perks, 2000). Climate change has the potential to impact very significantly on both the availability of and requirements for water in South Africa. There is evidence that global temperatures are increasing and some climate models suggest that this could increase the variability of climate and decrease rainfall in South Africa. According to these models, stream flow could decrease, possibly by as much as 10 per cent by 2015 in the most affected parts of the Western Cape (Schulze, 2009). An increase in the variability of stream flow would mean that, even if the average rainfall were to remain the same, natural yields and reliability would be reduced and the unit cost of water from dams would most probably increase (DWAF, 2004).

The crop water requirements of plants, and therefore irrigation requirements, would also increase should warmer climatic conditions manifest themselves. A study in 2000 assesses the potential effects of global climate change in South Africa, Lesotho and Swaziland. In the study,

[1] 60% of the world average

four global circulation models (GCMs) were used to estimate possible changes in temperature and precipitation. This was followed by application of a suitably modified Agricultural Catchments Research Unit (ACRU) model to estimate the potential impacts on hydrological response in terms of stream flow and recharge into the unsaturated soil above the groundwater table. General agreement among the GCMs with regard to climate projections is that an extension of summer season characteristics is indicated, with continental warming of between 1ºC and 3ºC, the maximum focusing on arid regions and the minimum occurring along coastal regions. There is less agreement with regard to precipitation, but in general terms reductions of the order of 5 to 10 per cent of current rainfall are suggested. This forecasts the likelihood of an increase in the duration of the dry-spell in the interior and north-eastern areas of the country, followed by more intense convective rainfall events, which could lead to more frequent and severe flood events. The probable net effect would be greater evapotranspiration and more stress on irrigation management in these areas (Schulze, 2009)

Linked to this is the indication that climate change will reduce wheat yields in 2050 by approximately 30% in developing countries like South Africa if farmers do not adopt new irrigation management technology and related adjustments

Hydrological studies indicated that runoff was found to be highly sensitive to changes in precipitation, since a relatively small fraction of rainfall in our country is converted to runoff. The conclusion from the study is that, under the hot and dry scenario, South Africa could realistically expect to experience a decrease in runoff of up to 10 per cent in some, but mainly in the western parts of the country. This could have a severe negative impact on groundwater recharge (Hart & Ashton, 2004).

A decrease in water availability will also impact on water quality, thereby further limiting the extent to which water may be used and developed for irrigation (Schulze, 2009).

These factors will eventually impact to greater uncertainty regarding water supplies and increased water control. Against this background three scenarios were developed through SAPWAT3 (Van Heerden, et al., 2008) to illustrate the expected impact of climate change on the irrigation water requirement of crops in the central parts of South Africa:

1. **Scenario 1**: Use current irrigation requirements for crops and assume a fairly efficient irrigation water management approach;
2. **Scenario 2**: Use the same irrigation strategy as for **scenario 1**, but assume an expected rise in temperature of 3ºC and a decrease in rainfall of 10 per cent in the next 15 years;
3. **Scenario 3**: Assume that the irrigation sector will have to provide the water that would be needed to cancel out shortages[2] in the other water use sectors, alter irrigation management strategies so that irrigation requirement will be reduced by at least 11% of present requirement. In this case soil water extraction by crops is allowed to reach 120% of readily available water, which results in limited periodic stress on the crop.

Crops used for this demonstration exercise are indicated in Table 1.

Table 1: Crops used for estimating irrigation requirements for the scenarios.

Crop	Plant / start date
Cotton	15/10
Wine grapes	1/09
Lucerne	1/06
Lucerne seed	1/06
Maize short grower	15/10
Maize short grower	15/12
Potatoes	15/01
Wheat	5/07

The results of the three scenarios are shown in Figure 1 and Figure 2.

[2] 900 million m³ extra water required for an expected population growth of 13 million in 15 years

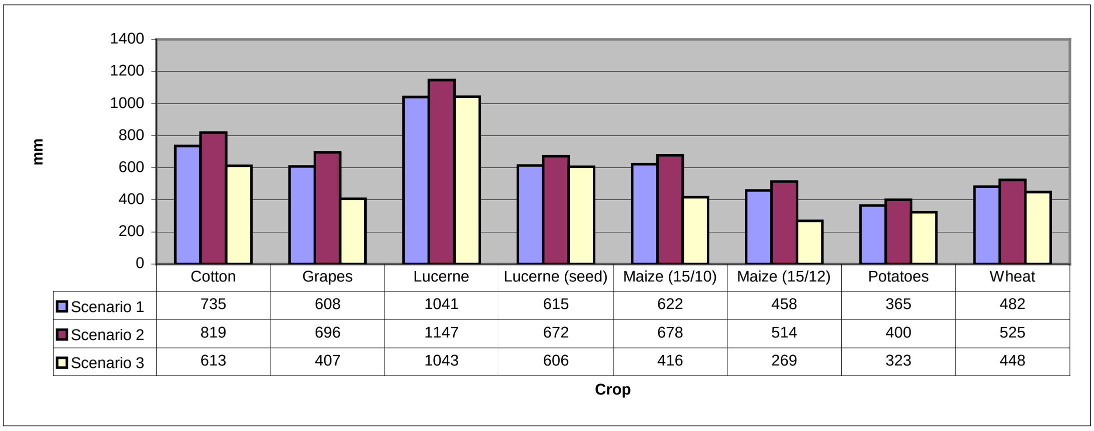

Figure 1: Irrigation requirements for crops irrigated according to the described three scenarios.

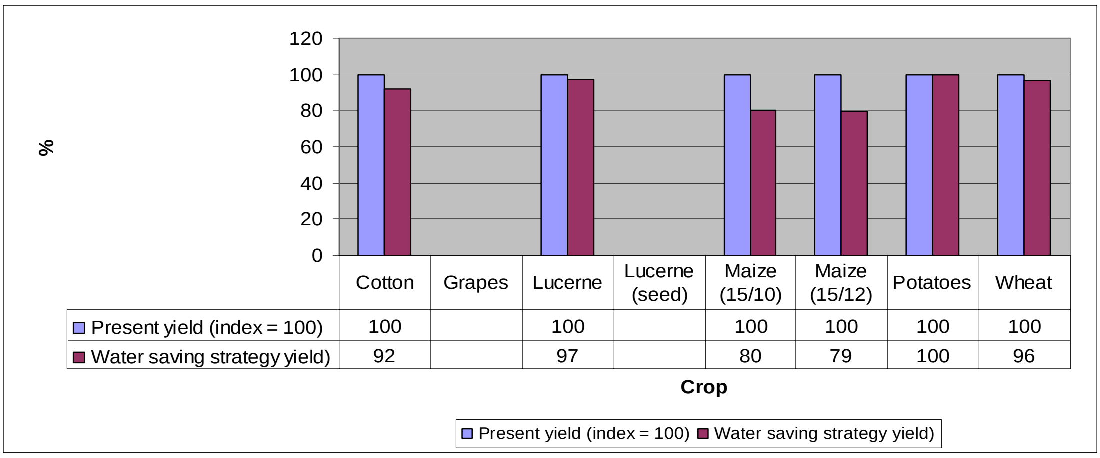

Figure 2: Relative yields before and after changing irrigation strategy.

If the present-day irrigation water management is not changed, the effect of climate change would result in an increase of eight percent in irrigation water requirement. However, it is necessary to reduce the present crop irrigation water requirement by 11 percent to provide for the water loss that the irrigation sector can expect because of higher urban sector demand. The result of applying scenario 3 as an irrigation water management strategy will result in a total saving of 20 per cent.

This background implies an agricultural extension challenge where irrigation water use should be reduced through increased irrigation water use efficiency as well as irrigation management strategies that save water, but without reducing irrigated food production significantly or endangering the economic viability of the irrigation sector.

3. EXTENSION STRATEGIES TO ENHANCE WATER SAVING AND IRRIGATION EFFICIENCY

The objective of a reduction in irrigation water use of at least an 11 percent over the next 15 years in order to neutralize an expected water shortage in the urban sector is a formidable extension challenge. In order to achieve this objective, the irrigation farmers' approach to irrigation management strategies will have to be changed from the present 'top yield per crop' approach to a 'water saving' approach. Under such a strategy a lower yield is to be expected, but if the reduction in yield can be limited so that the irrigation industry can still remain viable, there seem to be no reason why it should not be pursued. However, irrigation is multi-disciplinary by nature, therefore any extension programme that is aimed at decreasing irrigation water use without endangering the economic viability of the irrigation sector, will have to be a multi-disciplinary approach that should include crop, soil, irrigation engineering and irrigation economists as members of the team. Linkages to the target community, problem identification and programme planning, programme execution and monitoring should take place under the guidance of the extensionist, who, because of his understanding of the varying social and cultural contexts and engagement with the irrigation farming community, should also be the programme coordinator.

An irrigation management strategy to save water should include:

- Select crops adapted to the soil-climate environment that fit into the production system of the farm;
- Decide on the optimum crop area, taking into account irrigation water availability (water allocation/quota)
- Select crops that will give an income level at lower yield that will ensure long term economic viability;
- Grow crops under an irrigation system that is efficient and that can be managed by the farmer.

3.1 Crop Choice

The team should evaluate and consider crop varieties in terms of resistance to mild water stress, or alternatively, how much yield loss could be expected at a predetermined reduction in irrigation water application. The resultant lower crop yield must still ensure economic viability, because the future of the irrigation farmer is at stake.

Management approaches to this scenario include:

- using a fixed level of exceedence of readily available moisture extraction; or,
- aim for a specific saving in irrigation water requirement through a targeted lower yield.

Evaluate the effect of each proposed irrigation management strategy on the economic outcome of the farm by doing the necessary enterprise budgets.

Crops differ in their resistance to mild water stress. In Figure 2 the expected maize yield loss due to a mild water stress is estimated at 20 per cent, whereas it is <10 percent for crops like cotton, lucerne, potatoes and wheat at the same level of water stress. These differences in resistance are significant when deciding on the optimum crop choice or to determine at which level of water stress crop production is still economically viable.

In the case of fruit and vegetable farming, an expected lower yield through the application of less irrigation water could result in a higher net income, as product quality can also improve when deficit irrigation is applied at the correct phenology stage of the plant. *Less water is applied and therefore yield is lower, but a premium on the price of good quality produce is often paid. This premium could neutralize the effect of the lower yield.*

3.2 Crop Area

Another important decision to be made is whether it would be economically more justified to plant a full area at a lower crop yield because of a strategy of applying a mild water stress, or reduce the crop area to save water and aim for maximum yields by not implementing a deficit irrigation strategy.

3.3 Marketing Options

The farmer should be fully informed about possible marketing opportunities for the specific crops produced on the farm.

The following marketing options for the production of maize and lucerne are used to illustrate this:

- Instead of marketing maize as grain, it could be marketed as “green mealies” (corn-on-the-cob) after about 90 days of growth, compared to a full growing period for short growers of 120 days. This will result in at least 30 days fewer during which irrigation would have been required and would therefore reduce the total irrigation water requirement from about 30 mm to about 70 mm, depending on planting date and cultivar.

- Growing lucerne for seed production instead of for forage. The normal practice is to irrigate at the level of crop irrigation requirement during the first half of the season, then to allow the soil to dry out during seed formation and ripening and thereafter to allow the crop to go dormant because of severe water stress. The dormancy is broken when irrigations are resumed during the next winter. Reduction in irrigation water requirement is about 400 mm per season.

Crop irrigation requirement planning and real time irrigation water management go hand-in-hand. On the planning side it is important to know how much water will be required on a month-to-month basis to ensure that the farm will have enough irrigation water for the crop through its growing cycle. The weather around us is too fickle to predict specific irrigation requirements; therefore real-time control of crop water use is required to ensure that the right amount of water is given at the right time to satisfy crop requirements. Irrigation scheduling becomes even more important when an irrigator applies a practice such as deficit irrigation in order to save water and to increase the spread of his water.

3.4 Irrigation Systems

The choice of the irrigation system depends mainly on the water availability, soil type, topography, climate, energy availability, crop type, as well as the management skills of the farmer. Well-designed systems have a high potential efficiency, but poor design, insufficient maintenance and bad management could reduce the intrinsic efficiency of these irrigation systems.

The selection of an appropriate irrigation system for small-scale farmers is a huge challenge, since very often irrigation technology that is available is either too expensive and therefore out of reach for many small-scale producers, or does not match the needs and managerial skills of the farmer. Changing from traditional irrigation methods like short furrow irrigation to drip irrigation may often result in low irrigation efficiency due to the farmer's lack of skills.

Since the soil-plant-atmosphere is a continuum (SPAC) with respect to water, which changes quite unpredictably during the season, the irrigation system selected should be designed to cope promptly with SPAC principles as dictated by the weather. It is a matter of the right amount of water at the right time.

Apart from correctly designed systems, continuous maintenance of systems is required. The system needs to be evaluated regularly to ensure that wear and tear on the system has not shifted its performance to outside design specifications, in which case worn parts of the system need to be replaced.

4. CONCLUSION

Science is offering irrefutable proof of climate change and that this will have a negative impact on the availability of irrigation water. However, what we are unsure about is the regional scale change and the impacts on irrigation in the various areas of South Africa. These adverse effects of climate change, together with a population growth, poses various challenges to agricultural extension to ensure that enough, affordable food is produced for the majority of the population. The extensionists should be knowledgeable and skilled enough to help the farmer with the selection of adapted crop varieties with increased drought resistance, flood resistance and heat resistance. The application of irrigation technology, like well designed and adapted irrigation systems, together with efficient irrigation management tools, is essential in irrigation agriculture.

Irrigation is multi-disciplinary by nature; and therefore the extensionist cannot do this alone. It should be a team effort, with the extensionist facilitating the communication about climate change to irrigation farmers.

The team could include the following persons:

- specialists with knowledge regarding crops and soils;
- irrigation engineering;
- agricultural economist, and;
- social scientists (extensionist)

Important in the communication of the effect of climate change to farmers is the realization that there are different perspectives that guide the behaviour of irrigation farmers:

- Financial concern: - where climate change is perceived from a financial point of view, and here the aspects for financial viability should be emphasized
- Natural cycle: - where climate change is perceived as a natural cycle and actions enhancing sustainable agriculture production are highlighted.
- People concern: - where climate change is perceived as an issue for human responsibility, and the focus is on networking and collaboration between parties to address it.

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