PROSPECTS FOR IMPROVING IRRIGATED AGRICULTURE IN SOUTHERN AFRICA – LINKING WATER, ENERGY AND FOOD

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ABSTRACT

Sub-Saharan Africa (SSA) faces high incidence of food and nutrition insecurity. Consequently, increasing agricultural productivity has always featured prominently on regional agenda. The Comprehensive Africa Agriculture Development Programme’s (CAADP) set a target to expand the area under irrigation by at least 5 million ha by 2025. This review assessed the current status of irrigated agriculture in SSA from a water—energy—food nexus perspective, focusing on southern Africa. Gaps and opportunities for improving irrigated agriculture were also assessed in terms of the feasible limits to which they can be exploited. Sub-Saharan Africa faces water scarcity and projections show that countries in SSA will face increased physical and / or economic water scarcity by 2025. However, with agriculture already accounting for more than 60% of water withdrawals, increasing area under irrigation could worsen the problem of water scarcity. Recurrent droughts experienced across SSA reaffirm the sensitive issue of food insecurity and water scarcity. The region also faces energy insecurity with most countries experiencing chronic power outages. Increasing area under irrigation will place additional demand on the already strained energy grids. Projections of an increasing population within SSA indicate increased food and energy demand; a growing middle class also adds to increasing food demand. This poses the question - is increasing irrigated agriculture a solution to water scarcity, food insecurity and energy shortages? This review recommends that, whilst there are prospects for increasing area under irrigation and subsequent agricultural productivity, technical planning should adopt a water—energy—food nexus approach to setting targets. Improving water productivity in irrigated agriculture could reduce water and energy use while increasing yield output.

Keywords: Food security, irrigation, SADC, sub-Saharan Africa, water-energy-food nexus, water productivity.

1. INTRODUCTION

The Green Revolution defined agricultural advancements in the 20th century through the introduction of high yielding varieties, increased use of inputs such as fertilisers and chemicals. For a period, this translated to sustained increases in yields and significant improvements in global food security (Mabhaudhi et al. 2016a). However, by the turn of the millennium, there was already a realisation that agriculture in the 21st century needed a paradigm shift to deal with ongoing food insecurity in some regions of Africa, Asia and South America. There was also a growing realisation that water was going to become the most limiting factor to agriculture and that any further

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increases in agriculture would have to be achieved without increases in water use (Doorenbos and Kassam 1976). The challenges facing agriculture in the 21st century are compounded by climate change and variability which threaten to worsen water scarcity in many parts of the world, especially sub-Saharan Africa (SSA).

Already, about 43% of SSA is classified as either semi-arid or arid. The majority of people in SSA rely on rainfed agriculture and face poverty and food insecurity. For example, in the Southern African Development Community (SADC) region alone, rainfed agriculture accounts for 70% of agricultural land (IAM, 2015). Worsening rainfall variability threatens the sustainability of agriculture in areas where farmers were already struggling to achieve yield potential of crops. Despite the limitations on rainfed agriculture, irrigated agriculture accounts for a mere 9% of SADC’s arable land; the figure decreases to 7% for all of Africa (NEPAD, 2003). This is a far cry from similar developing regions e.g. South Asia (41%), East and South-East Asia (29%) and South America (10%), respectively. There is low uptake of irrigation technologies which could improve crop productivity and alleviate hunger. The low proportion of irrigated agriculture and worsening food insecurity in the region has led African leaders to suggest that improvements in crop productivity lie in increasing the share of irrigated agriculture (NEPAD, 2003).

The aim of this review is to critically assess the feasibility of increasing the area under irrigation in southern Africa. This is achieved by assessing the current status of irrigated agriculture in the region from a water–energy–food nexus perspective. The review also identified gaps and opportunities for improving irrigated agriculture in terms of the feasible limits to which they can be exploited.

2. METHODS

Several policies, including the Comprehensive Africa Agriculture Development Programme (CAADP) (NEPAD, 2003), the Malabo Declaration (NEPAD, 2014a), the Malabo Declaration Programme of Work (NEPAD, 2014b) and the SADC Regional Agricultural Policy (RAP) (SADC, 2014) were reviewed. Publicly available documents such as policy briefs, reports and journal papers on food, energy and water were also reviewed. Examples were mostly drawn from the SADC region which provided a good case study for reviewing and contextualising these targets. The review also focused on highlighting the water-energy-food linkages.

2.1 Africa’s vision for a food secure continent

The Comprehensive Africa Agriculture Development Programme (CAADP) was spearheaded by the New Partnership for Africa’s Development (NEPAD) in partnership with the United Nations’ Food and Agriculture Organisation (FAO) (NEPAD, 2003). It responds to the widening food crises in Africa with a specific mandate to promote agricultural investment and development to combat hunger and poverty. The CAADP set four pillars – (i) extending area under sustainable land management and reliable water control systems, (ii) improving rural infrastructure and trade-related capacities for improved market access, (iii) increasing food supply and reducing hunger, and (iv) research and development. Targeted investments in these pillars would bring immediate transformations to Africa’s food security crises. It suggested that rapidly increasing the area equipped with irrigation, especially small-scale irrigation, could provide opportunities for farmers to sustainably increase yield and address food insecurity. To that end, the CAADP proposed increasing area under irrigation (new and rehabilitated) to 20 million ha; at an estimated cost of US$37 billion while infrastructure operation and maintenance required a further US$31 billion.
While irrigation may ensure food availability, its capacity to reduce hunger and poverty in SSA depends on ensuring that poor rural people have access to water and inputs. The CAADP addressed this by emphasising on prioritising investment in small-scale irrigation, setting a target of about 14.2 million ha for small scale irrigation schemes. The Malabo Declaration Programme of Work, which operationalises the CAADP, outlined concrete ways to achieving Africa’s commitment to ending hunger by 2025. These included doubling crop productivity by focussing on inputs, irrigation and mechanisation. The SADC’s RAP, informed by CAADP, also highlighted the need to improve crop productivity through increasing irrigation. Although the CAADP seeks to promote irrigation, among other interventions, it also noted that increased irrigation was not the panacea for all of Africa’s food security ills. There is need to complement such interventions with improvements in water productivity, nutrition and human health (Mabhaudhi et al. 2016b). A holistic approach would be best placed to sustainably tackle the complex challenge of food insecurity.

The region’s policies on increasing area under irrigation as a strategy to combat poverty and food insecurity need to be reviewed. Increasing irrigated area implies increasing water withdrawals for agriculture which already accounts for the bulk of freshwater withdrawals. Secondly, it requires significant investments in infrastructure, especially in countries with economic water scarcity. Thirdly, irrigation requires significant energy outlays to distribute and pump water, yet the region currently faces energy insecurity (Mabhaudhi et al. 2016c). The SADC’s RAP also prioritises energy availability for irrigation, adding an interesting section that stresses on the region’s shared water resources and the establishment of cross-border irrigation schemes. The importance of incorporating energy in development planning and the transboundary nature of SADC’s watercourses was recently emphasised by Mabhaudhi et al. (2016c), underlining the need to balance and coordinate the region’s food security agenda with available water and energy resources i.e. the water-energy-food nexus approach.

3. RESULTS AND DISCUSSION

3.1 Rainfed versus irrigated agriculture

The total irrigated area in the SADC region is 9 million ha, representing only 9% of total cultivated land of 107 million ha (IAM, 2015); 21% of cultivated land is land under water management (non-equipped flood recession cropping area and non-equipped cultivated wetlands and inland valley bottoms) and 70% is under rainfed agriculture (Table 1). Most of the irrigated area is concentrated to countries on the east and south i.e. South Africa, Zimbabwe, Mozambique and Tanzania (Figure 1). Over 60% of SADC’s population reside in rural areas depending on agriculture and 58% of the economically active population are employed in the agriculture sector (FAO, 2016) making the region’s economy agro-based. However, most of the cultivated land produces crops once a year as rain, which is seasonal, is the only source of water. The high reliance on rainfall for crop production is the main cause of chronic poverty and food insecurity in the SADC region. Climate shocks, such as flood or drought, often result in total crop failure affecting all economic sectors. Under these circumstances, irrigation offers opportunities for mitigating effects of climate shocks on food security.
Table 1. Land area of agricultural systems in the SADC region.

<table>
<thead>
<tr>
<th>Agricultural system</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area</td>
<td>9 365 861.05</td>
</tr>
<tr>
<td>Rainfed area</td>
<td>74 466 578.58</td>
</tr>
<tr>
<td>Water managed area (non-irrigated)</td>
<td>22 746 744.80</td>
</tr>
<tr>
<td>Total cultivated area</td>
<td>106 579 184.43</td>
</tr>
</tbody>
</table>

Irrigation has been shown to be effective in increasing crop water productivity, that is to say, producing more crops with less water, thereby availing more water for other uses downstream (Cai et al. 2011). Although increasing land under irrigation may improve food security, enabling all year round production, its development should consider vertical and horizontal linkages with other sectors such as water and energy.

3.2 Challenges facing agricultural productivity

3.2.1 Irrigation infrastructure development in the SADC region

Most of the arable land in the SADC region is under smallholder farmers (Livingston et al. 2011). Lack of irrigation and heavy reliance on rainfall makes them vulnerable to the negative impacts of climate change as they are exposed to drought and floods. For example, in Malawi where there have been increase in smallholder irrigated area,
due to policies that promote smallholder irrigation, there has been food surplus of more than 1.1 metric tons (Nhamo et al. 2016).

Besides the exploitation of groundwater for irrigated area expansion, damming of runoff water is also vital as most of the surface water flows to the ocean without being used. Of the total mean annual runoff (MAR) of 98,926 km$^3$/year in the SADC region, only 0.43% is dammed and the rest, 99.57%, flows to the ocean (FAO, 2016). Were this water to be stored, it would go a long way in promoting irrigation expansion programmes. With the exception of South Africa and Zimbabwe, the rest of the SADC countries have very few dams that can ensure surface water availability throughout the year. The two countries also have much of their arable land equipped for irrigation (Table 2). The distribution of the 819 existing dams in the region is uneven (Figure 2) hence the need to build more dams. Even though there are 38 planned dams to the north (Figure 2), they may not be enough to meet the water requirements needed to irrigate the proposed 5 million ha by 2025.

Projections indicate that 14% more water will be needed for irrigated agriculture in the developing countries alone by 2030 (Faurès et al. 2002). This requires some 220 km$^3$ of extra storage. Current storage capacity is dwindling through siltation of existing reservoirs. Storage loss through siltation is estimated at about 1% or 60 km$^3$/yr. The total required over the next 30 years is thus in the region of an additional 2180 km$^3$ of storage, or more than 70 km$^3$ a year. More reservoirs should be constructed to meet the additional water requirements needed to meet the CAADP target of 5 million ha of irrigated land by 2025. This will also mean significant energy outlays.

Figure 2. Existing and proposed dams in the SADC region. Source: FAO Aquastat, 2016
3.2.2 Water, energy and food requirements

Water scarcity, energy shortages and food insecurity are among the major challenges facing southern Africa. The three cannot be considered in isolation as water is the key resource to energy generation and food production. Notably, crop production is the largest regional consumer of freshwater resources and currently consumes a lot of energy (Rosegrant et al. 2009). According to Mpandeli et al. (2014), water, energy and food are inextricably linked as energy is required to produce and distribute water and food, to pump water from groundwater or surface water sources, to power tractors and irrigation machinery, and to process and transport agricultural goods. This interrelationship is referred to as the water–energy–food nexus. Whilst the SADC’s RAP (SADC, 2014) speaks to prioritising energy for irrigation, it is silent on addressing the full extent of the linkages. Whilst it is acknowledged that irrigation increases food production, diverting water to fields may reduce river flows and hydropower potential. Mabhaudhi et al. (2016c) highlighted that the region’s economic development blueprint relies on adequate water and energy supplies. Accordingly, policies related to water and energy in the SADC region must be adopted at regional level as any changes done upstream affects the multi-uses downstream and may cause conflict (Wolf, 1998). Existing or planned dams could be used to accommodate the development of regional irrigation capacity and also provide hydropower development thus closing any gaps within the water–energy nexus.

Any plan to invest in irrigation infrastructure such as dams and pipes should, thus, consider energy availability for dam construction and subsequently pumping and distributing water. In as much as food security is a priority, it should not be made to override water and energy security. Rather, there should be coordination among the three sectors as they are all key to improving the living conditions of many, especially people living in rural areas. Recognizing these synergies and balancing the trade-offs is central to jointly ensure water, energy and food security. In this regard, a nexus approach to sectoral management, through enhanced dialogue, collaboration and coordination, is a prerequisite to ensure that co-benefits and trade-offs are considered and that appropriate safeguards are put in place (WWAP 2014; Mpandeliet al. 2014; Everson and Smith, 2016).

3.2.3 Climate change and variability

Across the region, three main climate related drivers of climate change – (a) rising temperature, (b) changes in rainfall patterns, and (c) increased incidence of extreme events (floods and droughts) – threaten agriculture productivity (Challinor et al. 2014). As already alluded, rainfall variability is one of the causes for declining yields under rainfed agriculture. It is envisaged that southern Africa will become drier in the near future impacting negatively on vulnerable and poor smallholder farmers who lack resources to adapt. Due to the reduction in water availability, the viability and sustainability of rainfed cropping systems will gradually reduce. The drive to increase irrigation, especially small-scale irrigation, could provide relief and help to ensure food supplies. Investments in irrigation will thus be pivotal in climate change adaptation, as irrigation promotes improved water productivity and soil water conservation.

3.2 Options for increasing agricultural productivity through irrigation

3.2.3 Increasing land area under irrigation

With increasing population and urbanisation, energy shortages and food insecurity are expected to worsen. The CAADP, Malabo Declaration and RAP speak to the need to increase agricultural productivity through increasing area under irrigation as a
strategy to combat food insecurity. The potential of the SADC region to increase the area under irrigation is immense as there are vast and underutilised groundwater resources (Macdonald et al. 2012), as well as large tracts of arable land not yet used for irrigation (Table 2). The exception is South Africa where all potential has been used. In other countries like Madagascar, Mauritius and Swaziland, more than half of this potential has been used, but in most member countries there is still significant unused potential.

In expanding the area under irrigation, integrated water resource management should be a priority in the SADC region as water is the main driver that ensures the availability of other resources. The present scenario where agriculture accounts for most of the freshwater withdrawals yet food insecurity remains a major challenge should be improved. This calls for water savings to be realised through greater irrigation efficiency.

Table 2. Irrigation potential area and area under water management in SADC countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Irrigation potential (1 000 ha)</th>
<th>Irrigation potential equipped for irrigation (1000 ha)</th>
<th>Potential area for new irrigation development (1000 ha)</th>
<th>Area under non-equipped agricultural water management (1000 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>3 700</td>
<td>85.5</td>
<td>3 614.50</td>
<td>0.4</td>
</tr>
<tr>
<td>Botswana</td>
<td>13</td>
<td>1.4</td>
<td>11.6</td>
<td>6.5</td>
</tr>
<tr>
<td>DRC</td>
<td>7 000</td>
<td>10.5</td>
<td>6 989.50</td>
<td>3</td>
</tr>
<tr>
<td>Lesotho</td>
<td>13</td>
<td>2.6</td>
<td>9.9</td>
<td>0</td>
</tr>
<tr>
<td>Madagascar</td>
<td>1 517</td>
<td>1 086.00</td>
<td>431</td>
<td>10</td>
</tr>
<tr>
<td>Malawi</td>
<td>162</td>
<td>73.5</td>
<td>88.4</td>
<td>0</td>
</tr>
<tr>
<td>Mauritius</td>
<td>33</td>
<td>21.2</td>
<td>11.8</td>
<td>0</td>
</tr>
<tr>
<td>Mozambique</td>
<td>3 072</td>
<td>104.4</td>
<td>2 967.60</td>
<td>13.7</td>
</tr>
<tr>
<td>Namibia</td>
<td>47</td>
<td>7.6</td>
<td>39.7</td>
<td>2</td>
</tr>
<tr>
<td>Seychelles</td>
<td>1</td>
<td>0.3</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>South Africa</td>
<td>1 500.00</td>
<td>1 500.00</td>
<td>0</td>
<td>170</td>
</tr>
<tr>
<td>Swaziland</td>
<td>93</td>
<td>49.9</td>
<td>43.4</td>
<td>4 935.10</td>
</tr>
<tr>
<td>Tanzania</td>
<td>2 132</td>
<td>184.2</td>
<td>1 947.80</td>
<td>0.3</td>
</tr>
<tr>
<td>Zambia</td>
<td>523</td>
<td>155.9</td>
<td>367.1</td>
<td>100</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>366</td>
<td>173.5</td>
<td>192.1</td>
<td>20</td>
</tr>
<tr>
<td>SADC</td>
<td>20 172</td>
<td>6 733.70</td>
<td>13 437.90</td>
<td>5 260.90</td>
</tr>
</tbody>
</table>

Source: Aquastat database (FAO 2013)

3.2.3 Improving irrigation and water use efficiencies and water productivity

Over the years, due to increasing recognition of the significant limitations to agriculture posed by finite water resources, the mantra of ‘more crop per drop’ has evolved. Efforts to increase area under irrigation should be preceded by improvements in the efficiency of existing irrigation schemes. This would lay the foundation upon which irrigation can be expanded. Improving water productivity would suggest minimising, were possible, unproductive water losses (Levidowet al. 2014)
such as soil evaporation, drainage and runoff. At a field level, improvements in water productivity could be realised through a combination of improved through agronomic, engineering, management and institutional strategies. Rain water harvesting and soil water conservation technologies should be promoted, especially for small-scale farmers. The use of improved varieties with high water use efficiency and improved agronomic practices should be strengthened. Alternative practices such as intercropping could be considered for small-scale farmers as they allow for increased water productivity. Investments in irrigation should favour efficient systems such as micro-irrigation systems (drip and sub-surface irrigation) in place of macro-irrigation systems (overhead and sprinkler type irrigation). Micro-irrigation has the potential to achieve the highest uniformity (90%) in water applied to each plant relative to macro-irrigation (Howell, 2003). Management strategies such as deficit irrigation should be adopted as they can increase water productivity. Improving water productivity also requires developing institutional arrangements to support integrated water resource management in catchments.

4. RECOMMENDATIONS

The success of irrigation expansion in agro-based economies of developing countries depends on the holistic approach of the water-energy-food nexus. Whilst food security is a priority, it should not affect other sectors of energy and water security.

The region should:

(a) Develop capacity for water storage through dam construction; this should prioritise small dams for small-scale irrigation in rural areas to improve agricultural production;

(b) Broaden the energy base through pursuing sustainable and renewable energy sources to increase energy supply;

(c) Exploit untapped groundwater resources to counter rainfall variability and add to surface water resources;

(d) Adopt policies that promote small-scale irrigation and empower smallholder farmers to adapt and build resilience to climate change and variability;

(e) Develop remote sensing and crop modelling technologies for precision soil water content determination and irrigation scheduling support; this could reduce over-irrigation and energy usage in large-scale irrigation schemes and improve water productivity;

(f) Prioritise human capacity development (Backeberg et al. 2010) as a strategy to support and sustain small-scale farmers’ adoption of soil water conservation techniques (mulching, conservation agriculture and intercropping) and improve water productivity of new and existing irrigation schemes;

(g) Champion the water-energy-food nexus approach as a cross cutting programme for integrated water resources management, energy and food security interventions; and

(h) Align interventions to improve agricultural productivity through irrigation with the Sustainable Development Goals (SDGs); the water-energy-nexus also offers a platform for aligning regional goals with several of the SDGs (Mabhaudhi et al. 2016c).
5. CONCLUSIONS

It is feasible to increase the area under irrigation in southern Africa. If done correctly, this could sustainably increase food production and improve food security. Targets to increase area under irrigation should be matched with available water and energy resources i.e. adopt a water-energy-nexus approach. This will allow for coordinated interventions and sustainable improvements in agricultural productivity. The inclusion of small-scale farmers through investments in small-scale irrigation schemes will assist in the development of resilient food systems and strengthening small-scale farmers’ capacity to adapt to climate change and variability. There is a need for human capacity development to ensure that small-scale farmers are equipped to take advantage of the investments. Investments in capacity developments will sustain gains achieved from increasing area under irrigation.

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