73RD INTERNATIONAL EXECUTIVE COUNCIL MEETING

24th ICID INTERNATIONAL CONGRESS 73rd IEC MEETING

3rd OCT - 10th OCT 2022

ADELAIDE | SOUTH AUSTRALIA

APPLICATION OF WATER-ENERGY-FOOD NEXUS FRAMEWORK TOOLS AT DIFFERENT SCALES: PRELIMINARY ASSESSMENT

Nwabisa Masekwana, Sue Walker and Michael van der Laan

INTERNATIONAL WORKSHOP ON "THE WATER ENERGY FOOD NEXUS: IMPLEMENTATION AND EXAMPLES OF APPLICATIONS"

04 October 2022: 08:45-10:30 and 11:15 to 13:00 Hours
Adelaide, Australia

APPLICATION OF WATER-ENERGY-FOOD NEXUS FRAMEWORK TOOLS AT DIFFERENT SCALES: PRELIMINARY ASSESSMENT

Nwabisa Masekwana, Sue Walker and Michael van der Laan

24th International Congress on Irrigation and Drainage & 73rd IEC Meeting
3-10 October 2022, Adelaide, Australia

Introduction

- Water, energy and food resources and sectors are interlinked and the study of these interactions is called the WEF Nexus.
- The connections can either be in synergy (beneficial) or negative (tradeoffs) (Taguta, personal communication).
- Imbalances may lead to challenges that can potentially aggravate, and transfer stress that is detrimental to other sectors,
- leading to a lack of sustainability and development of that particular resource.
- The application of WEF nexus framework tools through the calculation of indices helps seek integrated relationships between the three sectors or resources (Nhamo et. al. 2020a).
- Each sector has pillars, which may include availability, security, and accessibility (Nhamo et al. (2020a).

Introduction

- This conceptual tool provides a framework for understanding the complex interrelations, synergies, and possible trade-offs among water, energy, and food sectors by decision-makers (Lawford, 2019; Nhamo et al., 2020a).
- The WEF nexus is a transformative approach that aims to increase and protect these natural resources and inform coherent strategies for sustainable natural resources management (Nhamo et al., 2020b).
- The WEF nexus approach has been used to highlight resource, using WEF indicators, and related to SDGs (Sustainable Development Goals) indices by many users.

Methods

- **Case study situation analysis**

- Mpumalanga Province, Crocodile River Catchment, and in future Mbombela Municipality.

- An assessment of the current situation: water resources, land cover and development plans.

- **Application of WEF Framework Quantitative Tools**

- Analytical Livelihoods Framework (ALF) tool: Access and Availability.

Mabhaudhi et al. (2019)

- Sustainability Performance Indicators (SPI) calculation: Stress and Sustainability.

Zarei et al. (2021)

Methods

- The procedures used will include a quantitative process to calculate a range of indices for each of the component sectors that can be used to assess WEF nexus trade-offs at province, catchment, and municipal level.
- Preliminary data has been collected and calculations made using a range of available indices.
- The data is presented in tables, maps and charts as a spider-diagram in order to show the pattern of indices:
  - to reveal the relative strengths and weaknesses in each sector, and
  - to give guidance about priority areas where interventions are needed to bring balance and cohesion across the sectors.

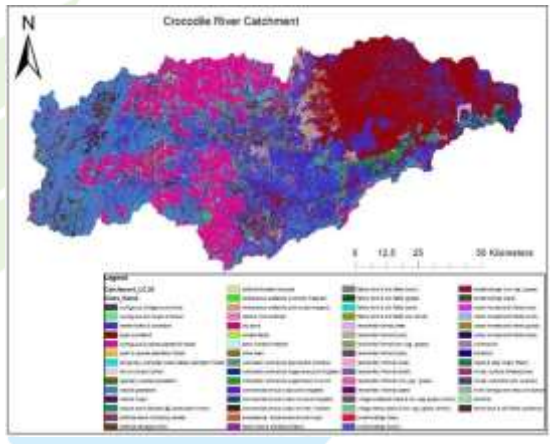
24th International Congress on Irrigation and Drainage & 73rd IEC Meeting
3-10 October 2022, Adelaide, Australia

Results

- Mpumalanga province is 2nd smallest province in RSA.
- Population of about 4 400 000 people and estimated 4 743 584 (1% annual increase) (StatsSA, 2017).
- Total area of the province is 76 495 km^2
- Fourth-largest economy in South Africa.
- Mbombela is the capital city of the province (administrative & business centre).
- A major challenge in the catchment is uncontrolled urbanization (City of Mbombela, 2020).
- Mpumalanga is characterised by
  - annual rainfall that ranges from 400 - 600 mm per annum in the north-east, and
  - 600 - 800 mm per annum in the west, while
  - central zone receives annual rainfall exceeding 1000 mm per annum (Simpson et al., 2019).

Results

- Land cover present in the catchment includes wetlands, indigenous forests, dense bush, open bush and grasslands.
- Most land is taken up by **forest plantations and cultivated lands,** which include sugarcane, and other smallholder annual and perennial crops (ARC-NRE, 2022).



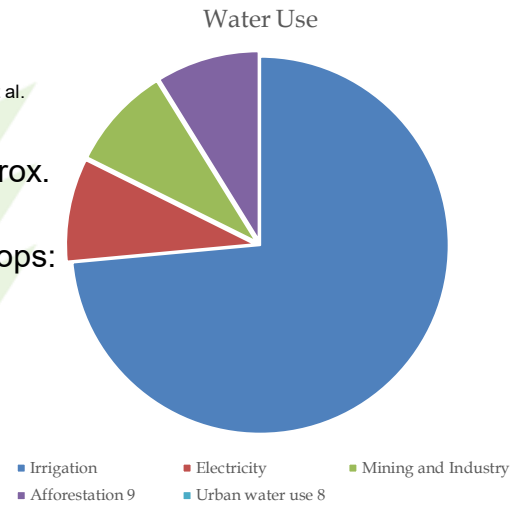
Land cover across the Crocodile River Catchment (unpublished ARC-NRE, 2022).

24th International Congress on Irrigation and Drainage & 73rd IEC Meeting
3-10 October 2022, Adelaide, Australia

Results

- Mean annual runoff is at 3 188 000 mm^3 (McLoughin et al. 2021) .
- Total volume of water allocated 2019/20 was approx. 958 419 m^3 $annum^{-1}$ (IUCMA, 2020).
- Main use of catchment water is for irrigation of crops: *Sugar & tropical fruit trees.*
- Surface water use in the province:
  - 75% is utilized for irrigation,
  - 9% is utilized for electricity generation,
  - 9% for mining and bulk industrial users,
  - 9% for afforestation, and
  - 8% for urban household water usage (including 3% for rural use)

Simpson et al., 2019).



WEF Nexus Tools and Frameworks: Water

- Estimate for Mpumalanga province is 205 litres per $capita^{-1}$ day^{-1} (Green Cape, 2021).
- **91% of households have access to water**, provided by the municipalities (Simpson et al. 2019).
- Total volume of water allocated 2019/2020 was 958 419 m^3 $annum^{-1}$ (IUCMA, 2020)
- Sectors where the water demand is increasing are domestic and industrial use. (Jackson, 2014).
- The water available will continue to be insufficient to distribute to all the critical sectors as the demand exceeds the supply. (IUCMA, 2022)

Calculated water sector measurements and quantifying WEF nexus interactions.

Measure	Units	Values	References
Available Freshwater Resources per Capita (availability)	m^3 $capita^{-1}$	198	Calculated according to Jackson (2014)
Economic Value of Water	\$USD m^{-3}	\$1,83	City of Mbombela data (2020)
Water Stress	%	87	Calculated by Jackson (2014)
Water Requirements Demand	Mm^3 $year^{-1}$	999	Calculated by Jackson (2014)
Households with Access to Water	%	91	Simpson et al. (2019)

24th International Congress on Irrigation and Drainage & 73rd IEC Meeting
3-10 October 2022, Adelaide, Australia

WEF Nexus Tools and Frameworks: Energy

- Percentage of households in Mpumalanga increased from 75.9% in 2002 to 87.8%.
- Mbombela Municipality households with electricity was 190 065 (90%).
- Total energy consumed in Mpumalanga in was 34 049 000 000 GWh (Monyei & Adewumbi 2017).
- Energy consumed per capita was 3200 kWh per capita^{-1} year^{-1} (Monyei & Adewumbi, 2017).
- **Sugar, the base crop uses estimated** 130 602 234 KWhr year^{-1}, **only 0.38% of total**.

Energy sector measurements and quantifying WEF nexus interactions province.

Measure	Units	Values
Access to Electricity (accessibility)	%	87,8
Annual Energy Consumption	kWh capita^{-1} year^{-1}	3200
Energy (@ farm gate)	KWh ha^{-1}	2 118
GHG Emission for Energy Use	g CO_2 kwh^{-1}	900
Total Electricity: Sugarcane	kWh yr^{-1}	130 602 234
Total Energy Consumed per annum	KWh	34 049 000 000
Percentage of Energy Used for Sugarcane	%	0,38
Residential Energy Use per annum	GWh	12 530,03

WEF Nexus Tools and Frameworks: Food

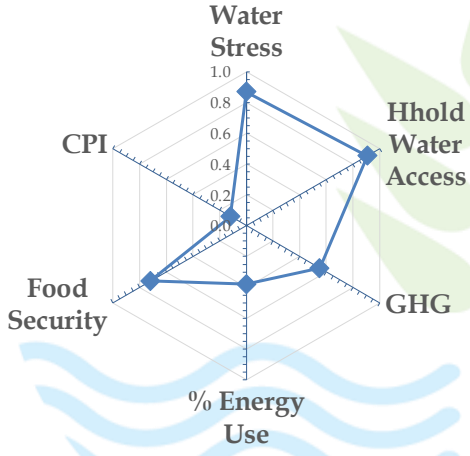
- Agriculture is responsible for about 3.4% of Mpumalanga's total GDP of ZAR 269 863 million (USD 15 mil) in 2013,
- The GDP per capita for the province is ZAR 64,91 (USD 3.6) (OECD Stats, 2018).
- Only about 19.3% of Mpumalanga land area is used for agricultural production of which 1,477 934.
- **Proportion of the population with adequate food is 72.6 %,**
- Those with an inadequate supply of food is 8.4% and those with severely inadequate food supply is 19%.

Food sector measurements and quantifying WEF nexus interactions province.

Measure	Units	Values
Food Security	%	72.6
Water Footprint for Sugarcane	m^3 t^{-1}	800
Water Requirement of Sugarcane	m^3 ha^{-1} year^{-1}	9 000
Water Productivity of Sugarcane	kg m^{-3}	13.09
Total Irrigation Water for Sugarcane	mm^3	524 136
Average Sugarcane Yield	t ha^{-1}	90
Cultivated Land	%	19.3
CPI: Weight	%	118

24th International Congress on Irrigation and Drainage & 73rd IEC Meeting
3-10 October 2022, Adelaide, Australia

Sustainable Performance Indicators = SPIs



Spider diagram of WEF nexus Sustainability Performance Indicators to show the interlinkages in the Mpumalanga Crocodile river catchment about water, food and energy for 2014-2019 (CPI=Consumer Price Index with base year 2016; GHG= greenhouse gas emissions).

Calculation of Sustainability Performance Indicators for period 2014/19 related to Sugarcane production.

Measure	Indices
Water Stress	0.87
Household Access to Water	0.91
GHG Emission for Energy Use	0.55
% Energy used by Sugarcane	0.38
Food Security	0.726
CPI Mpumalanga	0.118

Conclusions

- WEF nexus framework has been applied at the Crocodile River catchment level to obtain the synergies and trade-offs to be applied between the three different sectors as there are some inconsistencies in the distribution of resources to the critical sectors.
- The water sector is facing the challenge of increased demands from sectors such as mining and industry. Urban development or urbanisation means that more water resources need to be diverted toward household use and residential developments.
- The water resource, though available in the Crocodile basin, is used for food production under irrigation and for energy production via coal power stations.
- The energy sector has contributed to improved livelihoods by supplying almost all domestic requirements, as more households have steadily been electrified.

24th International Congress on Irrigation and Drainage & 73rd IEC Meeting
3-10 October 2022, Adelaide, Australia

Conclusions

- The amount of electricity consumption by the water and food sectors is still unclear and seems to be insignificant, but needs clarification in future.
- The majority of energy in the Crocodile Catchment is used in the industrial and transport sectors and very little is used for food production.
- The proposed use of clean and renewable energy is still a challenge and is developing at a very slow pace.
- The agricultural industry sector only contributes low employment volumes that are partly seasonal even though the GDP of the province is largely brought in through agricultural produce.
- The future calculation of indices for other agricultural food products in comparison with the main crop of sugar will help the stakeholders in allocation of resources in order to give a broader view of the food/agricultural sector, by expanding the analysis to other newly introduced crops such as Macadamia nuts, with less resource footprints and demands and increase efficiency.

Team

Funded by Water Research Commission of South Africa (C2019/2020-00326).

- Ms Nwabisa Masekwana: Agricultural Research Council - Natural Resources and Engineering (NRE), Pretoria, (masekwanan@arc.agric.za) & University of Pretoria, South Africa.
- Prof Sue Walker: Agricultural Research Council – NRE, Pretoria, & University of the Free State, Bloemfontein, South Africa.
- Dr Michael Van der Laan: ARC - NRE & University of Pretoria, South Africa.

24th International Congress on Irrigation and Drainage & 73rd IEC Meeting
3-10 October 2022, Adelaide, Australia