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Resilient by design: a modelling approach to support scenario and policy analysis in the Olifants River Basin, South Africa.

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Abstract:

In this paper, we report on a concerted modelling effort in the South African water resources sector in which system dynamics provides the paradigmatic framing for both a stakeholder engagement process and for developing an underpinning, integrative simulation model. We describe the design of the parallel modelling approach and examine the progress to date. We highlight the crafting of the engagement sessions to fit the different characteristics and needs of the participating stakeholders and reflect upon outcomes so as to set the project path into the future. In this, we choose to build resilience by a progression from **collecting** and exploring individual experiences of stakeholders' problems; to **connecting** individuals' experiences to their broader sectors' problems; and finally to **cross-connecting** the sectors' impacts and requirements to one another under different scenarios of change.

Keywords: climate change; water management; public policy; stakeholder engagement; resilience; simulation modelling

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Queries about this research can be directed to the corresponding author (jai.clifford.holmes@gmail.com).

1. Introduction

The resilience of ecosystems and people to changing climatic conditions, rapid urbanization, ongoing commercialization of agriculture, industrialization and degradation of the natural environment, is recognized as problematic in sub-Saharan Africa (Turton, 2013). The central role played by water security in coping with both the developmental challenges as well as building resilience, is also recognized (Muller et al., 2009; Vörösmarty et al., 2010). The RESILIM-O research programme, funded by the United States Agency for International Development: Southern Africa, focuses on water security as a unifying thread in building resilience. RESILIM-O's overarching objective is to improve the trans-boundary management of the Limpopo River Basin to enhance the resilience of people and ecosystems. The RESILIM-O research programme is implemented by the Association for Water and Rural Development (AWARD). AWARD has a specific focus on the Olifants River Basin (*hence* RESILIM-**O**), which is a major tributary of the Limpopo River and is an international watercourse shared by South Africa and Mozambique (see Figure 1).

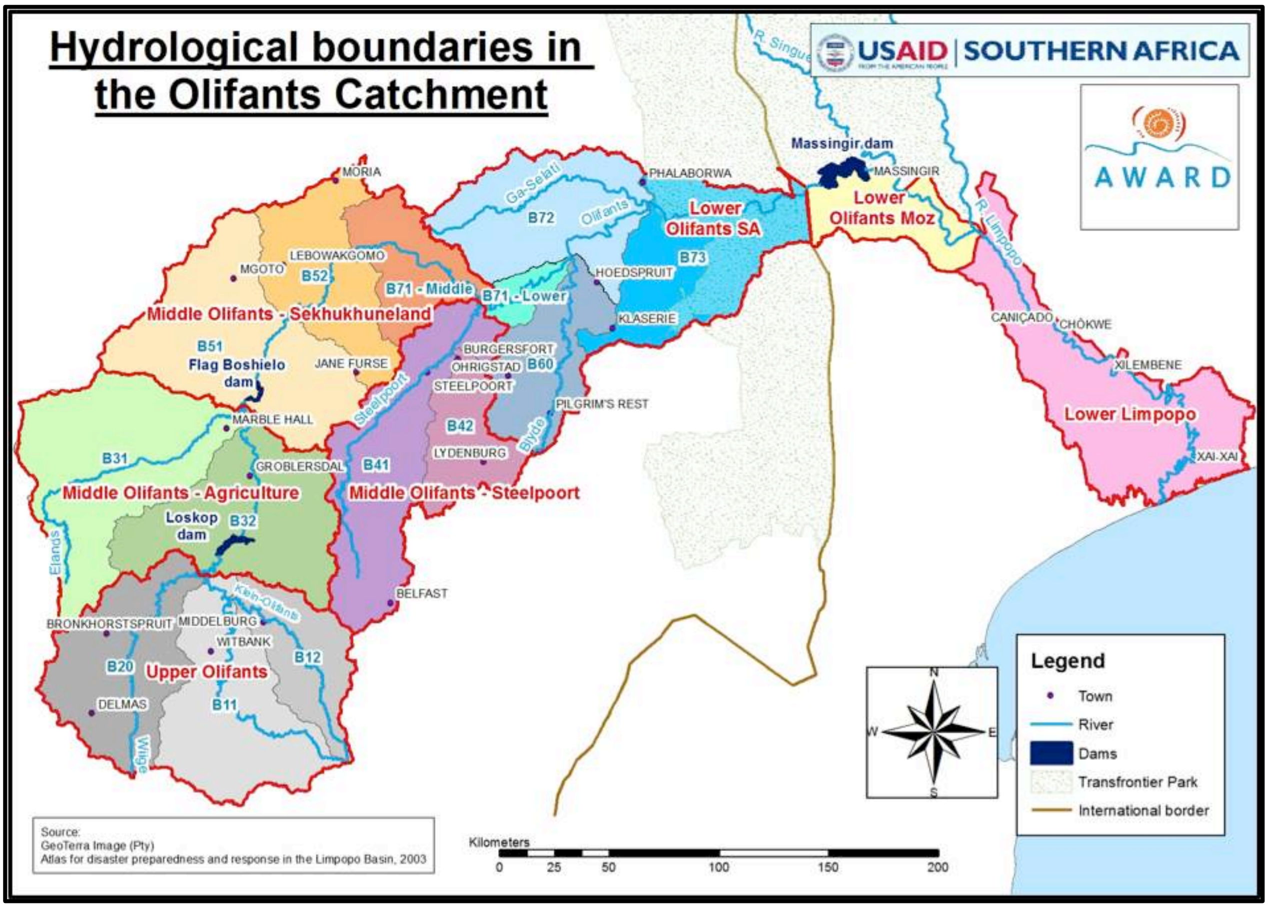

Figure 1: Hydrological boundaries in the Olifants Catchment of the Limpopo basin. Source: AWARD.[1]

In the first phase of RESILIM-O, a grounded understanding of water resource management and the ecosystems in the Olifants catchment was developed. A Resilience Assessment Process (RAP), designed to garner understanding of risks and vulnerabilities and build more resilient

[1] http://award.org.za/resilim-o/olifants-river-basin/

practices across stakeholder groups, was pioneered in this phase, according with Objective 1 of RESILIM-O, namely:

> To institutionalise systemic, collaborative planning and action for resilience of ecosystems and associated livelihoods through enhancing the capacity of stakeholders to sustainably manage natural resources of the Olifants River Basin under different scenarios.

In 2015, the RESILIM-O project management team decided to focus attention on the Selati River quaternary catchment (B72 in Figure 1), identifying the Selati to be an exemplar of land uses and key social dynamics within the Olifants catchment. The dominant land-uses in the Selati catchment are game ranching; dryland agriculture and rangelands; mining; urban settlements in villages and towns; and conservation, both within public parks (specifically the Kruger National Park) and private game reserves, such as the Selati Game Reserve (Pollard & Laporte, 2015). Central problems in the Selati pertain to ephemeral river flow, fluctuating water quality, mining effluent, inadequate access to drinking water, and inadequate sanitation and the poor management of wastewater. The governance and management dimensions of these challenges differ from the upper to the lower reaches of the Selati River, yet the cumulative impact of these diverse activities calls for integrated, catchment-level management and strategic planning. The longer-term projections of the declining yield, associated with increased evaporation and decreased rainfall in the upper Selati (Climate System Analysis Group (CSAG), 2016), provides a further reason why scenario thinking and planning is required in the region. However, many of the disbenefits associated with Selati River being in a poor state are externalised, with the biodiversity impacts of elevated phosphate and sulphate concentrations experienced primarily by Kruger National Park, which is located outside of the Selati River catchment but which is reliant on environmental compliance within the Selati. Hence, there is a disjuncture between the low set of incentives for stakeholders within the Selati to improve the state of the river, and the high requirement for a functioning river system by stakeholders outside of the catchment. Indeed, payment for ecosystem services have been considered in the region (Chapman, 2006) and offsets are being debated.

In this paper we report on the Selati sub-catchment case study. In 2015, RESILIM-O began using system dynamics modelling (SDM) in an integrative fashion, drawing on the earlier stakeholder engagements and collaborative research efforts in Phase 1 (including the dedicated modelling on water quality, hydrology, and land use patterns that had been undertaken within the broader Olifants catchment). We examine how the System Dynamics modelling (SDM) process acted to support understanding, planning, and action systemically, and we seek to develop scientific insights on the concerted modelling effort in which system dynamics provided the paradigmatic framing for both a stakeholder engagement process and for developing an underpinning, integrative simulation model.

[*paper excluded from here onwards*]

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The research reported on in this paper was funded by the USAID: RESILIM-O program. The USAID: RESILIM-O program is funded by the United States Agency for International Development, under USAID Southern Africa – RFA-674-12-000016 RESilience in the LIMpopo Basin Program (RESILIM). The program is implemented by the Association for Water and Rural Development (AWARD), in association with project partners. A full list of the 50+ deliverables that have been developed in the System Dynamics Modelling (SDM) component of the RESILIM-O programme can be accessed via the link provided in Appendix A.

ResiMod version 1 was primarily developed by Willem Jonker and Theo York (independent consultants) with oversight and input from Jai Clifford-Holmes (an AWARD Research Associate). Additional technical input and modelling was provided by Fabio Diaz (an independent consultant also contracted by AWARD).

The Social Ecological Systems (SES) working group of RESILIM-O, led by Sharon Pollard, provided crucial modelling input and the original project framework within which the modelling could be undertaken. Key inputs from the following AWARD researchers and research associates are gratefully acknowledged: Derick du Toit, Eureta Rosenberg, Dirk Versveld, Stephen Holness, Jan Graf, Hugo Retief, Taryn Kong, Charles Chikunda, Tebogo Mathebula, Fredrick Govere, Reuben Thifhulufwelwi, Manuel Mangombeyi, Farnaz Farhang, and Wehncke van der Merwe. The input from Doreen Robinson, Regional Environment Chief, USAID: Southern Africa, is also gratefully acknowledged, as is the SDM training facilitated at AWARD by Josephine Musango.

Initial modelling efforts were presented for peer-review as two presentations at the 3rd Eskom System Dynamics Conference (in collaboration with the South African System Dynamics Chapter), held in Johannesburg, South Africa, on the 10th November 2015. The prototype dashboard design produced by Sovtech for AWARD was presented as a draft only and remains the intellectual property of Sovtech, pending the outcome of the contractual negotiations between AWARD and Sovtech between April – May 2016.

Finally, the authors acknowledge the valuable input from the following stakeholders: managers and technicians from the Ba-Phalaborwa Local Municipality; Safety, Health, Environmental Quality (SHEQ) engineers and officers from the Palabora Mining Company (PMC) and Foskor Mining; Commercial and emerging farmers and irrigation managers from the Selati Irrigation Board (SRIB); water resource managers from Kruger National Park and bio-monitoring river managers from the South African Earth Observation Network (SAEON).

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END OF DRAFT PAPER

Appendix A Summary of the supplementary material

1. Association for Water and Rural Development (AWARD). (2016). *Report-back to the Ba-Phalaborwa Local Municipality: Systems modelling, wastewater management, and scenarios for building resilience*. P.O. Box 1919, Hoedspruit, Limpopo, 1380, South Africa.

To download:

https://www.dropbox.com/s/iebmt0db04nhgao/1.%20Report%20for%20BPLM_Feb2016%20update_reduced.pdf?dl=0

2. Powerpoint slides from the mining workshop ran with Palabora Mining Company (PMC):

To download:

https://www.dropbox.com/s/6ttikpz8dk9iivy/2.%20PRESENTATION%20PMC%2012%20NOV.pdf?dl=0

3. Example of blank baseline survey used in the System Dynamics Modelling (SDM) workshops

To download:

https://www.dropbox.com/s/rexqekl675zuqb8/3.%20SDM%20Workshop%20Commercial%20Farmers%20Baseline%20Questions_HB%2BJCH_10March_final.pdf?dl=0

4. Association for Water and Rural Development (AWARD). (2016). *Key to SDM [System Dynamics Modelling] deliverables to date (as of 06/04/2016)*. AWARD internal reporting. P.O. Box 1919, Hoedspruit, Limpopo, 1380, South Africa.

To download:

https://www.dropbox.com/s/okljh1ii1z82tj0/6.%20Key%20to%20SDM%20deliverables_6April2016.pdf?dl=0

Appendix B Summary of desirable features of a core modelling platform RESILIM-O

Table B.1 : List of desirable features for the core modelling platform in the RESILIM-O project. Source: drawn from Pollard et al. (2013: 50).

	Feature	**Description**
1	Intuitive & diagrammatic	Facilitates model construction, model transparency, and stakeholder involvement in the modelling process.
2	Expressive	Allows various classes of model to be implemented (e.g. system dynamics, agent-based, stochastic, spatial).
3	Computationally efficient	Allows for complex models to be run quickly.
		Allows for rapid experimentation with simple models.
4	Scalable	Enables the handling of very large models, both in terms of number of equations and degree of disaggregation.
5	Conceptual closeness	Conceptually close to other peri-modelling activities (e.g. concept mapping, causal loop analysis, ecosystem services concepts).
		Reduces the "conceptual gap" between the per-modelling activities and a corresponding model.
6.	Integration and conversion friendly	Allows for software integration with other modelling platforms.
		Allows for automatic conversion between the platform's native model-representation format and the formats used by other modelling systems.
		Obtains maximum leverage from available resources.
		Enables the model to be linked to external data sets.
7	Modularity	Supports modular modelling.
		Allows for the re-use of sub-models.
8	Supports scenario planning	Enables scenarios to be modelled through alternative model settings, linked to external data sets and/or other models.
9	Customisable	Allows for the customisation of the run-time user interface: to make it possible for people with no modelling experience to experiment with the models.