ResiMod: A Model to Assist Facilitating Strategic Conversations in the Olifants River Catchment of South Africa

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Abstract:

How can systemically-oriented simulation models be used to support climate change planning for water resources? This paper reports on an innovative approach to support climate change planning using a collaborative, integrative process based on system dynamics. The approach (called Collaborative Dynamic Modeling, or CoDyM) was piloted between 2015 and 2016 to support strategic planning and scenario thinking in a multi-stakeholder context in the Olifants River Catchment of South Africa. In the pilot study described in this paper (and in many similar contexts), planning for different scenarios of climate change remains particularly challenging given the many under-capacitated organisations. The model that was collaboratively developed in this context, called ResiMod, has three aims: (1) to integrate perspectives of multiple, diverse stakeholders; (2) to improve stakeholder understanding and increase the recognition of possible climate change impacts on the stakeholders' sectors; and (3) to uncover and communicate learning and management insights – through the model-building process and through the resulting simulations. The model itself is detailed in the paper along with the results, nested within a description of the broader process undertaken within the CoDyM pilot. By using a quantified simulation model as part of a collaborative process, the project team has begun facilitating cross-sectoral learning as a step towards fostering joint custodianship in the catchment.

1. Introduction & Context

The Olifants River Catchment (ORC) located in the Limpopo Province of South Africa is beset with diverse management challenges. Here, the need to improve water security must be balanced within a contested governance context which currently faces severe capacity constraints. These capacity constraints emerge as issues such as inadequate physical and operational capacity for water supply & sanitation services (WSS), a lack of 'clean-up' funding allocated to ageing mining & industrial sites, as well as weak enforcement and understanding of environmental regulations. Involved stakeholders work within different sectors including agriculture, mining and industry, conservation and municipal WSS. The diversity of roles within this stakeholder group as well as their occupation of different levels of government creates the additional challenge to navigate conflict-riddled communication pathways that can hinder efforts to reconcile crises occurring across the catchment. The overall problems faced become even more vexing when water security is considered in the context of the potential effects of climate change. In the ORC, rainfall events are expected to become more severe, and overall water supply is projected to decline into the future. When this amalgamation of pressures is considered, the requirements for catchment-based management and adaptive, long-term strategies become essential (Pollard & Laporte 2015; Clifford-Holmes, Pollard, et al. 2016; Clifford-Holmes, Carnohan, et al. 2016).

The Association for Water and Rural Development, a non-governmental organization, implements a program known as RESLIM-Olifants (or RESLIM-O) in association with project partners[1], that aims to improve management in the ORC. The work described here focuses on a sub-catchment within the ORC, the Ga-Selati River, which is a tributary to the Lower Olifants. As shown in Figure 1, the Olifants flows into Mozambique, first passing through Kruger National Park (KNP, *Transfrontier Park* in Figure 1). This park is internationally renowned as a habitat for an extensive range of sensitive flora and fauna, including world-famous mega-fauna (rhino, elephant, lion, leopard, cheetah). As such, KNP is a beacon of biodiversity within southern Africa. Its geographical position within the ORC makes it highly vulnerable to impacts from the upstream activities of multiple actors along the Ga-Selati (Selati). To date, elevated sulphate and phosphate levels from mismanagement along the Selati and elsewhere in the catchment have had negative impacts on KNP biodiversity (CER 2016). This context gives credence to the RESLIM-O program primary aims of improving "trans-boundary management of the Limpopo River Basin to enhance the resilience of people and ecosystems"(Clifford-Holmes, Pollard, et al. 2016, p.1).

[1] United States Agency for International Development, under a USAID Southern Africa grant – RFA-674-12-000016 RESilience in the LIMpopo Basin Program (RESILIM)

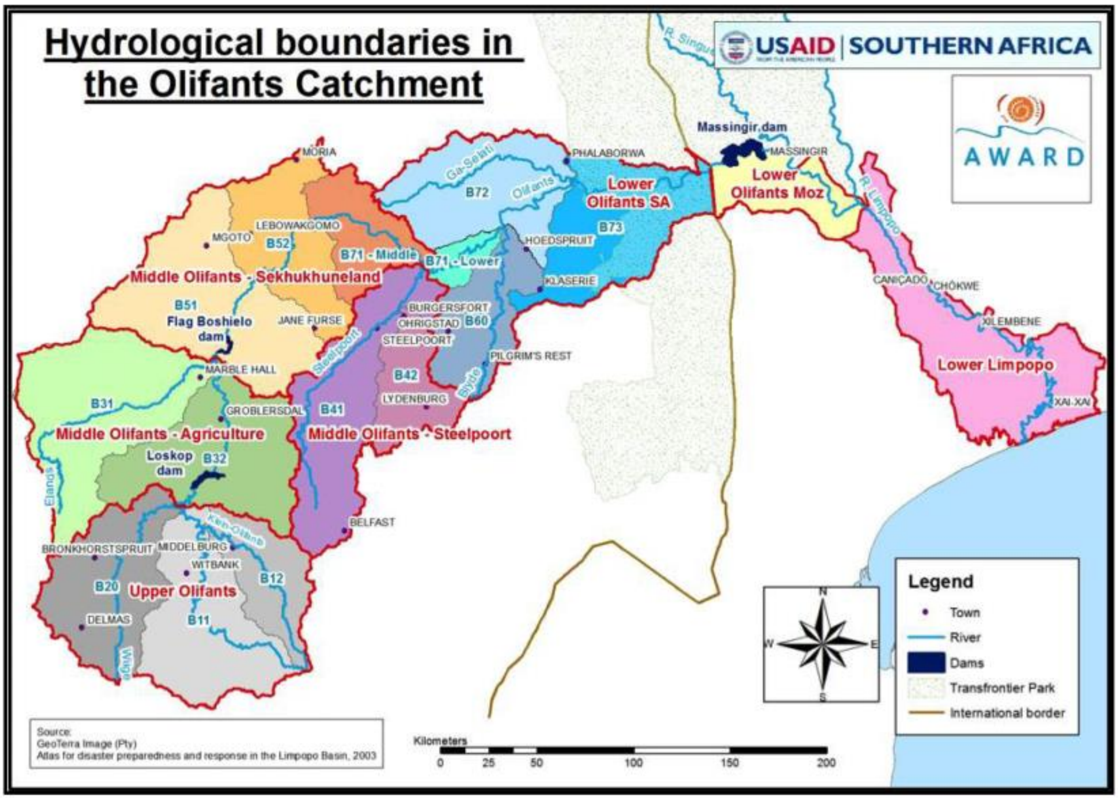

Figure 1. Hydrological boundaries of the Olifants River Catchment of the LImpopo basin, South Africa. Source: http://award.org.za/reslim-o/olifants-river-basin/

A participatory system dynamics modeling (SDM) approach has been utilized to address these management challenges together with the stakeholders throughout the Ga-Selati sub-catchment. It is known as the Collaborative Dynamic Modelling process, or CoDyM. This paper details work that follows-on from work presented at the 2016 International System Dynamics Conference (ISDC), which covered the inception of CoDyM and initial phases occurring in early 2016 (Clifford-Holmes, Pollard, et al. 2016; Clifford-Holmes, Carnohan, et al. 2016). This work was originally conceptualized as a development project, later developing an action research lens. This report then, gives an account of the proceeding process of CoDyM into late 2016, early 2017, and emphasizes the simulation modeling aspects of the work that led to the development of **'ResiMod v.2'**.

Methodology & Model Purpose

The design and use of ResiMod v.2 emerged from the context in which it was developed and is intrinsically tied to the process by which it was built and is used.

An Overview of the Process

The CoDyM process explicitly considers the ethnographic context within which it is applied, building upon the ideas pertaining to the 'muddled middle' of stakeholder engagement (Clifford-Holmes, Jill H Slinger, et al. 2017). Here highly structured participatory processes such as Group Model-Building (GMB) are not always suitable, particularly as they seek consensus on the model built within multi-stakeholder workshops. As evidenced during a study addressing the delivery of municipal water services in the Lower Sundays River Valley in South Africa, conflicts between stakeholders can be at such a level that multi-stakeholder workshops are not a tenable option. In contrast, an approach termed 'Modeling in the Muddled Middle' (or 'M^3'), departs from the perspective that the modeling team should engage stakeholders within their own problematic context (Clifford-Holmes 2015). This can include their working environments, homes or community venues.

The modeling team then adaptively employs aspects of System Dynamics modelling in seeking to understand, conceptualize and communicate with stakeholders regarding their issues, thus circumventing the constraints of a more structured method (Clifford-Holmes, Jill H Slinger, et al. 2017; Clifford-Holmes, Palmer, et al. 2016).

The primary aims of the CoDyM process are as follows:

1) To foster collective action, while
2) Improving systems thinking, and
3) Developing the capacity of affected stakeholders to adaptively respond to climate change.

In the current situation, linear or reductionist thinking is pervasive amongst stakeholders in the catchment, leading to naively simplistic planning, which entrains similar actions. This creates a reinforcing, vicious cycle – simplistic planning leads to lacklustre outcomes, which drives a desire for more short-term fixes that produce undesirable long-term outcomes. CoDyM starts by phasing in systems thinking (through systems modelling and scenario thinking) which, in turn, aims to encourage systemic practices and more systemic planning and acting. In this way, CoDyM seeks to turn the vicious, linear-thinking driven loop into a virtuous cycle of systemic thinking, planning and acting (Clifford-Holmes, Jill H Slinger, et al. 2017).

M3 approach: facilitated mode or expert mode?

The M^3 approach contains elements of 'expert' and 'facilitated' modes of modeling. Franco & Montibeller (2010) describe, with great contrast, modeling processes which support process-based insights (outcomes) and those that support simulation-based insights. They assert that the expert mode typically considers problems with a strictly objective lens, and thus emphasizes the role of the modeler in defining the core problem and arriving at 'optimal' solutions. Solutions are then given to the stakeholders by the modeler, with the assumption that the logical conclusion from a well-researched analysis will be adopted. Such expert mode approaches are common in SDM literature, however, the impacts of this mode on the stakeholder group remain unclear (Größler 2007; Snabe & Größler 2006). Facilitated approaches are more stakeholder inclusive and are considered to improve the uptake of findings through process-based outcomes such as increased problem ownership. Of course, the two modes of expert and facilitated modeling represent extremes and most SDM modeling takes place in between these (for a broader discussion of continuums upon which modeling interventions can be placed, see Clifford-Holmes et al. (2017). Considering simulation approaches along such a spectrum is useful for pinpointing the outcomes of the CoDyM process, which can be understood as an approach to navigate in the intervening space.

Model Purpose

The preceding sections provided the theoretical and contextual framing for the principal model purposes to now be explained. These are:

1. Integrating perspectives and communication for the multiple, diverse stakeholders
2. Improve stakeholder understanding and consideration of climate change impacts.
3. Uncover learning and management insights, through process and simulation.

The primary purpose falls in line with the process-based outcomes that are possible within participatory modeling studies. Here the model is intended to serve as a 'boundary object' or tool to provide stakeholders with ownership of the problem. Whether or not ResiMod v.2 fulfills all of the requisite aspects to be considered as boundary object is a question better left for further research. However, previous efforts to utilize multiple, separate, sessions with diverse stakeholders has given support to the notion that such utilization returns results traditionally desired from boundary objects (see Carnohan 2016). These include the integration of perspectives and the generation of ownership among the involved stakeholders (Black 2013; Star & Griesemer 1989).

The secondary purpose is in line with the desired outcomes of the overall RESLIM-O project. The exploration of plausible climate change scenarios is intended to encourage stakeholders to carefully consider the multiple ways in which climate change will possibly impact on their systems of concern. RESILIM-O aims to facilitate the understanding that that many of these impacts are systemic in nature.

Finally, the understandings developed should encourage coordinated actions through the primary and secondary purposes already outlined, but are also intended to involve simulation-based insights that develop either through the modeling process or in later stages of dissemination.

Developing the model to achieve these intended purposes required trade-offs, as well as continuous learning on the part of the CoDyM team. In the next section, ResiMod will be described and situated within the CoDyM process, in order to better explain how these decisions were made within the action research program.

Phases in the Development of ResiMod v.2

ResiMod was initially intended as catchment-scale model. The action research approach taken led to recognition of distinct phases in the model development process. In the initial phase, rounds of *workshops with individual stakeholder groups* informed modeling that was completed largely in 'expert mode'. The intermediate phase included, *working sessions, sector-based workshops and a multi-sector workshop*. During this phase a process re-design occurred to address process issues relating to time constraints, stakeholder availability and desired outcomes (as described in Carnohan et al. 2016). The final, dissemination phase of sharing collaborative insights will draw on lessons learned from the intermediate phase.

Box 1: Brief explanation of model versions.

ResiMod has been under an iterative development process since the CoDyM process began in 2015. **Version 1 (v.1)** was created by a different modeling team. This was reported on in the paper: *Resilient by design: a modelling approach to support scenario and policy analysis in the Olifants River Basin, South Africa* (Clifford-Holmes, Pollard, et al. 2016).

Version 2 (v.2) developed throughout the intermediate phase (working sessions & sector based workshops) and was utilized at the end of this phase in the multi-sector workshop. Following a validation process, feasible required changes were incorporated before the conclusion of the 2016 CoDyM work plan. This updated **ResiMod v.2** is reported in this paper.

Initial Phase

In the first phase of the CoDyM process, a detailed version of ResiMod v.1 was developed. It contained 13 sub-modules with more than 600 variables and 30 stocks. The model interfaced with Excel spreadsheet files and was divided between two separate Vensim model files. The benefit of its large size lay in the wide range of issues addressed. The developers chose this level of aggregation strategically, in order to incorporate 'key players' within the catchment at this early stage in the CoDyM process. For instance human health aspects, different land uses (including invasive floral species), agricultural water usage of up-stream users were included (Jonker et al. 2015). However, as the model grew in size its documentation base did not, nor was reference material relating to the variables included. Although stakeholder involvement was an integral part of the wider project, the majority of the early modeling effort took place without direct interactions with stakeholders. The level of detail and the catchment scale was useful to scope the weight of different impacts on overall river health. The upstream (largely agricultural) users were shown to have a limited effect on water quality as compared to downstream users (mining, industry, WWTW). In other words, ResiMod v.1 was a useful first iteration that helped determine the use of SDM in the remainder of the process and guided subsequent choices regarding model boundaries.

Intermediate Phase: Exploring the Muddled Middle of water resource management in the Selati sub-catchment

ResiMod v.2 was developed primarily during this phase of CoDyM, over the period of August-November 2016. This phase exemplifies the M^3 approach in that the modeling team met the stakeholders in their domains and elicited information whilst situated in the problem context together with the stakeholders.

'Working sessions' in the intermediate phase

These meetings were varied in their facilitation, many times using model structure, and other times relying upon open interview questions. A simple model was created before each session that could be used to help align stakeholders to the way in which their ideas could be represented. This would be shared, or 'unfolded' gradually and used to explain narratives of the important challenges as understood by the modelling team. This intermediate phase benefitted from the boundary scoping that had taken place within the first phase of modeling work. This helped the new modeler (who joined the CoDyM project in August 2016) to become familiar with the problem context.

Within each of these sessions, the stakeholders' narratives of the problems served to direct the modeling. As the CoDyM team continued engaging stakeholders, connections between these sectors were always sought (either directly through interview questions, or via a combination of interviews and model structure that would be used to help frame the conversation). As the 'sessions' progressed, stock and flow (SF) model structure could sometimes be drawn by hand, shown and described to some stakeholders as a means of validation, whereas others simply provided examples or personal accounts of challenges to be captured by the modeling team at a later stage.

The scarcity of data meant that emphasis had to be placed on data derived from the different databases (oral, written, numerical; see (Forrester 1992, p.56)). As will be described in the following sections, some of the most crucial variables contain data which is yet to be published. During this period, the catchment-wide approach taken at the outset was re-designed to utilize time effectively and address a number of tensions between project goals and constraints (Carnohan et al. 2016).

Stakeholder Sectors Guide Development and Assumptions

As indicated, a major source of information for ResiMod v.2 came from the previously indicated working sessions with stakeholders. The CoDyM team used its discretion to incorporate these stories into model structure, sometimes drawing on additional data when available, and (crucially) when time for additional research was also available. The components of interest and their interactions are depicted in the causal loop diagram in Figure 2 below. This diagram exemplifies the way in which qualitative information was incorporated with quantitative data – and developed with deference to the narratives shared by stakeholders. For example, the feedbacks through public awareness are useful for stimulating discussion with the stakeholders contributing to phosphate and sulphate violations in the Selati.

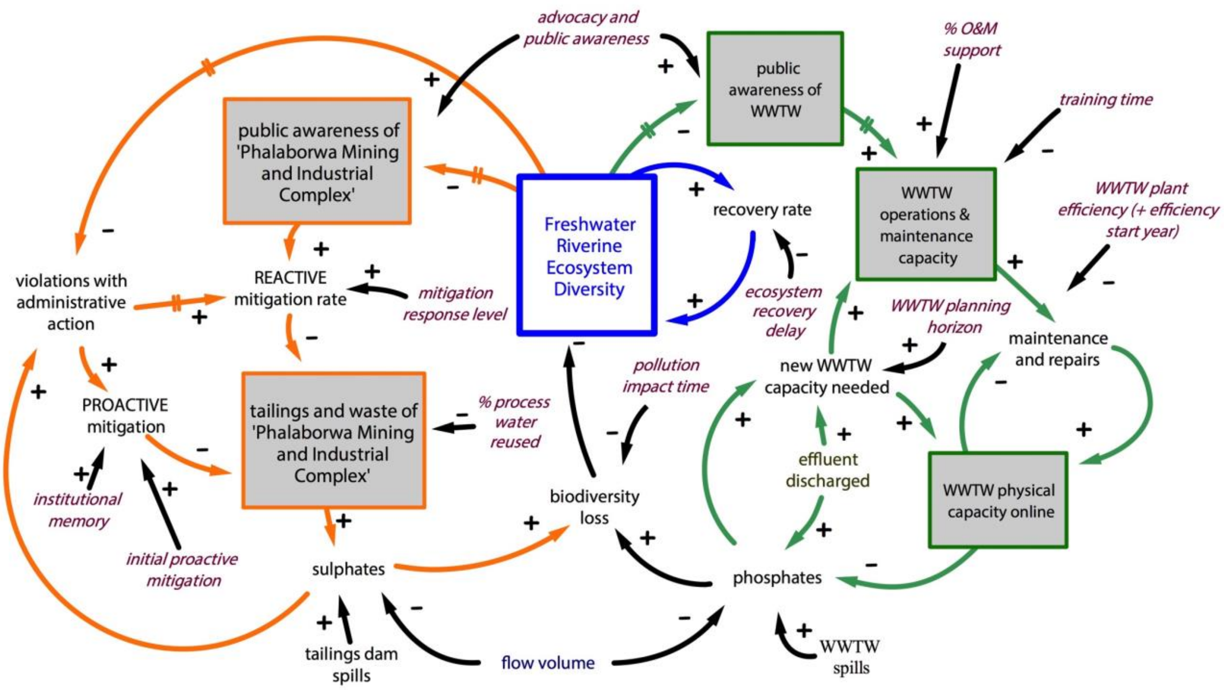

Figure 2. An aggregate CLD of the main feedbacks as described and utilized with stakeholders. The central indicator, freshwater riverine ecosystem diversity, is shown in blue. The Mining Sector is coloured orange, while the Waste Water Treatment Works sector is coloured green.

Sector Workshops & Multi-Stakeholder Workshop Utilizing the Visual User Interface of ResiMod v.2.

Iterative development of the model did not end with the working sessions in the Intermediate Phase. This phase of model development and use included stakeholder workshops. In the weeks leading up to the final, multi-stakeholder workshop individual sector workshops were held with WWTW, mining representatives and conservation representatives from KNP. These provided an opportunity to scope the model interface – different sectors were exposed to a different suite of levers. Within the process of the individual sector workshops the aim was to understand which levers were most salient to the group. This was done in a relatively informal manner, largely based upon which levers the groups were most interested in. Some sector workshops, such as the one held with conservation representatives and WWTW, provided additional means for validation as the model boundary was revealed and some simulation results shown and described. The sector workshops also served as a testing and training period for the would-be multi-sector stakeholder workshop participants.

On the basis of the CoDyM team's experience with displaying and utilizing ResiMod v.2, nine levers were chosen for the final model interface. These levers are shown below in Figure 3 as part of the final interface of ResiMod v.2. The graph of FRED shown here is only one of the many variables that were utilized during the workshop to demonstrate system behavior. The primary variables shown in the interface are the stock variables captured in the CLD in Figure 2.

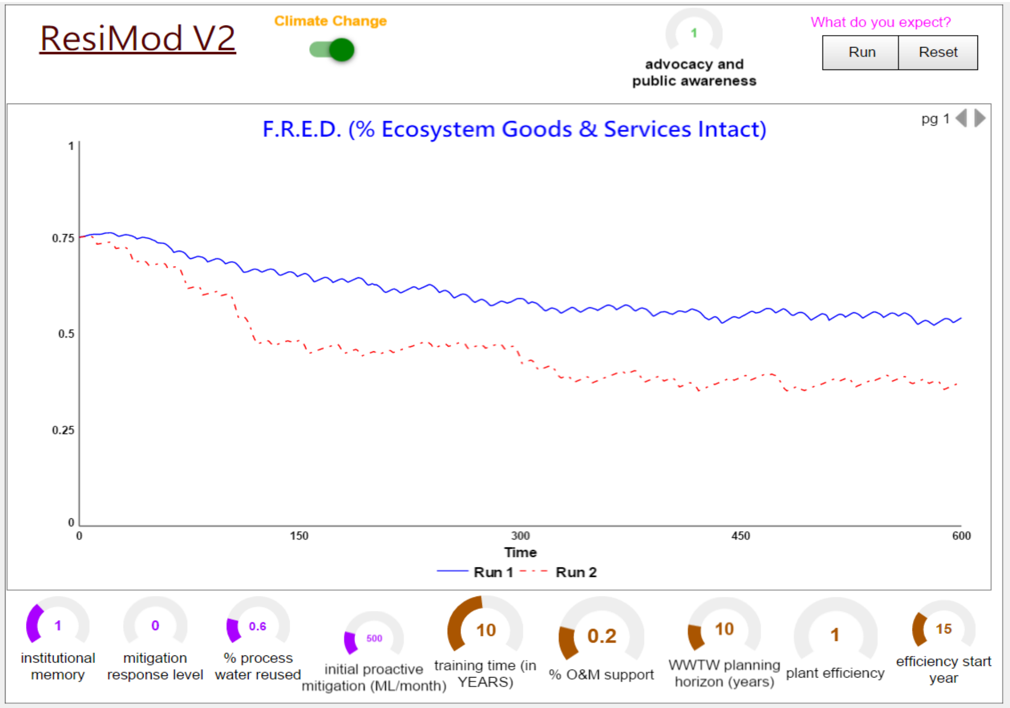

Figure 3. Example of the ResiMod v2 interface that was used with stakeholders in the multi-sector workshop on 03/11/2016.

This paper purposefully avoids placing emphasis on developing simulation scenarios for decision support or policy planning scenarios. As mentioned previously with regards to the model purpose, the current version of ResiMod v.2 may still undergo revision and validation for further use as a tool with stakeholders, a determination to be made in late 2017.

Evaluation of CoDyM and ResiMod v.2

The CoDyM process was one of the RESLIM-O case studies that was utilized by the monitoring, evaluation, reporting and learning (MERL) program. This is an adaptive evaluation program that places "the notion of *systemic social learning* by stakeholders in the catchment" (AWARD 2017, p.8) at the core of its theory of change. The MERL team develops and utilizes indicators to guide quantitative and narrative (qualitative) reporting in order to determine whether or not intended goals are being met within these case studies (Kotschy 2016; AWARD 2017). To evaluate ResiMod, then, it is useful to refer back to expert and facilitated modes of modeling (Franco & Montibeller 2010), acknowledging that the primary purpose of the model is process-oriented, as introduced above.

According to these reports, the workshop process utilizing ResiMod was successful in gaining stakeholders' active participation in scenario thinking and strategic planning, as shown in the following sample of stakeholders' reflections submitted in writing[2] at the end of the workshop:

- *"I learned more about climate change and know its impacts on our waste water plants of which in a long run [will] cost our municipality more money to address";*
- *"It was very interesting to note that climate change links to [other] sectors";*
- *"Making climate change practical and [finding] solutions on the ground [was valuable]";*

[2] These stakeholder comments are reproduced from a draft report submitted to stakeholders which summarized the CoDyM process following the multi-sector workshop (Association for Water and Rural Development (AWARD) 2016, p.6).

- *"The value of dynamic modelling to drive decisions and test results";*
- *"[I] think that running this model and factoring in the climate change factor will improve horizon planning and developing more resilient management plans";*
- *"… fabulous to dwell on the fact that climate change can be an opportunity – crises can be [a] kind [of] opportunity to coalesce around".*

Stakeholders also praised the facilitation using the model – highlighting both the CoDyM team's successful stimulation of group discussion as well as the way the participants had been organized. In the conclusion of the evaluation reporting, ResiMod v.2 was listed as an element of the process that 'worked well', stating: "The value of the CoDyM approach really lies in the possibility for developing a tool which can help stakeholders from different sectors to confront the impacts of their own practices and to explore options together" (Kotschy 2016, p.25). However, the use of a simulation model in this case was also acknowledged to be limited because it reduced, in some ways, the flexibility of the CoDyM team to respond to individual stakeholder needs (Kotschy 2016). In the perspective of the CoDyM team, this was especially notable when stakeholders with varying levels of technical ability are utilizing the tool. This is one aspect that will be addressed in continued work.

Discussion/Conclusion

This paper has provided a description of ResiMod v.2 along with an account of its development and a description of the assumptions made within. The emphasis has been on the model, however the indivisible nature of such a model, built within a participatory process, gives way to a mixed style of reporting – breaking from oft-seen, repeated time-series graphs and explanations of the structure-behavior relationship giving way to these results. The model interface, which is available online as supporting documentation to this paper, provides an opportunity for the interested reader to explore the model behavior and assumptions in much the same way Selati stakeholders in Limpopo have previously.[3]

Although the model does not incorporate all changes envisioned at this time – the current model and relevant insights can be updated and shared on an iterative basis, via the platform provided by Stella Architect and Stella Online (which is occurring as part of the dissemination phase). By moving quickly to get the model in the hands of stakeholders during this time, they can use it and improve their understanding – and further improvements to the model will be shared in the same 'muddled' participatory way there have been. Expanding on this idea, the model could continue to serve as a conflict mediating tool and provide a basis for discussion in future meetings. However, this still requires that a trained SDM modeler be available to update the model periodically, even if infrequently.

A significant challenge with the CoDyM Selati pilot was that the main impacted stakeholder (KNP) was outside of the sub-catchment within which the problems were generated, reducing the impact of their actions (i.e. they had few levers to pull within ResiMod and in the real world). This was a lesson in itself, however, and this pilot served as a platform to successfully demonstrate the potential for collaborative modeling in a developmental context. For 2017 and onwards the project work of the CoDyM team used the Selati pilot (and ResiMod) to motivate for the expanded process to be run with the Olifants Catchment Management Agency (OCMA) as the central stakeholder

[3] See: https://exchange.iseesystems.com/public/jai/resimod-v.2.5/index.html#page1

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