An economic assessment of local farm multi-purpose surface water retention systems in a Canadian Prairie setting

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Online Resource 2. Model Assessment

Table 1. Tests for assessment of dynamic models (adapted from Sterman (2000)).

Test	Purpose of Test	Results
1. Boundary Adequacy	Are the important concepts for addressing the problem endogenous to the model?	As suggested by Sterman (2000) stock and flow maps were used to ensure important concepts for addressing the problem were endogenous to the model. The stock flow diagram was then divided into subsystem components to highlight feedback loops (Figure 3, main text). An inspection of model equation accuracy was also performed.
	Does the behavior of the model change significantly when boundary assumptions are relaxed?	The main boundaries of the model are the watershed area and reservoir volume. When these boundaries are increased, the model behaves as expected.
	Do the policy recommendations change when the model boundary is extended?	The model boundary was not extended as this is not within the scope of this paper. However, the focus of future work is to extend the model boundary from the local scale to a regional scale.
2. Structure Assessment	Is the model structure consistent with relevant descriptive knowledge of the system?	Yes, a stock flow diagram was used to mimic real life situations as closely as possible.
	Is the level of aggregation appropriate?	Yes, the model assumes agricultural activities are owned primarily by one producer as is the case at Pelly's Lake.

		Expert opinion was attained from Richard Grosshans with the International Institute of Sustainable Development (IISD) who helped in the design of Pelly's Lake, our study site. Dr. Grosshans had a chance to review and provide feedback on our model. Consultation on the model was also attained from Dr. Glenn Benoy with the International Joint Commission who is an expert on the Manitoba region of the Prairies including the area's hydrology. Dr. Grosshans and Dr. Glenn Benoy felt the model was suitable for answering the research objectives and did not suggest changes or improvements were required.
	Does the model conform to basic physical laws such as conservation laws?	Yes, we used established discharge equations for flow and drawdown of the reservoir. Established methods were used to determine rain runoff and to describe plant growth. On the economic side of the model, traditional approaches for analyzing revenue were used.
3. Dimensional Consistency	Is each equation dimensionally consistent without the use of parameters having no real world meaning?	Yes, please refer to Online Resource 1 for a full description of the equations used within the model. The model is based on established equations, parameters, and engineering methods. All dimensions within the model are real, with no scaling up or down. As true dimensions were used along with established methods, we do not anticipate any dimensional inconsistencies.
4. Parameter Assessment	Are the parameter values consistent with relevant descriptive and numerical knowledge of the system?	Parameters are adopted from the literature on traditional agricultural engineering practice.

	Do all parameters have real world counterparts?	Yes, parameters have real world counterparts.
5. Extreme Conditions	Does each equation make sense even when its inputs take on extreme values? Does the model respond plausibly when subjected to extreme policies, shocks, and parameters?	Extreme values were input for 1) initial reservoir volume, inflow, and rain, 2) crop prices, and 3) Maximum crop yield. For each of the three scenarios above, the values were first adjusted to equal zero. Next, the values were adjusted to represent an extremely large value. All normal parameter values can be found in Online Resource 1, Table 1. Initial reservoir volume, inflow, and rain being set to 0 for the duration of the simulation period had the expected result. Gross revenue for all crops equaled zero, as there was no water to allow for plant growth. The reservoir also remained empty. To model extreme values, initial reservoir volume was set at 10,000,000 m^3, inflow at 1,000,000 m^3/day, rain depth at 100 mm/day, and when irrigation was applied, maximum irrigation abstraction was set at 1,000,000m^3/day. Actual yield in this scenario did not reach optimal yield for any of the four crops as expected. Gross revenue is subsequently slightly lower than under normal conditions. The reservoir drained initially to its full capacity and maintained this level with constant outflow. When irrigation was applied, the reservoir level was lower due to the abstractions. Gross revenue remained the same as no additional water was needed for maximum crop growth. All responses were as expected.

		Crop prices set at zero for the simulation period, both with and without irrigation also had the expected results. Crop yield was increasing, however gross revenue remained at zero. Crop prices were then set at a very large value of $10,000/tonne for each crop. As expected, this resulted in a substantial increase to gross revenue. When irrigation was applied at normal levels, gross revenue incrementally increased also as expected. Maximum crop yields set at zero for the simulation period, with and without irrigation resulted in no crop yield or crop revenue as expected. To test maximum crop yield with a very large value, all maximum crop yields were set at 10 tonnes/m^2. As expected, crop yield increased substantially resulting in increased gross revenue with and without irrigation.
6. Integration Error	Are the results sensitive to the choice of time step or numerical integration method?	The results are not sensitive to the choice of time step or numerical integration method. The analysis was run with three different integration methods: Euler's Method, Runge-Kutta 2, and Runge-Kutta 4. All methods resulted in the same response. The time step was reported every six hours initially. The time step was altered to report every 24 hours. There was no change in the model output when the time step was adjusted.
7. Behavior Reproduction	Does the model reproduce the behavior or interest in the system (qualitatively and quantitatively)?	The MESH hydrologic model simulated discharge was compared to observed discharge at the study site with an NSE of 0.73, an MSE of 5.45, and a br^2 of 0.58. These results indicate a good fit between the MESH discharge

		simulations and observed discharge for the study site (Nash and Sutcliffe 1970; Yapo et al. 1996; Krause et al. 2005).
	Do the frequencies and phase relationships among the variables match the data?	Output was set on a daily basis as input values were mostly on a daily time step. Economic values were yearly; however daily output was used to match with the physical parameters.
8. Behavior Anomaly	Do anomalous behaviors result when assumptions of the model are changed or deleted?	No anomalous behaviors were observed.
9. Family Member	Can the model generate the behavior observed in other instances of the same system?	This question is out of the scope of the paper, but is a focus of future work.
10. Surprise Behavior	Does the model generate previously unobserved or unrecognized behavior?	None were observed.
	Does the model successfully anticipate the response of the system to novel conditions?	Fluctuations to crop yield in very wet and dry years were as expected.
11. Sensitivity Analysis	Numerical sensitivity: Do the numerical values change significantly… Behavioral sensitivity: Do the modes of behavior generated by the model change significantly… Policy sensitivity: Do the policy implications change significantly… when	Sensitivity analyses were performed. Refer to the main text for results.

	assumptions about parameters, boundary, and aggregation are varied over the plausible range of uncertainty?	
12. System Improvement	Did the modeling process help change the system for the better?	The modeling process helped us to better define our feedback loop. Our original model did not incorporate a feedback loop.