Spatial effects of sensor information in inducing cooperative behaviors for managing non-point source pollution : Scaling from experimental games to agent based models

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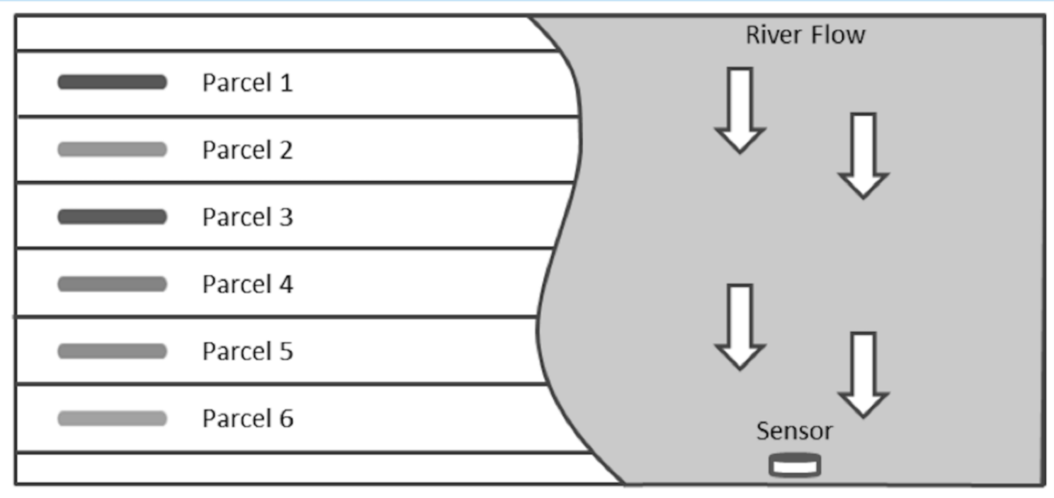


Longstanding debate in behavioral sciences about selfish versus cooperative behaviors

- Results from previous experimental studies, mostly of voluntary mechanisms and conducted under controlled laboratory conditions, suggest that the behavior of human agents is neither perfectly selfish nor perfectly cooperative (Ledyard 1995, Gintis 2000, Messer et al. 2007).

- After reviewing experimental research conducted to estimate cooperative and non-cooperative decision behaviors for provision of public goods under voluntary mechanisms, Ledyard (1995:172-173) noted that:

  - **"There appear to be three kinds of players: dedicated Nash players who act pretty much as predicted by game theory with possibly a small number of mistakes, a group of subjects who will respond to self interest as will Nash players if the incentives are high enough but who also make mistakes, and respond to decision costs, fairness, altruism, etc., and a group of subjects who behave in an inexplicable (irrational?) manner. Casual observation suggests that the proportions are 50 percent, 40 percent, 10 percent in many subject pools."**

Hypotheses & Game Design

(1) Incentives in the form of taxes and subsidies induce cooperative behavior among agents in a river-system network.

(2) The number and frequency of water-quality sensors increases cooperative behavior.

(3) The spatial locations of the decision-makers relative to the spatial locations of the sensors affects the induction of cooperative behavior.

Table 1: *Theoretical predictive prodcution levels (Nash Equilibrium) of each parcel*

Treatment/Parcel	Parcel 1	Parcel 2	Parcel 3	Parcel 4	Parcel 5	Parcel 6
Status quo	50	50	50	50	50	50
Treatment A	33.5	33.4	33.3	33.3	33.3	33.3
Treatment B	21.8	22.8	28.5	36.5	44.6	48.8
Treatment C	Multiple Nash Equilibrium					
Treatment D	33.3	33.3	33.3	33.3	33.3	33.3
Treatment E	22	20.2	29	38.4	45	48.9
Treatment F	Multiple Nash Equilibrium					
Social optimum	20	24	30	33	44	49

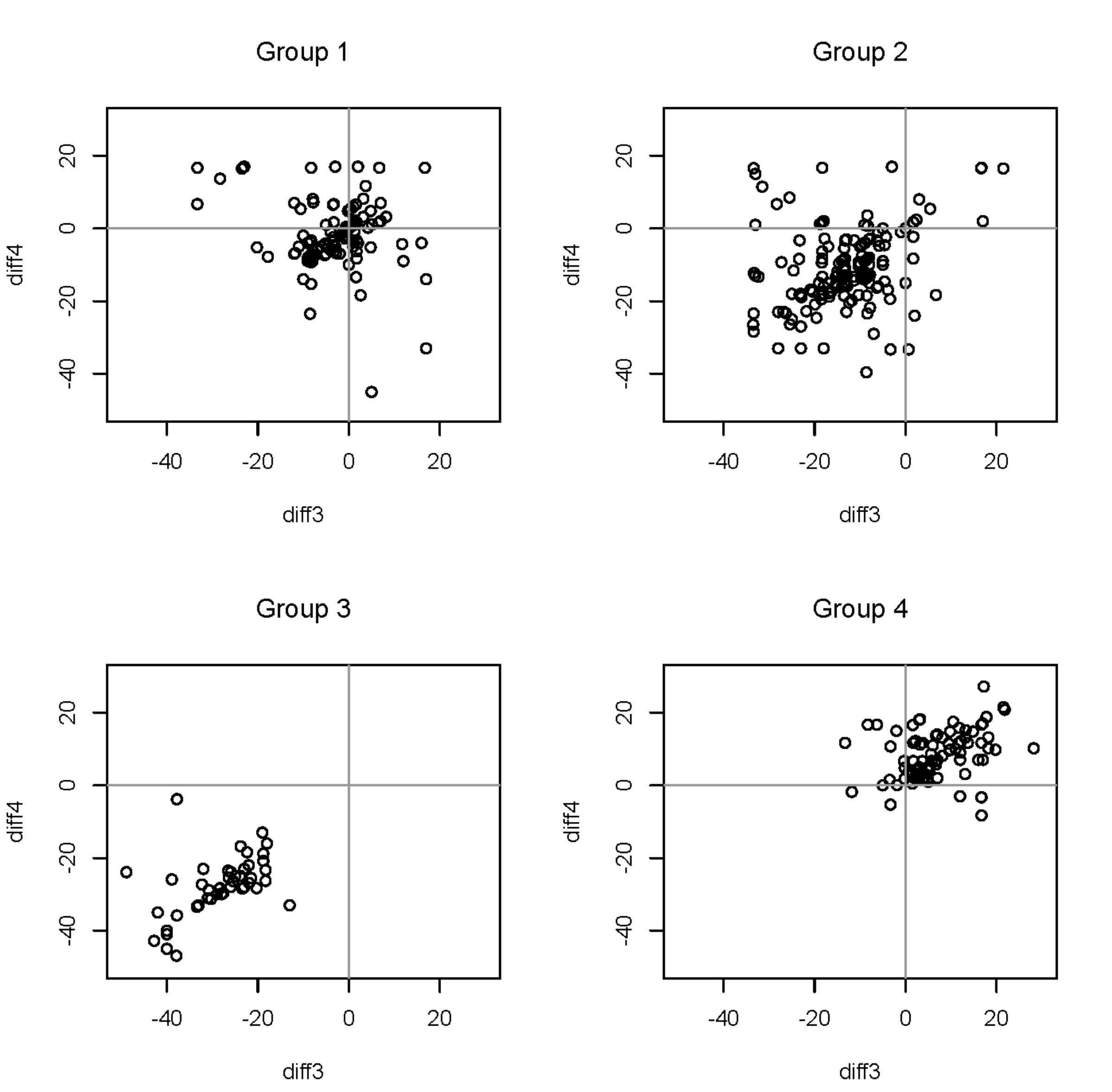
Table 2: *Treatment table*

Treatment/Parcel	Sensor Number	Frequency of Sensing	Ambient Tax/Subsidy
Treatment A	One	One time	Yes
Treatment B	One	Four time	Yes
Treatment C	One	Continuous	Yes
Treatment D	Two	One time	Yes
Treatment E	Two	Four time	Yes
Treatment F	Two	Continuous	Yes

Clustering analysis of gaming data reveals four types of behavioral strategies

Competitive /selfish

Cooperative



Hyper-Cooperative

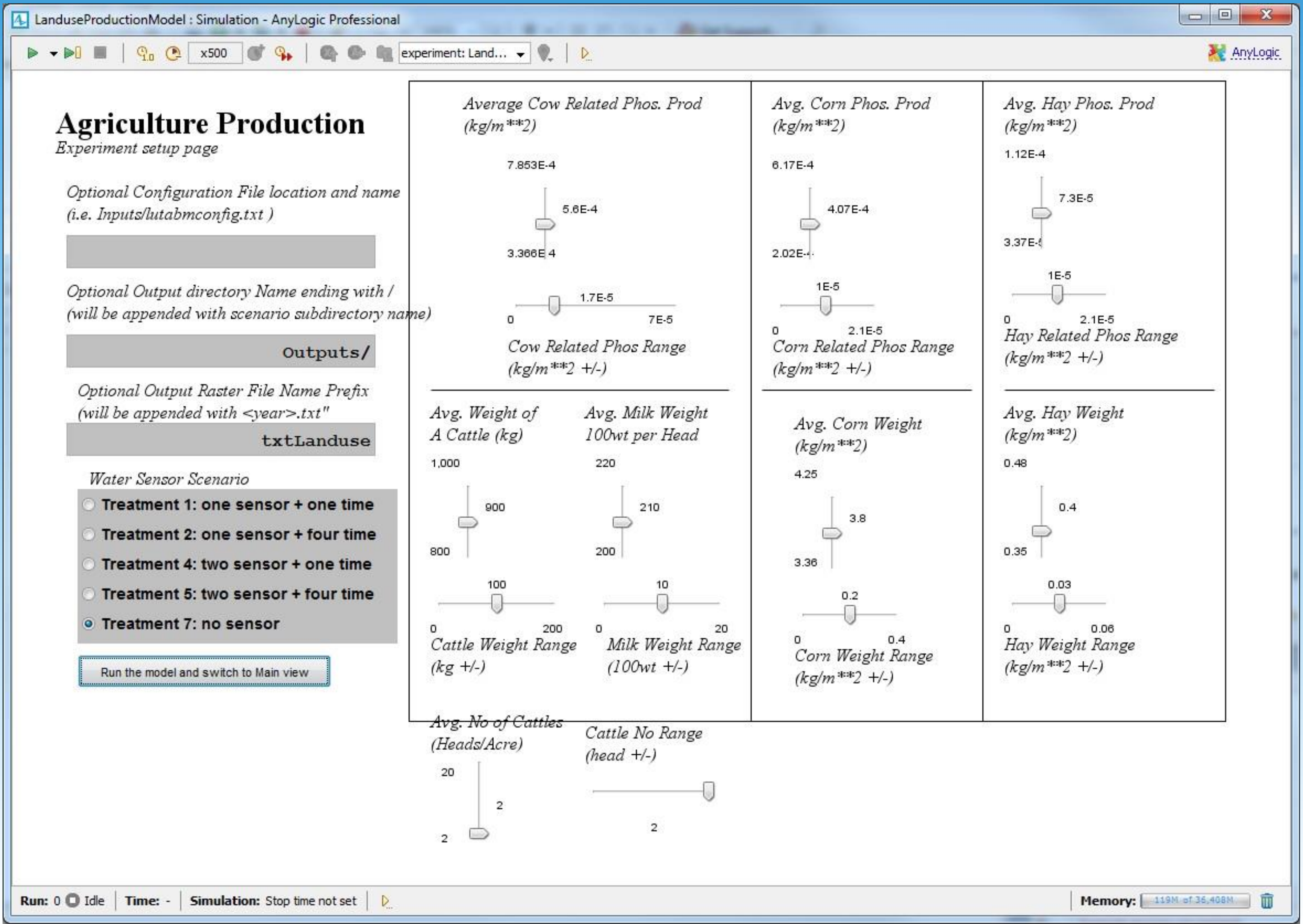
Hyper-Competitive /selfish

Multilevel multinomial logistic regression models predict induction of cooperative behaviors for different policy and sensor regimes

- Incentives in the form of taxes and subsidies generally induce cooperative behavior but the effect is conditional on the location of the agent's property in the river network
  - Downstream agents display a slightly greater likelihood to behave selfishly/competitively despite the tax/subsidy incentives.
  - The number of sensors and frequency of sensing has the greatest effect in inducing cooperative behavior for upstream agents.

- There is an optimal number of sensors and frequency of sensing that can maximize the induction of cooperative behavior. Beyond that number and frequency, the addition of sensors and frequency of sensing diminish the likelihood of cooperation in maintaining water quality.

Scaling from Games to ABMs



ABM models farmer joint production behaviors at watershed scales under different policy and sensor regimes

Control: No Sensor

Treatment 1: One Sensor & One time

ABM model calibration for Missisquoi watershed is in process

ABM model will likely be replicated in DE and/or RI watersheds

THANK YOU

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- Acknowledgements: NSF-EPSCOR & NEWRNET social science collaborators Kent D. Messer; Shanshan Ding; Haoran Miao; Jordan Suter; Jacob Fooks; Todd Guilfoos; Simona Trandafir; Emi Uchida; Yushiou Tsai; Scott Merrill; Scott Turnbull; Christopher Koliba