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Supplement of

Linking economic and social factors to peak flows in an agricultural watershed using socio-hydrologic modeling

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S1.1 Stochastic Variability of Agricultural Economic Variables

Differences in land quality causes production costs to range by approximately 20% between low and high quality land, with 50-60% of the difference due to cash rental rates, and 30-40% of the difference due to crop production inputs (i.e. seed, fertilizers, crop insurance) (Plastina, 2017b). To account for the impact of land quality, crop production costs are adjusted and stochastically varied using values and ranges derived from historical crop production costs for 2000-2018 and Cash Rental Rates from Iowa surveys for 2002-2017 (Plastina, 2017b, 2017a).

The production costs of a farmer agent are adjusted up or down based on the average Corn Suitability Rating (CSR2) value of the agent's land. CSR2 values for different soil and field conditions available from the NRCS SSURGO database were used to calculate a weighted average CSR2 value according to the fraction of soil types present (Section S2). Based on the 2015-2017 Iowa State University Land Value surveys (Zhang, 2017), low, medium, and high quality CSR2 values were determined to be 61, 74, and 86, respectively. Assuming that the historical average production costs correspond to medium quality land, a farmer agent's production costs are scaled linearly using a 10% decrease in the median cost for the lowest quality land and a 10% increase in the median cost for the highest quality land.

Stochastic variability was added to the production costs based on variability in cash rent and crop production input prices. Cash rent variability was found to be consistent across land qualities, but changed with crop price. The 25th percentile of cash rent linearly decreased from -10% to -40% from the average value between a crop price of $2.00 and $7.00, and was represented through the regression equation:

$$Decrease = -0.0449 \times CropPrice - 0.0982 \tag{S1}$$

The 75th percentile of cash rent linearly increased from +10% to +45% from the average value

between a crop price of $2.00 and $7.00, and was represented through the regression equation:

$$Increase = 0.0565 \times CropPrice + 0.0780 \tag{S2}$$

Based on the crop price, the stochastic variability added to the cash rent is randomly

drawn from the uniform distribution: $\mathcal{U}(Decrease, Increase)$. Further, it is assumed that cash

rents are unlikely to vary significantly from below to above the mean cash rent from one year to

the next. Therefore, the final variability added to the cash rent is based on a weighted average

between the previous year's and current year's variability, with equal weight place on both years.

The inputs portion of the production costs (i.e. cost of seed, fertilizer, crop insurance,

etc.) increased and decreased by ~3-4% of the total historical production costs between medium

and high quality land, and medium and low quality land, respectively. It was assumed that

variability in the input costs could range between +1.5% and -1.5% of the total production costs.

Thus, input variability was randomly drawn from a uniform distribution: $\mathcal{U}(-0.015, 0.015)$.

The final production cost is represented by the equation:

$$\begin{aligned} ProdCost_t = &[ProdCostHist_t \cdot ProdCostAdjust(CSR2)] \\ &+CashRentRandom(CropPrice_t) \\ &+[ProdCostHist_t \cdot InputCostRandom] \end{aligned} \tag{S3}$$

where $ProdCost_t$ is the final adjusted production cost for year t, $ProdCostHist_t$ is the

historical production costs, $ProdCostAdjust(CSR2)$ is the production cost adjustment based on

CSR2 value, $CashRentRandom(CropPrice_t)$ is the stochastic variability added to cash rent

based on Eqs. (S1) and (S2), and $InputCostRandom$ is stochastic variability added to input

costs.

S1.2 Opportunity Cost Adjustment

Because production costs vary based on land quality, opportunity costs are adjusted up or down such that farmer agents with higher (lower) land quality will have higher (lower) opportunity costs associated with implementing conservation land.

Based on financial analysis conducted by (Tyndall et al., 2013), farmer agents consider three key cost variables associated with implementing conservation land: cost of establishing the prairie (i.e. materials, site preparation and planting), cost of maintaining the prairie through annual mowing or burning, and cost of forgone revenue from the land taken out of crop production. Opportunity costs account for 53% of total costs of native prairie strips for low quality land and scale up to 88% for high quality land, while establishment costs account for 10% or less of total costs for high quality land and scale up as land quality decreases (Tyndall et al., 2013). For simplicity purposes, we assume opportunity costs are 90% of $Cost_{prairie}$ under high quality land and 60% of $Cost_{prairie}$ under low quality land. The remaining percentage of $Cost_{prairie}$ is assumed to be split evenly between establishment and maintenance costs. The final opportunity cost for farmer agents with land between low and medium quality is calculated as:

$$OppCost = OppCostIncreasedPerCSR2 \cdot WeightedAvgCSR - 0.104 \qquad \text{(S4)}$$

where $OppCostIncreasedPerCSR2$ is the increase in opportunity costs per point increase in the CSR2 value (i.e. slope), and the value -0.104 is the intercept which gives an opportunity cost of 60% of total costs at a CSR2 value of 61. A similar equation is used for finding the opportunity cost between medium and high quality land, with the difference being the intercept coefficient. The final cost per acre of implementing conservation land is calculated using the following equation:

$$Cost_{prairie:t} = OppCost + Establishment + Maintenance \qquad \text{(S5)}$$

where $OppCost$ is based on the cash rent input, and establishment and maintenance costs are

calculated as:

$$\frac{Establishment}{Maintenance} = CashRent \cdot \frac{\dfrac{1 - 0.9}{2}}{0.9} \tag{S6}$$

S2. Soil Crop Yield Adjustment and Stochastic Variability

A farmer agent's land can be defined by up to 8 different soil types at different

percentages. The soil types used are common to the Squaw Creek watershed: Nicollet Loam (1-

3% slope), Clarion Loam (2-5% slope), Webster clay loam (0-2% slopes), Canisteo clay loam (0-

2% slopes), Clarion loam (5-9% slopes, moderately eroded), Harps loam (1-3% slopes), Clarion

loam (5-9% slopes), and Okoboji mucky silt loam (0-1% slopes). To account for differences in

soil crop productivity, adjustments were developed using field scale data spanning 1995-2006

from 10 fields in central Iowa (USDA-ARS Cooperative Grower 3625-13660-14S). Mean yearly

yields were derived for each soil type over the course of the 11-year period. The mean yearly

yields for each soil type were compared against mean historical central Iowa crop yields for the

same period. Soil type adjustments were calculated as the mean differences between the mean

yearly yield and mean historical yield. In general, the soils displayed on average a 0.35 Mt/Ha

higher yield over mean historical central Iowa yields. For Clarion loam (5-9% slopes, moderately

eroded), yields were approximately 0.11 MT/Ha lower than the mean central Iowa yield, while

Nicollet Loam (1-3% slope) on average produced 0.63 MT/Ha higher yields. All other soil type

displayed differences in mean yield between these values. The adjustment factors were added to

the crop yield for each soil type over the entire simulation period, thereby assuming that the

factors are constant through time.

To account for other factors that influence crop productivity, stochastic variability drawn from a uniform distribution between the 5th and 95th percentile yields for each soil type are added to the yield for that year. For example, the 5th and 95th percentiles of yields for Nicollet Loam were on average 0.9 MT/Ha lower and 0.95 Mt/Ha higher than the mean yearly yield for Nicollet loam. Thus, after adjusting the soil yield up by 0.63 MT/Ha, stochastic variability was then added from the uniform distribution: $\mathcal{U}(-0.9, 0.95)$.

S3. Farm Agent Network

The farmer agent network influences the diffusion of conservation adoption. Farmers trust their neighbors for providing reliable information about crop production (Arbuckle, 2017) and are heavily influenced by their neighbors' practices (Davis and Gillespie, 2007; McGuire et al., 2013; Saltiel et al., 1994). In the farmer agent module, a probabilistic-based network is established where the number of connections that an agent makes is randomly drawn from a binomial distribution (Newman et al., 2002) which describes the probability of forming k connections:

$$P(k) = \binom{n-1}{k} p^k (1-p)^{n-1-k} \qquad n \in \{0, .., n-1\} \qquad (S7)$$

where a farmer in a subbasin of n agents can make up to $n-1$ connections, each with the same success probability of p. Currently, p is set to 0.5 in the model, indicating a 50% probability of forming a connection with any one farmer. A second parameter that describes the farmer network is the connection strength, $ConnStrength$ (Granovetter, 1973) which indicates the probability of the agents sharing their land use information during any given year. Once a farmer agent initiates a connection with another farmer agent, their connection strength is randomly chosen from the uniform distribution: $\mathcal{U}(0, 1)$. A farmer agent wanting to communicate with

another farmer agent is defined by a random choice from a Bernoulli distribution with $p = ConnStrength$. If the choice of connection is a success for both farmer agents, they share information; however, if the choice of connection is a success for only one farmer agent (i.e. one farmer agent wants to communicate with the other, but the other farmer agent does not want to communicate back), then the agents do not share information.

S4. Farmer Agent Profit Decisions

The past profits decision is solely based on outcomes that have been fully realized for the previous X years. In this decision, the land allocated to conservation is based on the net amount of money that could have been earned per hectare of conservation land versus crop land and is calculated as:

$$\delta C_{profit:X} = \left[A * Profit_{diff}{}^2 + B * Profit_{diff} + C\right] \cdot Cons_{max} \cdot Hectares_{tot} \quad \text{(S8)}$$

where $Profit_{diff}$ is the difference in profit between a hectare of cropland and a hectare of conservation land (Table S1), $Cons_{max}$ is the farmer agent's maximum conservation parameter, $Hectacres_{tot}$ is the area of the agent's land, and A, B, C are equation coefficients discussed later.

$Profit_{diff}$ is calculated as:

$$Profit_{diff} = \frac{1}{n} \sum_{t=t-1}^{t=t-X} Profit_{crop:t} - Profit_{cons:t} \quad \text{(S9)}$$

where,

$$Profit_{crop:t} = (CropPrice_t \cdot Yield_t) - ProdCost_t + FedSub_t + CropIns_t \quad \text{(S10)}$$

and,

$$Profit_{cons:t} = ConsSubsidy_t - Cost_{prairie:t} \quad \text{(S11)}$$

$Profit_{crop:t}$ is the profit received for cropland in year t (Table S1), $CropPrice_t$ is the realized

crop price for year t, $Yield_t$ is the farmer's realized mean yield (per hectare) for year t,

$ProdCost_t$ is the crop production cost for year t, $FedSub_t$ is the amount of federal subsidies the

farmer received in year t, $CropIns_t$ is the total amount of crop insurance received in year t

(Section S6), $Profit_{cons:t}$ is the profit received for conservation land in year t, $ConsSubsidy_t$ is

the conservation subsidy established in year t, and $Cost_{prairie:t}$ is the cost associated with

establishing and maintaining conservation land in year t (Section S1.2).

The future crop prices decision is based on a combination of past performance

information and projected future crop prices. Equations (S8), (S9) and (S11) are used to calculate

the land allocated to conservation based on future crop price, $\delta C_{futures:Y}$, with $CropPrice_t$ in

Eq. (S10) being replaced with $CropPrice_{t:t+Y}$. $CropPrice_{t:t+Y}$ is the projected crop price for

the Y upcoming growing seasons, and is based on historical crop prices with an added

adjustment calculated from historical errors in crop price forecasts produced by the U.S.

Department of Agriculture (Section S5).

The first term in Eq. (S8) is a second-degree polynomial of form $Ax^2 + Bx + C = y$,

therefore three equations need to be simultaneously solved to determine coefficients A, B, C.

δC_{profit} and $\delta C_{futures}$ can take on values between -100% to 100% depending upon whether the

farmer agent observes a positive or negative $Profit_{diff}$. If the farmer agent observes a positive

$Profit_{diff}$, the agent uses all historical positive $Profit_{diff}$ values from the start of the

simulation through $t - 1$ to solve for the coefficients using the following system of equations:

$$A(P_{upper})^2 + B(P_{upper}) + C = -maxChange$$
$$A(P_{middle})^2 + B(P_{middle}) + C = -0.5maxChange \qquad \text{(S12)}$$
$$A(P_{lower})^2 + B(P_{lower}) + C = 0$$

where P_{upper}, P_{middle}, and P_{lower} are upper, middle, and lower percentiles of the historical

positive $Profit_{diff}$ values (Table S1), respectively, and $maxChange$ is the maximum allowed

change in conservation land in any given year, which is equal to 1.0 (up to 100% change

possible). In this study, P_{upper}, P_{middle}, and P_{lower} are set to the 75th, 50th, and 25th percentiles.

When $Profit_{diff}$ is positive (i.e. greater profit was earned from crop production than

conservation land), the farmer agent will potentially decrease the amount of land in conservation.

A similar process occurs when the farmer observes a negative $Profit_{diff}$; however, the system

of equations now becomes:

$$A(P_{lower})^2 + B(P_{lower}) + C = maxChange$$
$$A(P_{middle})^2 + B(P_{middle}) + C = 0.5maxChange \qquad \text{(S13)}$$
$$A(P_{upper})^2 + B(P_{upper}) + C = 0$$

Under negative $Profit_{diff}$, conservation land is potentially increased because the farmer earned
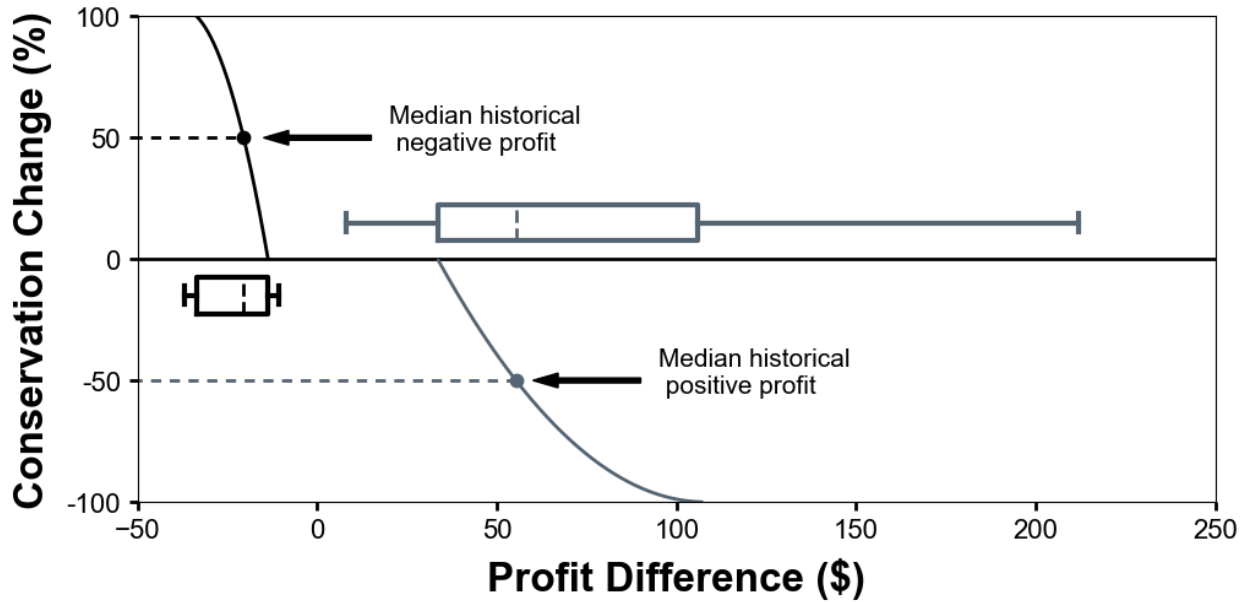
a lower revenue through crop production.

Figure S1. Example of percent conservation change for δC_{profit} and $\delta C_{futures}$. Gray curves indicate negative percent change (decrease conservation land), black curves indicate positive percent change (increase conservation land).

Equations (S12) and (S13) are illustrated in Fig. S1. Half of the maximum allowable percent increase in conservation land $(+0.5 maxChange)$ is assumed to correspond to the median historical negative $Profit_{diff}$, whereas half of the maximum allowable percent decrease in conservation land $(-0.5 maxChange)$ corresponds to the median historical positive $Profit_{diff}$ (Figure S1). We assume that farmer agents will not change land use when a very small profit difference between the two possible options is observed because changing land use requires extra upfront time and resources (Duffy, 2015). Similarly, we assume that farmer agents will fully implement the maximum land conversion possible prior to reaching the most extreme $Profit_{diff}$ values. Therefore, an increase in conservation land begins to occur when the negative $Profit_{diff}$ value is less than the 75th percentile of historical negative $Profit_{diff}$ and reaches a maximum (100% change) when the negative $Profit_{diff}$ reaches the 25th percentile (black curve

in Figure S1). A decrease in conservation land begins to occur when the positive $Profit_{diff}$ is greater than the 25th percentile of historical positive $Profit_{diff}$ and reaches a maximum (-100%) when the positive $Profit_{diff}$ reaches the 75th percentile (gray curve in Figure S1). A farmer increases or decreases conservation land as a fraction of the $Cons_{max}$ parameter (Equation S8).

S5. Market Module

The primary purpose of the market is to provide forecasts of crop prices at the start (February) of each year and realized crop prices at the end (October) of each year when farmer agents harvest their crop. Each farmer agent receives yearly forecasts of future crop prices that predict crop prices for 10 years into the future (i.e. year t to year $t + 10$). The market module formulates a forecast based on historical crop prices and error estimates of U.S Department of Agriculture (USDA) crop price forecasts.

Twelve years of USDA crop price forecasts for 2001-2012 were analyzed against realized crop prices to form error functions. For each 10-year forecast, errors were calculated between the historical crop prices and the forecasted crop prices. Through marketing year 2009/2010, errors were generally in the -$1/Bu to -$2/Bu range (-$39.3/MT to -$78.7/MT) with errors reaching a peak of -$4.44/Bu (-$174.5/MT) for 2012/2013 when crop prices were high. A multiple linear regression was performed between crop price magnitude, time from forecast year and error. In general, crop price magnitude explained most of the error pattern in each forecast, with error showing little correspondence with time from forecast year. When the starting crop price was low (i.e. crop price at the beginning of the forecast), the USDA forecasts underestimated future high crop prices by as much as 50-60% (Figure S2, errors labeled <2007). However, when starting crop prices were higher (Figure S2, errors labeled > 2007), the USDA forecasts underestimated future high crop prices by 20-40%. From $2/Bu – $7/Bu ($78.7/MT –

$275.1/MT), errors change from approximately +30% to -40%. The error for each forecast was modeled as:

$$Error_{CropPrice} = A \cdot Price^2 + B \cdot Price + C \qquad \text{(S14)}$$

where A, B, C are coefficients from the regression. For each year from 2001-2011, the Pearson's r value was 0.9 or higher except for 2012, which had a Pearson's r of 0.71. This is indicative of a strong relationship between price and error.
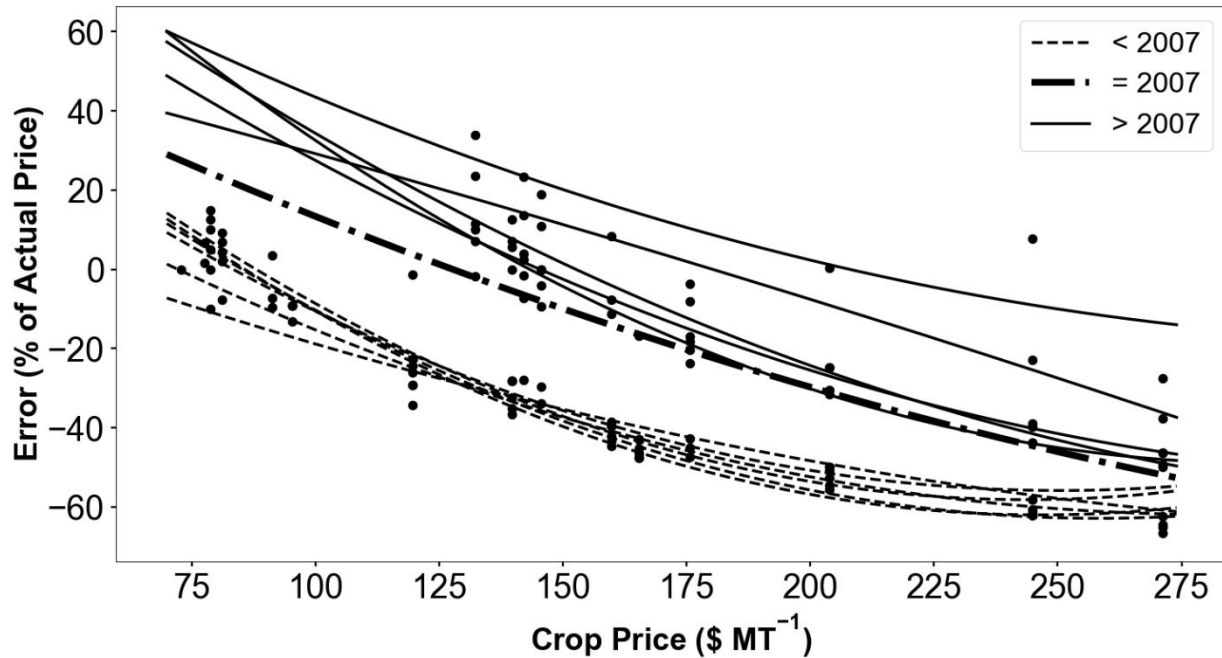

Figure S2. Relationships between crop price and error used in the Market Agent module. Fine dotted curves indicate errors for forecasts prior to 2007 while solid curves indicate errors for forecasts after 2007.

In the market module, each of the 12 error equations for the 12 price forecasts are used (Figure S2) and the error equation with a starting crop price closest to the current year's crop price is chosen for formulating the 10-year forecast based using the following equation:

$$CropPriceForecast_{t+n} = CropPrice_{t+n} + \left(\frac{Error_{CropPrice}}{100} \cdot CropPrice_{t+n} \right) \qquad \text{(S15)}$$

where $CropPriceForecast_{t+n}$ is the forecasted crop price for year $t + n$ (t is the current year),

$CropPrice_{t+n}$ is the historical crop price for year $t + n$, and $Error_{CropPrice}$ is the error based on

$CropPrice_{t+n}$.

S6. Farmer Agent Crop Insurance

The crop insurance protection in the model follows the Revenue Protection (RP) plan,

which accounts for 95-100% of the insurance plans chosen by farmers in the U.S corn belt

(Schnitkey, 2017) from the options available through the USDA Agricultural Risk Management

agency in the Common Crop Insurance policy. Each farmer agent is on the RP crop insurance

plan at an 80% coverage level with insurance premiums factored into the crop production costs.

The RP plan protects farmer agents against poor yields and suppressed crop prices. In a given

year, the insurance payout per hectare (Gross Indemnity) at an 80% coverage level for corn crop

is calculated as (Plastina, 2014a):

$$Gross\ Indemnity\ = Rev\ Guarantee - Actual\ Rev \qquad (S16)$$

where,

$$Rev\ Guarantee = max(Projected\ Price, Harvest\ Price) * Coverage\ Level \\ * TrendAdj\ APH\ Yield \qquad (S17)$$

and,

$$Actual\ Rev = Harvest\ Price * Harvest\ Yield \qquad (S18)$$

The trend-adjusted actual production history (APH) yield is calculated as (Plastina, 2014b):

$$TrendAdj\ APH\ Yield = \frac{\sum_{n=1}^{n=10} Yield_{t-n} + \ AdjustmentFactor \cdot n}{10} \qquad (S19)$$

where $Yield_{t-n}$ is the historical yield for year $t - n$, with year t being the current year. The yield

is based on the mean yield of the previous 10 years. For each year, the yield is adjusted upward

by $AdjustmentFactor \cdot n$, where n is the number of years back in time from the current year.

The most recent adjustment factors for Iowa have ranged from 1.90 -2.40 (Plastina, 2014b), with

an $AdjustmentFactor$ value of 2.0 used in the model. The mean of the adjusted yields then gives the trend-adjusted APH yield.

S7. Flood Damage Calculation

Flood damages are calculated using a flood damage function defined by Tesfatsion et al. (2017):

$$FDam = \frac{FDmax}{1 + \exp[-(peakQ - Q50)/dQ)]} \tag{S20}$$

where $FDam$ is the total flood damage in dollars ($) (Table S2), $FDmax$ is the maximum flood damage that can be incurred in dollars ($), Q50 is the flow at which damage is 50% of the maximum, and dQ is the width of the transition of the flood damage curve. $Q50$ is defined as:

$$Q50 = \frac{Q_{min} + Q_{max}}{2.0} \tag{S21}$$

where Q_{min} is the flow at which damage is 1% of the maximum damage and Q_{max} is the flow at which damage is 99% of the maximum damage. Currently, Q_{min} is set to 317.46 m³/s and Q_{max} is set to 620.62 m³/s. These values were obtained by simulating the Squaw Creek Watershed at Ames, IA over the 1970-2016 period and calculating the 10 year flood stage and 100 year flood stage. Maximum damage is set to $50 000 000 based on estimates of flood damage during the 2010 Ames, IA flood. dQ specifies how rapidly flood damages accrue from minor flood stage to maximum flood stage (Tesfatsion et al., 2017):

$$dQ = \frac{Q_{max} - Q_{min}}{9.2} \tag{S22}$$

References

Arbuckle, J. G.: Iowa Farm and Rural Life Poll 2016 Summary Report, Ames, IA., 2017.

Davis, C. G. and Gillespie, J. M.: Factors affecting the selection of business arrangements by U.S. hog farmers, Rev. Agric. Econ., 29(2), 331–348, doi:10.1111/j.1467-9353.2007.00346.x, 2007.

Duffy, M.: Conservation Practices for Landlords, Ames, IA., 2015.

Granovetter, M.: The Strength of Weak Ties, Am. J. Sociol., 78(6), 1360–1380, 1973.

McGuire, J., Morton, L. W. and Cast, A. D.: Reconstructing the good farmer identity: Shifts in farmer identities and farm management practices to improve water quality, Agric. Human Values, 30(1), 57–69, doi:10.1007/s10460-012-9381-y, 2013.

Newman, M. E. J., Watts, D. . J. and Strogatz, S. H.: Random graph models of social networks, Pnas, 99(suppl. 1), 2566–72, doi:10.1073/pnas.012582999, 2002.

Plastina, A.: Current Crop Insurance Policies, Ames, IA., 2014a.

Plastina, A.: Trend-Adjusted Actual Production History (APH), Ames, IA., 2014b.

Plastina, A.: Cash Rental Rates for Iowa 2017 Survey, Ames, IA., 2017a.

Plastina, A.: Estimated Costs of Crop Production in Iowa - 2017, Ames, IA., 2017b.

Saltiel, J., Bauder, J. W. and Palakovich, S.: Adoption of Sustainable Agricultural Practices: Diffusion, Farm Structure, and Profitability, Rural Sociol., 59(2), 333–349, 1994.

Schnitkey, G.: Revenue Protection (RP) Use on Corn in the Midwest, Champaign, Il., 2017.

Tesfatsion, L., Rehmann, C. R., Cardoso, D. S., Jie, Y. and Gutowski, W. J.: An agent-based platform for the study of watersheds as coupled natural and human systems, Environ. Model. Softw., 89, 40–60, doi:10.1016/j.envsoft.2016.11.021, 2017.

Tyndall, J. C., Schulte, L. A., Liebman, M. and Helmers, M.: Field-level financial assessment of

contour prairie strips for enhancement of environmental quality, Environ. Manage., 52(3), 736–747, doi:10.1007/s00267-013-0106-9, 2013.

Zhang, W.: 2017 Iowa State University Land Value Survey: Overview, Ames, IA., 2017.

Farmer Agent Variables	Description	Unit
$C_{t-1:t-X}$	Mean total amount of land allocated to conservation during the previous X years	Hectares
D_{t-1}	Previous year's conservation land decision	Hectares
$\delta C_{futures:Y}$	Conservation decision based on crop price projections for Y years into the future	Hectares
$\delta C_{profit:X}$	Conservation decision based on mean past profit of previous X years	Hectares
δC_{cons}	Conservation decision based on conservation goal	Hectares
$C_{neighbor}$	Weighted mean conservation land of the farmer agent's neighbors	Hectares
$Profit_{diff}$	Differences in profit between an acre of crop and an acre of conservation land	($/Hectare)
$Hectares_{tot}$	Total land owned by farmer agent	Hectares
$Profit_{crop:t}$	Profit derived from an acre of crop land in year t	($/Hectare)
$Profit_{cons:t}$	Profit derived from an acre of conservation land in year t	($/Hectare)
$CropPrice_t$	Crop price for year t	($/MT)
$Yield_t$	Average farm yield per hectare for year t	(MT/Hectare)
$ProdCost_t$	Production cost per hectare for year t	($/Hectare)
$FedSub_t$	Federal subsidy per hectare for year t	($/Hectare)
$CropIns_t$	Crop insurance per hectare for year t	($/Hectare)
$ConsSubsidy_t$	Conservation subsidy rate per hectare for year t	($/Hectare)
$Cost_{prairie:t}$	Cost of establishing and maintaining native prairie for year t	($/Hectare)
P_{upper}	Upper percentile of historical profit differences	($)
P_{middle}	Middle percentile of historical profit differences	($)
P_{lower}	Lower percentile of historical profit differences	($)
maxChange	Conservation change as a fraction of $Cons_{max}$	Dimensionless

Table S1. Variables in farmer agent equations.

City Agent Variables	Description	Unit
FDam	Current year's flood damage	($)
FDmax	Maximum attainable flood damage	($)
Q50	Discharge at with flood damage if 50% of maximum	(m³/s)
Q_{min}	Discharge at with flood damage if 1% of maximum	(m³/s)
Q_{max}	Discharge at with flood damage if 99% of maximum	(m³/s)
dQ	Width of transition of flood damage curve	(m³/s)
G_t	Government agent conservation goal for the current year t	Hectares
G_{t-1}	Unfullfilled conservation land from the previous year's t-1 conservation goal	Hectares
A_{tot}	Total agricultural land in watershed	Hectares
C_{tot}	Total land currently in conservation	Hectares
P	Total conservation land to be added to the goal as a percentage of production land	Dimensionless
P_{new}	Variable describing change in conservation goal with flood damage	(1/$)

Table S2. Variables in city agent equations.