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Farm and County Scale Scenarios for Sustainable Agriculture in Western Iowa

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Abstract. *This paper deals with ecosystem, social, and economic impacts of changes in land-use, crop rotations, and farm management in two counties in western Iowa. In this region, expansion of farm size, increase in the average age of farmers, and reductions in labor availability have been continuous processes, caused by agro-economic and social factors over the last several decades. The landscape of the Loess rolls in western Iowa includes fields with hill slopes ranging from 0 to beyond 14%. Many of the soils are highly erodible. A two-year rotation of corn-soybeans is currently the most common cropping system, and results in considerable soil loss from bare soils in winter and spring. On many farms livestock production has dramatically decreased or disappeared entirely over the last 25 years. Our project focuses on re-integration of crop and livestock production. Our main goal is to investigate the ecological impacts of replacing chemical fertilizers by animal manure and of including perennial crops and pastures in the cropping system.*

The I-FARM simulation model is being used to estimate the ecological effects of various crop and livestock production systems at the farm scale. When using local land-use data and the simulation model, we are able to predict effects of alternative cropping systems and livestock production at the county scale on soil loss, nutrient balances, and associated labor requirement. The paper will show some results of simulations in terms of crop diversity patterns, livestock to be raised in a closed system at the county level, fertilizer replaced by manure, farm labor required, erosion and nutrient control, and economic consequences. We also present some social trends.

Keywords. Model, web-based, interactive, sustainable, farming, simulation, erosion, nutrients, ecology, agro-economics, social structure, energy, labor, scenario.

Introduction

In western Iowa farm size expansion, increasing average age of farmers, and decreasing labor availability have been continuous processes, caused by agro-economic and social factors over the last several decades. The landscape of the Loess rolls in western Iowa contains fields with hill slopes ranging from 0 to beyond 14%. Many of the soils are highly erodible. A two-year rotation of corn-soybeans is the most common cropping system, and causes considerable soil loss from bare soils in winter and spring. Specialization has led to the disappearance of livestock from many farms over the last 25 years, while others have focused on intensive livestock production. This paper focuses on re-integration of crop and livestock production. Our main goal is to investigate the ecological impacts of replacing chemical fertilizers by animal manure and of including perennial crops and pastures in the cropping system.

A simulation model is being used to estimate the ecological effects of various crop and livestock production systems at the farm scale. By applying the simulation model to regional soil, topography, and land use data, we are able to predict effects of alternative crop and livestock production systems at the county scale. Indicators being evaluated include soil loss, nutrient balances, and associated farm labor requirements. The paper shows results of simulations in terms of crop diversity patterns and livestock numbers, fertilizer replaced by manure, farm labor required, erosion and nutrient control, and economic consequences, at both farm and county scales. We also present socio-economic farming trends in the area.

Methods

Simulation model

A new farm-scale simulation model, called I-FARM, has recently been developed at Iowa State University. The model is web-based and database-driven and incorporates the USDA-ARS RUSLE 1.06 soil erosion model, a crop and forage budget module, a nutrient budget module, and an economic evaluation module. Global built-in inputs, of which many are adjustable, include: soil erodibility, soil drainage classes, cover-management factors, livestock feed intake and manure production, crops, crop residues, and crop rotations, farm labor requirements, field practices such as tillage, fertilization, planting, weed control, harvest and residue removal, fuel consumption of field operations, and fixed and variable unit and market prices for inputs and commodities. Local inputs, of which many are built-in and all are adjustable, include: topographical and statistical information on livestock production, crop yields, rainfall intensity and atmospheric deposition.

The model can be accessed at http://evo.ae.iastate.edu. The web site provides extensive global data and their references, and a number of examples that include local inputs to develop scenarios similar to those provided below.

Analytical approach

We defined farm-scale and regional-scale baseline and alternative scenarios based on hill slope classification and varying degrees of crop-livestock integration. Then we ran the simulations and interpreted the results.

Farm-scale scenarios
We made the following assumptions for the farm-scale scenarios:

- the size of the farm is 1000 acres. This is about 2.5 times the average farm size in the region; a size of farm that is likely to accept major management changes.
- soils: Ida silt loam for slopes <5%, with the remainder Marshall silty clay loam
- pigs are kept in conventional buildings
- available labor (farmer's family) 6000 hours/year, hired labor (>6000 hrs/year) at $ 10 per hour
- base yields (Shelby County, IA, 2002 Census of Agriculture): corn 143 bu/acre, soybeans 47 bu/acre, forages 3.3 tons/acre
- all the scenarios have 400 acres of corn and 400 acres of soybeans, except the fully-integrated beef farm with more pastures, which only has 266 acres of corn and 133 acres of soybeans
- government payments: direct payments (DP), counter cyclical payments (CCP), and loan deficiency payments (LDP), based on 2002 Farm Bill
- all land owned (no land rent costs, the bank loans below reflect land mortgages)
- bank loans: $1 million for the non-integrated farm, $1.2 million for the beef farm, and $1.4 million for the pig farm with buildings, at 6% interest/year

County-scale scenarios
We made the following additional assumptions for the county-scale scenarios:

- two western Iowa counties (Crawford and Shelby Counties, total area 774,000 acres of agricultural land) were evaluated as a single farm
- livestock numbers were derived from 2002 Census of Agriculture
- current land-use was derived from remote sensing data (2001): 82% in row crops and oats, 18% in pasture/hay or conservation land
- hill slope classes: corn, soybeans, and oats 5%, alfalfa and grass/legumes for forage and grazing 10%, other land 20%
- alternative land use:
    - 20% in 2-year rotation corn-soybeans, on fields 0-5% hill slope,
    - 60% in 6-year rotations including grazing, on fields 5-14% slope,
    - 5% in permanent pasture, 14-30% slope, and
    - 15% in ecological reserve >30% slope

Other data and assumptions, used for the scenario evaluations
Livestock manure data were taken from USDA (1992) standard tabular values. The nutrient uptake and removal of crops were derived from NRCS (2004) values, and modified for nitrogen Hurburgh (2004) and for phosphorus Sawyer et al. (2002). For nitrogen fixation of legume crops

we used values presented by Brick (2001). Soil properties were taken from ISPAID (2004), where denitrification from the soil was calculated according to Meisinger and Randall (1991). The nitrogen deposition was derived from the NADP web site (NADP 2004).

For economic inputs, we used fixed and variable unit prices and labor requirements from May et al. (2003) and Duffy and Smith (2003) and varied the market prices for livestock, corn, and soybeans according to the Census of Agriculture data of the last 10 years (Table 1). We used the fuel required for field operations as described by Hanna (2001).

Table 1. Market prices in Iowa (1993-2002, National Agricultural Statistical Service)

Product	Unit	10-year average	year 2002	current (Jan. 2004)
corn	$/bushel	2.22	2.22	2.30
soybeans		5.58	5.54	6.80
hogs	$/lb of live weight	0.43	0.34	0.47
beef cattle		0.65	0.66	0.90

Three crop rotations are considered in the analysis (Table 2). The 2-year corn-soybean rotation is only applied on the fields with hill slopes below 5%. Other rotations (6-years with perennials) are primarily designed to limit soil loss on fields with hill slopes beyond 5%. We assume that fields with hill slopes beyond 14% cannot be cropped with annual row crops. There we only allow grass land for forage production or grazing. On fields with hill slopes beyond 30% we do not allow any agricultural use, but classify the land as ecological reserve.

Table 2. Crop rotations

year	2-year	6-year with grass hay/grazing	6-year with alfalfa
1	corn	corn	corn
2	soybeans	soybeans	soybeans
3		corn	corn
4		grass/legumes for forage	oats/alfalfa for forage
5		grass/legumes for grazing	alfalfa for forage
6		grass/legumes for grazing	alfalfa for forage

For the alternative land-use scenarios we tried to avoid corn grain export from the region and increased the numbers of livestock until all corn grain was fed to them locally. For both beef cattle and swine production we evaluated two options: one without local reproduction, i.e. import of calves or piglets from outside the region, which we call semi-integrated, and one with reproduction (i.e. closed production systems of cow-calf pairs and finishing beef cattle or farrow to finish swine production), which we call fully-integrated. For the fully-integrated beef production scenarios we set a pasture constraint of 2.5 acres per cow-calf unit, which is an acceptable ratio of land to livestock for non-rotational grazing in Iowa.

Results

Farm-scale scenario input

The simulation model allows a farm to be divided into multiple fields with different slopes, soil characteristics, and land management strategies. We divided this hypothetical farm into three fields with areas proportional to areas of corresponding slope classes in the two western Iowa counties (Crawford and Shelby). This resulted in two land-use strategies associated with five farming system scenarios. The first farming system scenario is the non-integrated farm without livestock. The other four scenarios are farms with either pigs or beef cattle. For the farms with livestock we estimated the corn grain production and the number of animals that the corn produced on that farm could support. Table 3 provides the livestock input for the five land-use scenarios, while table 4 indicates the land-uses and slope classes.

Table 3. Livestock input for the five farm-scale scenarios and the allowed imports

	non-integrated	semi-integrated	fully-integrated	semi-integrated	fully-integrated
	crops	pigs		beef	
	(1)	(2)	(3)	(4)	(5)
Animals	none	2,500 hogs	1,500 hogs 462 nursing pigs 58 lactating sows 97 gestation sows	930 beef	175 cow-calf pairs 134 beef
Imports	none	piglets	none	calves, forages	none

Table 4. Land-use and slope classes for the five farm-scale scenarios

non-integrated	semi-integrated	fully-integrated	semi-integrated	fully-integrated
crops	pigs		beef	
(1)	(2)	(3)	(4)	(5)
200 acres 2-year rotation at 2.5% slope 600 acres 2-year rotation at 9.5% slope 200 acres grass/legume for hay at 22% slope				200 acres 6-year hay rotation at 2.5% slope 520 acres 6-year hay rotation at 9.5% slope 80 acres 6-year alfalfa rotation at 9.5% slope 200 acres grass/legume for grazing at 22% slope

Farm-scale scenario output

Ecosystem impacts for the simulations of the five farm-scale scenarios are shown in Table 5. Although each field has a different output, the table gives the average value for the whole 1000 acre farm.

Table 5. Ecosystem impacts of the five farm-scale scenarios

	non-integrated	semi-integrated	fully-integrated	semi-integrated	fully-integrated
	crops	pigs		beef	
	(1)	(2)	(3)	(4)	(5)
soil erosion (tons/acre/year)	11.5	11.5	11.5	11.5	3.4
nitrogen fertilizer required (lbs/acre/year)	108	75	82	97	72
phosphate fertilizer required (negative values represent a phosphate excess) (lbs/acre/year)	23	-26	-14	-16	-12
energy required for arable farming part (diesel gallons/acre/year)	3	3	3	3	1.5

Only scenario 5 has a sustainable rate of soil loss. For all the other scenarios the soil loss exceeds the tolerable soil loss for these soils, which is 4-5 tons/acre/year. Manure fertilization in scenarios 2 through 5 significantly decreases the additional chemical nitrogen fertilizer required. For all scenarios with livestock the farm has a phosphate excess, which is particularly problematic for the farm having pigs. In swine systems farmers can decrease the phosphate content in manure by including phytase enzymes in the swine diet, so we are currently implementing phytase diet parameters in the animal nutrition model. The fuel consumption on the ‘pasture farm’ (scenario 5) is significantly lower than on the farms that use large tillage and harvest equipment.

Table 6 presents selected socio-economic impacts for the five farm-scale scenarios.

Table 6. Socio-economic impacts of the five farm-scale scenarios

	non-integrated	semi-integrated	fully-integrated	semi-integrated	fully-integrated
	crops	pigs	pigs	beef	beef
	(1)	(2)	(3)	(4)	(5)
labor required (hrs/year)	2,540	6,040	7,800	5,330	3,970
farm income before taxes ($/labor hour)					
10-year average	37	32	25	6	4
year 2002	37	6	12	7	4
current	47	47	33	58	15

Farmers on farms of this size would typically be part-time farmers who earn part of their annual income off-farm, while hiring assistance during planting and harvest seasons when on-farm labor demand is extremely high. Livestock farming is less profitable and requires full time involvement. Under current prices, the semi-integrated beef farms are more profitable than non-integrated farms per labor hour, providing at least temporary rewards for farmers raising beef.

If we assume that the US 2002 Farm Bill had already been effective during the last 10 years, we can consider the government payment contribution to before tax farm income. This is shown in table 7.

Table 7. Government payments contribution as a percent of total the farm income before tax for the five farm-scale scenarios

	non-integrated	semi-integrated	fully-integrated	semi-integrated	fully-integrated
	crops	pigs		beef	
	(1)	(2)	(3)	(4)	(5)
10-year average	29	14	14	87	104
2002 average	29	81	28	68	96
current (Jan. 2004)	20	8	9	7	22

Here we see that non-integrated farming is structurally supported by government payments and integrated farming with income levels below the hired labor levels is just kept 'alive' by the government payments.

County-scale scenario input

For the county-scale analysis, we generated two cropping strategies. The baseline vegetation strategy uses current land-use data, while the alternative vegetation strategy uses the slope-based land-use distribution described in the Method section above.

To generate a realistic baseline livestock scenario, we analyzed the recently published 2002 Census of Agriculture data and recalculated the reported animal numbers for six livestock categories that are differentiated in I-FARM (Table 8). When we compare these numbers with the reported animals sold we conclude that there is an ongoing and considerable import of young livestock (calves and piglets) and forages in those counties, as well as significant exports of corn and soybean. Matching the corn produced with the corn consumed within the two county study area, we generated two alternative livestock scenarios. The first is a fully-integrated beef production system with an allowance for corn export (scenario A in table 8), and the second is a combination of fully-integrated beef production with semi-integrated swine production that locally consumes all corn produced (scenario B in table 8).

Table 8. Livestock input for the three county-scale scenarios and the allowed imports and exports

	current conditions	fully-integrated beef	fully-integrated beef and semi-integrated swine
	(C)	(A)	(B)
animals	20,090 gestation sows 6,000 lactating sows 64,760 nursing pigs 210,820 finishing hogs 27,485 cow-calf units 28,050 finishing beef	70,000 cow-calf units 53,470 finishing beef	70,000 cow-calf units 53,470 finishing beef 1,300,000 finishing hogs
imports	piglets, calves, forages	no	piglets
corn export	yes	yes	no

Even under current conditions, we see that there is a certain level of integration of crop and livestock production in this region, although the livestock numbers are considerably smaller than could be supported with the feed produced. It is not known how much locally produced manure is actually applied on the local farms.

County-scale scenario output

The ecosystem impact simulation output for the county-scale scenarios is presented in table 9.

Table 9. Ecosystem impacts of the three county scale scenarios.

	current conditions	fully-integrated beef	fully-integrated beef and semi-integrated swine
	(C)	(A)	(B)
soil erosion (tons/acre/year)	7	3.2	3.2
nitrogen fertilizer required (lbs/acre/year)	110	88	60
phosphate fertilizer required (the negative value represents a phosphate excess) (lbs/acre/year)	8	3	-30
energy required for arable farming part (diesel gallons/acre/year)	2.1	1.85	1.85

The future livestock scenarios (A and B) show reasonable soil losses. Under current conditions this soil loss exceeds the tolerable soil loss for the local soils (3-5 tons/acre/year). The two alternative scenarios contribute to a large reduction in average per-acre soil loss. Manure fertilization in scenarios A and B significantly decreases the current chemical nitrogen fertilizer requirement of the two counties. For the scenario with swine there is a phosphate excess, similar to that noted in the farm-scale analysis. As previously mentioned, we could decrease the phosphate content in this manure by incorporating phytase enzymes in the swine diets. The fuel consumption on the ‘pasture land’ scenarios (A and B) is lower than on the farms that use large tillage and harvest equipment under current conditions.

Table 10 presents the socio-economic impacts of the three county-scale scenarios. A maximum integration of crop and livestock production in the two counties (scenario B) could provide a significant increase of local employment (by 58%) on-farm, although the level of farm income per labor hour decreases (by 23%) under current market price conditions and government subsidy system. A government payment system that supports more ‘green’ farm solutions could contribute to the reverse of current social trends in the counties.

Table 10. Socio-economic impacts of the three county scale scenarios

	current conditions	fully-integrated beef	fully-integrated beef and semi-integrated swine
	(C)	(A)	(B)
labor required (hrs/acre/year)	3.30	2.85	5.21
farm income before tax at current market prices ($/acre/labor hour)	48	33	37

Figure 1 shows the trend for the percentage of farm operators claiming farming as their principal occupation during the last 15 years. The downward trend (toward a greater percentage of part-time farmers) seems to stabilize or even reverse in the latest dataset available (2002).

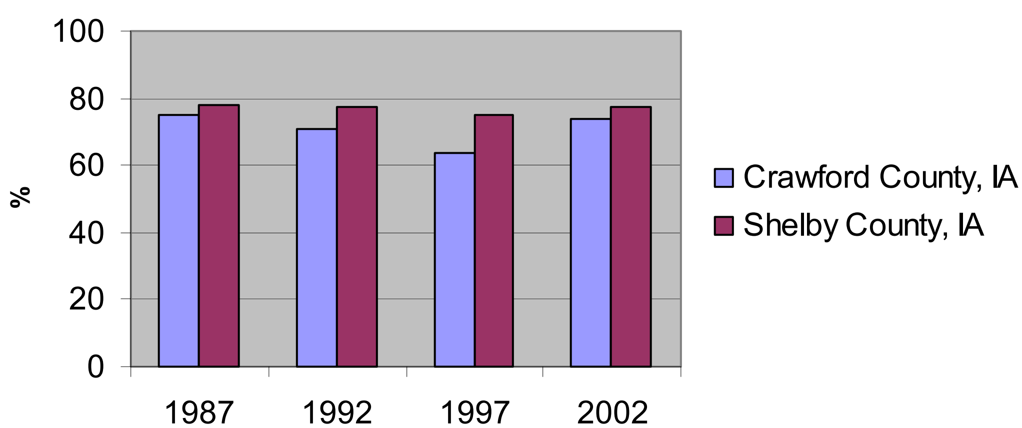

Figure 1. Farm operators claiming farming as their principal occupation (%) in two western Iowa counties (Source: Census of Agriculture, 1987-2002)

Farms in this region, as elsewhere in North America, continue to decrease in number while increasing in size (Figures 2 and 3). This trend has had a devastating impact on rural communities, as reflected in declining school enrollments, closed Main Street businesses, and general community distress. While re-integration of crop and livestock production is not a panacea for all these ills, this study demonstrates that alternative scenarios can promise improvements in both rural economies and the environment.

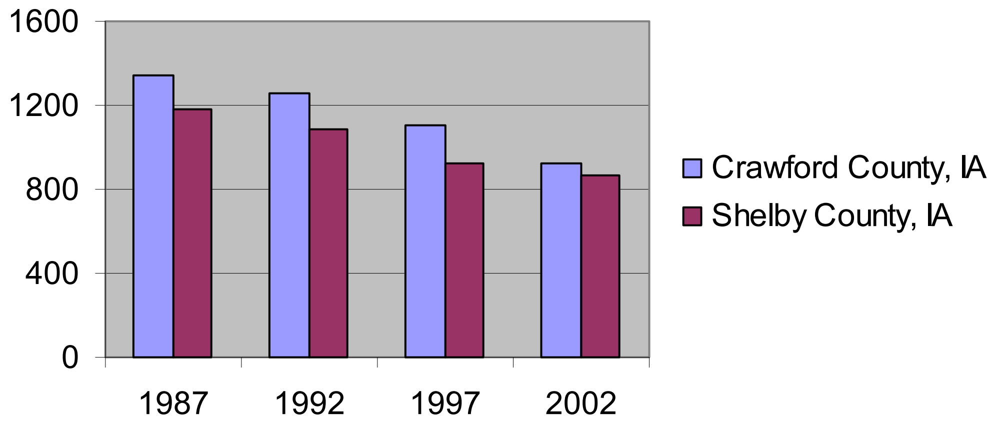

Figure 2. Number of farms in the two counties

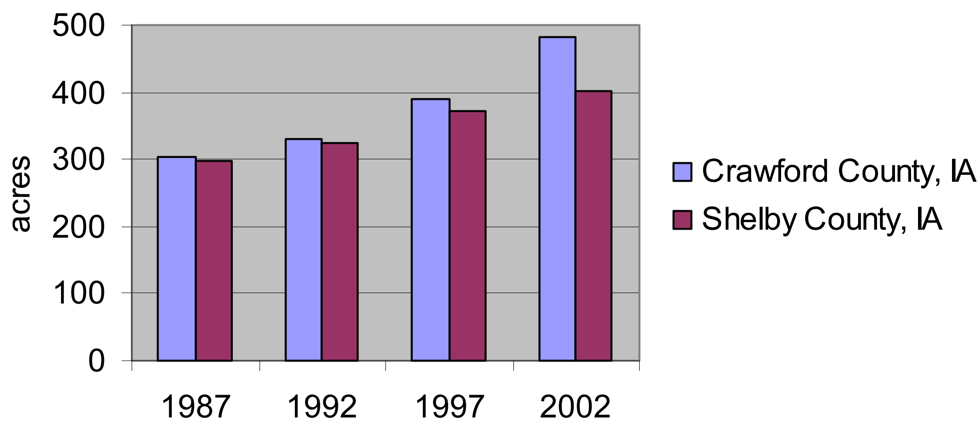

Figure 3. Size of farms in the two counties

Conclusions

The current situation in Crawford and Shelby Counties, Iowa, with 82% of the agricultural land used for growing annual row crops, results in considerable soil and nutrient losses to the environment. Over the past several decades of agricultural specialization, farms in the region have been decreasing in number while growing in size. Although a larger proportion of farmers still consider farming their primary occupation, the reduction in numbers of integrated crop and livestock farms has taken a socio-economic toll.

Scenario studies show that changing land-use toward crop rotations that include perennials and pastures can offer opportunities for land conservation that reduce soil and nutrient losses, minimize the export of commodities, and increase the availability of value-added products (e.g. meat) and related skilled employment. However, maintaining farm income when adopting longer rotations and raising more livestock is a challenge under current economic and policy conditions. The current government subsidy structure, with incentives for annual row crops and limited 'green' payments, does too little to encourage the practices needed for environmental stewardship on steep and erodible but still productive agricultural lands.

While many farm organizations and rural communities are working proactively to improve the current situation, they lack tools to consider the impact of alternatives on farm and regional economics and the environment. We hope a web-based simulation model like I-FARM can help farmers and policymakers design, evaluate, and most importantly, implement, more sustainable farming systems for the future.

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