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LOW-INPUT, SUSTAINABLE AGRICULTURE: ECONOMIC AND  
ENVIRONMENTAL IMPLICATIONS OF INCREASED  
ALFALFA PRODUCTION IN THE EASTERN CORN BELT \*

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## ABSTRACT

Title: "Low Input, Sustainable Agriculture: Economic and Environmental Implications of Increased Alfalfa Production in the Eastern Corn Belt"

Inclusion of alfalfa in crop rotations on Eastern Corn Belt farms with high and low productivity soils was analyzed with a mathematical programming model. Net incomes were larger with the government program but inclusion of alfalfa in the rotation reduced nitrogen fertilizer and herbicide use, potentially reducing environmental degradation.

LOW-INPUT, SUSTAINABLE AGRICULTURE: ECONOMIC AND ENVIRONMENTAL  
IMPLICATIONS OF INCREASED ALFALFA PRODUCTION IN THE EASTERN CORN BELT

Alfalfa! Clover! Nitrogen fixing legumes! Wonder crops of the 1990s? Some proponents of Low-Input, Sustainable Agriculture (LISA) suggest that using forages in a cropping sequence of grains and oilseeds will reduce soil erosion, water degradation, and use of agricultural chemicals without undue impact on farmers' incomes. However, evidence to support this claim is largely anecdotal or case-studies (National Research Council, 1989).

Legislators and other policymakers are looking for reliable research information to establish regulations regarding fertilizer and pesticide use and food safety. These environmental issues are being widely debated as Congress deliberates the 1990 Farm Bill.

The purpose of this study is to estimate the income and agricultural chemical use impacts for farming systems in the Eastern Corn Belt which include alfalfa in the rotation to reduce soil loss and water pollution. Empirical results should be useful to farmers and policymakers as pressures grow to implement LISA practices.

PREVIOUS RESEARCH

Several studies have examined the input use and environmental effects of alternative cropping systems. Continuous corn production using conventional practices can require more than twice as much total energy as a non-chemical, biologically-structured system (Culick et. al., 1983). Legumes can benefit succeeding grain crop yields by fixing nitrogen. Also, Baldock, et. al. reported that corn yields immediately following a legume are greater than corn yields in subsequent years, even when the subsequent crop was provided sufficient nitrogen.

Crop rotations can reduce nitrogen and soil losses. Nitrogen runoff was reduced by 55 to 80 percent and phosphorus by 30 to 75 percent in studies by Smith, et al. and USDA-SCS.

Lockeletz, et. al compared organic and conventional farms in the Midwest. The organic farms incorporated nitrogen fixing legumes in the rotations and used cultural practices to control insects and weeds. Their results indicate that gross production per acre (value of all crops at prevailing prices) was lower on the organic farms by 6 to 17 percent, but production expenses also were consistently lower. Thus, net income per acre was about equal for the two types of farms.

#### RESEARCH DESIGN

A farm firm mathematical programming model was selected for this study (McCarl). This type of model can capture the relationships between alternative rotations, commercial fertilizer and pesticide use, and contributions from legumes such as reduced insect problems and nitrogen fixation.

It is important to determine the effects on net farm income of a farming system which is more highly dependent on forages. It is anticipated that per acre production costs will decline with the inclusion of alfalfa in the rotation. However, due to potentially lower yields and/or prices for alfalfa, incomes also may be lower.

Two 500 acre farms representative of the Eastern Corn Belt were modeled: for high and low productivity soils, respectively. Drummer Silty Clay Loam is a high productivity soil commonly found in northwestern Indiana and eastern Illinois. Clermont Silt Loam is a typical low productivity soil found in southern Indiana and Ohio.

Production, harvesting, drying and storage equipment was assumed to be of sufficient size and capacity for a 500 acre farm. Technical coefficients and input prices (adjusted to 1989) were based upon Purdue

University crop production budgets (Doster and Dobbins, and Petritz, et. al.). Data for nitrogen credit from the production of alfalfa were taken from Purdue agronomic research data (Harms and Mengel).

For a grain farmer that is not in the hay business, the cost of harvesting and storage equipment for alfalfa production can be viewed as a variable cost of production, since he will not incur these costs unless he chooses to produce hay. Therefore, in this study, these costs are considered as variable rather than fixed. Contracting additional hay harvesting services also is considered.

Crop prices were based on the average of Indiana prices reported for the years 1980-87 (Indiana Agricultural Statistics). Relative prices among the crops were within normal relationships, e.g. a soybean to corn price ratio of 2.4 to 1.0.

#### RESULTS

Several scenarios were modeled including participation in the government program, all market prices without a government program, and forcing one-fourth of the farm to be planted to alfalfa. Highlights are summarized below.

##### High Productivity Soil

Initially the model was run to see if alfalfa would enter the solution at an average yield of 5 tons/acre and an average price of \$70.00/ton with participation in the government program. Case 1 assumed a 10 percent set-aside for corn, a \$25/acre set-aside cost, and a target price of \$2.84 per bushel for corn. This option provided the highest net return per acre of any scenario modeled at \$120.17/acre with 225 acres planted to corn, an equal number of acres planted to soybeans, and 25 acres in set-aside (Table 1). Alfalfa did not enter this solution.

Case 2 looked at the optimal solution when market prices were assumed for all crops under consideration. Alfalfa still did not enter

the solution. One-half of the farm was planted to soybeans and one-half to corn with a per acre net return of \$104.69.

Since alfalfa did not enter either of these initial optimal solutions, a sensitivity analysis was conducted to determine the price and yield at which alfalfa would enter and generate the same net income, assuming market prices for the other crops. Alfalfa entered the solution at a price of \$86.50 (Case 3 -- with a yield of 5 tons/acre) or at a yield of 7.33 tons/acre (Case 4 -- with a price of \$70.00/ton).

Given the potential benefits of legumes in rotation described in previous studies and possible regulatory and/or legislative requirements that farmers may face in the 1990s to satisfy environmental goals, one-fourth (125 acres) of the farm was forced into alfalfa production. Initially, only 28.4 acres of alfalfa could be grown because tractor time, part-time labor, and mower/baler time were binding constraints.

In case 5 these constraints were removed by allowing for additional tractor time, more part-time labor, and extra mower and baler time during the peak hay-making season of June, July and August. This necessitated the hiring of between 6 and 7 custom harvesting operators with the same machinery complement as the existing farmer, and up to 19 men to make all the hay. Obviously, this is not a very realistic scenario. Hay-making is very labor intensive and must be done within a narrow window of opportunity given weather constraints and the desire to harvest high quality hay. Per acre net returns in this case dropped to \$60.52/acre.

#### Low Productivity Soil

As in the case of the high productivity soil, an initial model run was conducted to see if alfalfa would enter the optimal solution with a government program of a 10 percent corn set-aside and a target price of \$2.84 per bushel. Net returns per acre were \$67.38 (Case 6). The

acreage allocation was 196.6 acres, respectively, to both rotation corn and rotation soybeans, 25 acres each to set-aside and continuous corn, and 56.8 acres to alfalfa hay (Table 2).

The model was then run with market prices for all crops (Case 7). Given a base price of \$70.00/ton and a yield of 5 tons/acre, 11.4 acres of alfalfa were planted. In addition, 238.6 acres of both rotation corn and rotation soybeans were planted along with 11.4 acres of corn rotated with alfalfa. Per acre net returns were \$51.47. Due to lower corn and soybean yields on the less productive soil, more acres of alfalfa were grown compared to the high productivity soil situation.

Sensitivity analysis helped determine the impact of lower alfalfa prices and yields with the same net income, assuming market prices for all other crops. In Case 8, 8.5 acres of alfalfa were planted when the price fell to \$57.50/ton. Below this price, no alfalfa was planted. In addition to the 8.5 acres of alfalfa, an identical number of acres was planted to rotation corn following alfalfa, and 241.4 acres each of rotation corn and rotation soybeans. Net returns per acre were \$50.63.

When the alfalfa yields fell to 4.13 tons/acre, alfalfa remained in the solution (Case 9). Below this yield none was planted. Net returns per acre were \$50.69. Rotation soybeans and corn acres, respectively, were 239.6, plus 10.3 acres of both alfalfa and rotation corn following alfalfa.

Finally, the farm was forced to plant 125 acres of alfalfa (Case 10). In the initial solution only 28.4 acres of alfalfa were planted due to tractor time, part-time labor, and mower/baler constraints. Once these constraints were removed (Case 11), the full 125 acres was allocated to alfalfa, combined with 125 acres of rotation corn following alfalfa, and 125 acres each of corn and soybeans in rotation. However, net returns fell to \$33.54/acre. It should be noted that, as in the

case of high productivity soils, the additional machinery and manpower necessary to complete this scale of haymaking are unrealistically large.

#### Input Use Comparisons

Total input usage for each case was calculated (Table 3). With high productivity soils, total nitrogen fertilizer use was minimized at 32,219 pounds when one-fourth of the farm was planted to alfalfa (Case 5). Nitrogen fixation by the alfalfa contributed 6,750 pounds of nitrogen. However, total fertilizer use was greater due to a much larger amount of potash needed for alfalfa production. Total commercial fertilizer use was the least when the farm participated in the government program where a total of 79,500 pounds of commercial fertilizer were applied including 38,500 pounds of nitrogen (Case 1).

Case 5 (one-fourth of farm in alfalfa) also utilized the lowest total amount of herbicides -- 1,128 quarts. This is in contrast to the all market price situation (Case 2), when herbicide use was 21 percent greater. Corn acreage was 225 acres under the government program (Case 1) and 250 acres in the remaining cases. Thus, corn herbicide use changed very little with the growing of alfalfa. Since alfalfa acres were substituted for soybean acres in Case 5, it was the use of soybean herbicides that declined sharply.

Insecticides use was the least when the farm was enrolled in the government program (Case 1). In this case, no alfalfa or continuous corn was grown; thus eliminating the need for any insecticide use. At the other end of the spectrum, planting 125 acres of alfalfa required the largest amount of insecticide use -- 212 pints.

In the case of low productivity soils, total commercial nitrogen use was a minimum when 125 acres was planted to alfalfa -- 14,719 pounds. Although alfalfa contributed 4,875 pounds of nitrogen, fertilizer use increased due to the large potash requirements for alfalfa.

Total quantities of fertilizer were minimized (Case 8) when the price of alfalfa fell to the point where it could not be grown profitably. In this case, a total of 43,758 pounds of fertilizer were applied. Total insecticide use was minimized in this situation also. Total insecticide use was greatest when one-fourth of the farm was planted to alfalfa.

Total herbicide use was the least when one-fourth of the farm was planted to alfalfa (Case 10). A total of 938 quarts of herbicide was required. Corn acreage varied from only 221.6 acres to 250 acres. Consequently, corn herbicide use did not vary significantly with increases in alfalfa production but soybean herbicide use fell as the alfalfa acreage was increased.

#### CONCLUSIONS

This study suggests that alfalfa cannot be grown profitably on highly productive soils in the Eastern Corn Belt, at recent average market prices for all crops, or under provisions of the 1989 farm program. However, with above average alfalfa yields and/or prices as a result of good management and marketing skills, alfalfa could become a profitable option. Specifically, if alfalfa can be sold for more than \$86.50/ton with average yields, or a farmer can achieve a yield greater than 7.33 tons/acre with average prices, then alfalfa competes favorably with corn and soybeans. The wide alfalfa price fluctuations associated with weather variability suggest that alfalfa demand is price inelastic. Hence, rightward supply shifts resulting from increased alfalfa hay production could significantly reduce market prices, forcing farmers to use top management skills to produce low-cost, high quality alfalfa hay which remains profitable in an optimal crop mix.

For lower productivity soils, alfalfa is more easily incorporated into the optimal crop mix. In fact, alfalfa enters the optimal solution

with participation in the 1989 farm program and at recent average market prices. Corn and soybean yields on this soil type are lower relative to the high productivity soil.

On both soil types commercial nitrogen fertilizer use decreased when alfalfa was included in the crop mix, potash use increased, and phosphate use remained essentially the same. Soybean herbicide use fell as alfalfa was substituted for soybeans. Use of the corn herbicides atrazine and alachlor remained high in all cases, except the government program participation case when less was used. These two herbicides are of concern from an environmental perspective and are under Environmental Protection Agency review (Schreiber).

For both the high and low productivity soils, insecticide use increased sharply when alfalfa was grown on one-fourth the farm. The insecticides applied to alfalfa are considered environmentally benign and should only be applied if justified by scouting reports, i.e., integrated pest management procedures. However, they can pose a potential toxicity risk for the farmer/applicator (Edwards).

Farmers and policymakers are in the process of analyzing the economic and environmental trade-offs associated with farming systems that rely more heavily on forages. Most environmentalists would favor the reduction in nitrogen fertilizer and herbicide use, and in soil erosion (although not specifically quantified here), estimated in this study to be associated with increased forage production. Of course, farm suppliers of herbicides and nitrogen fertilizer would suffer sales losses if government policies were implemented to require farmers to grow more alfalfa, but would benefit from some increased potash sales.

If legislation were introduced which mandated that certain acreages be planted to alfalfa, net returns per farm and per acre would fall. In the case of the 500 acre farm analyzed in this study, net returns per

acre fell from \$120.17 under the government program to \$60.52 when one-fourth of the farm was planted to alfalfa on the high productivity soil and from \$67.38 to \$33.54 per acre on the low productivity soil -- a decline of 50 percent in both cases.

A policy option that could be included in the 1990 Farm Bill would be to reallocate all deficiency payments to "environmental support payments," and allow all prices to fall to market levels. Assuming program and actual yields were the same, in this study the deficiency payments for the high and low productivity farms in 1989 would have been \$11,093 and \$6,083, respectively. These government payments would approximately compensate the farmer on the low productivity soil for shifting from the all market price situation (Case 7) to the one-fourth alfalfa situation (Case 10). However, on the high productivity soil the government payments would only cover one-half of the farmer's net income loss. Of course, on both soil types net farm income would decline if no deficiency payments were made.

This study attempted to quantify some of the private costs and benefits associated with incorporating forages into crop rotations on representative Eastern Corn Belt farms with different soil productivity potentials. Clearly, alfalfa production can reduce the application of nitrogen fertilizer and selected herbicides and thereby reduce some ground and surface water contamination. However, without rather strict government regulations, large economic incentives would be necessary to induce farmers to include more forages in their rotations, especially on the high productivity soils.

Table 1. Results for 500 acre farm, high productivity soil.

Crop	Yield/Acre on Model Farm	Prices	Crop Acres	Net Returns on Model Farm	Per Acre Net Return
<b><u>CASE 1*</u></b>					
R. Beans C-S	45 bu.	6.07/bu.	225.0		
R. Corn C-S	145 bu.	2.84/bu.	225.0	60,083	120.17
Cont. Corn	135 bu.	2.84/bu.	0.0		
Set Aside	--	--	25.0		
Alfalfa	5.00 tons **	70.00/ton	0.0		
Soybeans	45 bu.	6.07/bu.	25.0		
<b><u>CASE 2*</u></b>					
R. Beans C-S	45 bu.	6.07/bu.	250.0		
R. Corn C-S	140 bu.	2.50/bu.	250.0	52,346	104.69
Cont. Corn	130 bu.	2.50/bu.	0.0		
Alfalfa	5.00 tons **	70.00/ton	0.0		
R. Corn C-AL	140 bu.	2.50/bu.	0.0		
<b><u>CASE 3*</u></b>					
R. Beans C-S	45 bu.	6.07/bu.	245.7		
R. Corn C-S	140 bu.	2.50/bu.	245.7	52,360	104.72
Cont. Corn	130 bu.	2.50/bu.	0.0		
Alfalfa	5.00 tons **	86.50/ton	4.3		
R. Corn C-AL	140 bu.	2.50/bu.	4.3		
<b><u>CASE 4*</u></b>					
R. Beans C-S	45 bu.	6.07/bu.	244.1		
R. Corn C-S	140 bu.	2.50/bu.	244.2	52,478	104.95
Cont. Corn	130 bu.	2.50/bu.	0.0		
Alfalfa	7.33 tons **	70.00/ton	5.8		
R. Corn C-AL	140 bu.	2.50/bu.	5.8		
<b><u>CASE 5*</u></b>					
R. Beans C-S	45 bu.	6.07/bu.	125.00		
R. Corn C-S	140 bu.	2.50/bu.	125.00	30,260	60.52
Cont. Corn	130 bu.	2.50/bu.	0.0		
Alfalfa	5.00 tons **	70.00/ton	125.00		
R. Corn C-AL	140 bu.	2.50/bu.	125.00		

\* Description of Cases:

CASE 1: Govt. program -- 10% set aside, \$25/acre set aside cost.

CASE 2: Market Prices -- Let model grow alfalfa if profitable.

CASE 3: Hay Price Sensitivity -- At what price does alfalfa enter the solution?

CASE 4: Hay Yield Sensitivity -- At what yield does alfalfa enter the solution?

CASE 5: Force 1/4 of the farm into alfalfa -- no limiting resources.

\*\* This is the yield following the establishment year. Annual yield assuming a 4 year crop would be 75% of this value.

Table 2. Results for 500 acre farm, low productivity soil.

Crop	Yield/Acre on Model Farm	Prices	Crop Acres	Net Returns on Model Farm	Per Acre Net Return
<u>CASE 6*</u>					
R. Beans C-S	28 bu.	6.07/bu.	196.6		
R. Corn C-S	91 bu.	2.84/bu.	196.6	33,691	67.38
Cont. Corn	85 bu.	2.84/bu.	25.0		
Set Aside	--	--	25.0		
Alfalfa	5.00 tons**	70.00/ton	56.8		
Soybeans	28 bu.	6.07/bu.	0.0		
<u>CASE 7*</u>					
R. Beans C-S	28 bu.	6.07/bu.	238.6		
R. Corn C-S	86 bu.	2.50/bu.	238.6	25,729	51.47
Cont. Corn	80 bu.	2.50/bu.	0.0		
Alfalfa	5.00 tons**	70.00/ton	11.4		
R. Corn C-AL	86 bu.	2.50/bu.	11.4		
<u>CASE 8*</u>					
R. Beans C-S	28 bu.	6.07/bu.	241.4		
R. Corn C-S	86 bu.	2.50/bu.	241.4	25,313	50.63
Cont. Corn	80 bu.	2.50/bu.	0.0		
Alfalfa	5.00 tons**	57.50/ton	8.5		
R. Corn C-AL	86 bu.	2.50/bu.	8.5		
<u>CASE 9*</u>					
R. Beans C-S	28 bu.	6.07/bu.	239.6		
R. Corn C-S	86 bu.	2.50/bu.	239.6	25,346	50.69
Cont. Corn	80 bu.	2.50/bu.	0.0		
Alfalfa	4.13 tons**	70.00/ton	10.3		
R. Corn C-AL	86 bu.	2.50/bu.	10.3		
<u>CASE 10*</u>					
R. Beans C-S	28 bu.	6.07/bu.	125.00		
R. Corn C-S	86 bu.	2.50/bu.	125.00	16,772	33.54
Cont. Corn	80 bu.	2.50/bu.	0.0		
Alfalfa	5.00 tons**	70.00/ton	125.00		
R. Corn C-AL	86 bu.	2.50/bu.	125.00		

## \* Description of Cases:

CASE 6: Govt. program -- 10% set aside, \$25/acre set aside cost.

CASE 7: Market Prices -- Let model grow alfalfa if profitable.

CASE 8: Hay Price Sensitivity -- At what price does alfalfa enter the solution?

CASE 9: Hay Yield Sensitivity -- At what yield does alfalfa enter the solution?

CASE 10: Force 1/4 of the farm into alfalfa -- no limiting resources.

\*\* This is the yield following the establishment year. Annual yield assuming a 4 year crop would be 75% of this value.

Table 3. Total Input Use Under Different Scenarios

<u>HIGH PRODUCTIVITY SOILS</u>					
	<u>Case 1</u>	<u>Case 2</u>	<u>Case 3</u>	<u>Case 4</u>	<u>Case 5</u>
<b>HERBICIDE USE</b>					
Metolachlor (qts.)	312.50	312.50	305.13	301.75	156.25
Bentazon (qts.)	250	250	244.1	241.4	125
Atrazine (qts.)	270	300	300	299.88	300
Alachlor (qts.)	450	500	499.8	499.8	500
Eptam (qts.)	0	0	2.18	6.375	46.88
Total Herbicide Use (qts.)	1282.50	1362.50	1351.21	1346.02	1128.13
<b>INSECTICIDE USE</b>					
Organophosphate (lbs.)	0	0	0	0	0
Furadan (pts.)	0	4.859	6.554	9.605	141.25
Cygon (pts.)	0	2.4209	3.2654	4.7855	70.375
Total Insecticide (pts.)	0	7.2799	9.8194	14.3905	211.625
<b>FERTILIZER USE</b>					
Nitrogen (lbs.)	38500	38283.93	38193.15	38057.47	32218.75
Phosphate (lbs.)	14000	13909.7	13872.6	13815.9	11375
Potash (lbs.)	27000	27976.1	28310.8	28918.7	55375
Total Fertilizer (lbs.)	79500	80169.73	80376.55	80792.08	98968.75
<u>LOW PRODUCTIVITY SOIL</u>					
	<u>Case 6</u>	<u>Case 7</u>	<u>Case 8</u>	<u>Case 9</u>	<u>Case 10</u>
<b>HERBICIDE USE</b>					
Metolachlor (qts.)	245.75	238.6	241.4	239.5	125
Bentazon (qts.)	196.6	78.662	79.662	79.068	41.25
Atrazine (qts.)	199.46	225	224.91	224.91	225
Alachlor (qts.)	393.2	500	499.8	499.8	500
Eptam (qts.)	21.3	4.28	3.188	3.863	46.875
Total Herbicide Use (qts.)	1056.31	1046.54	1048.96	1047.14	938.125
<b>INSECTICIDE USE</b>					
Organophosphate (lbs.)	25	0	0	0	0
Furadan (pts.)	64.184	12.882	9.605	11.639	141.25
Cygon (pts.)	31.98	6.4182	4.7855	5.7989	70.375
Total Insecticide (pts. *)	96.164	19.300	14.3905	17.438	211.625
<b>FERTILIZER USE</b>					
Nitrogen (lbs.)	19626.65	18892.15	19399.98	19327.53	14718.75
Phosphate (lbs.)	9626.64	8561.22	8478.75	8527.89	11662.5
Potash (lbs.)	23547	16358.2	15879.7	16173.1	34875
Total Fertilizer (lbs.)	52800.29	43811.57	43758.43	44028.52	61256.25

\* Excludes organophosphate which is in pounds.

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