HIGHEST RETURN FARMING SYSTEMS for Tama and Muscatine soils

An application of linear programming to 240- and 480-acre farms operated by two men

By G. A. Peterson and Earl R. Swanson

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HIGHEST RETURN FARMING SYSTEMS

For TAMA and MUSCATINE Soils

By G. A. Peterson and Earl R. Swanson[1]

The purpose of this bulletin is to present the highest return farming systems (combinations of crop and livestock enterprises) for 240- and 480-acre farms on Tama and Muscatine soils. In determining the highest return farming systems for these farms, all possible combinations of eight crop rotations and eleven livestock enterprises were considered under varying levels of livestock management. These farming systems were determined by the method of linear programming.[2]

ASSUMPTIONS

Assumptions made in this study involve those relating to crop and livestock enterprises and to prices and costs. The assumptions concerning crop enterprises include yields and fertilizer and labor required; those concerning livestock enterprises include feed and labor required; those concerning prices and costs are based on past price and cost relationships among agricultural products.

Crop Enterprises

Muscatine silt loam and Tama silt loam are highly productive, dark-colored prairie soils.[3] For grain production under a moderately high level of management, Muscatine has a productivity index of 125; Tama, of 115. Muscatine has imperfect natural drainage, but tiles well and occurs on slopes of 0.5 to 3.5 percent. Tama is well drained and has a slope range of 3.5 to 7.0 percent.

Tables 1, 2, and 3 present the estimated annual yields and fertilizer required for eight crop rotations for Muscatine with 2-percent slope and for Tama with 3.5- and 7-percent slope respectively. These estimates were made by the Department of Agronomy, University of Illinois, and were based, wherever possible, on experimental data.

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[2] This is a mathematical procedure which insures that, given the conditions and assumptions, the highest return farming system for a farm can be derived. For an explanation of this method, see *An Introduction to Linear Programming,* by A. Charnes, W. W. Cooper and A. Henderson (New York, John Wiley and Sons, 1953).

[3] *Illinois Soil Type Descriptions,* by H. L. Wascher, J. B. Fehrenbacher, R. T. Odell, and P. T. Veale (Ill. Agr. Exp. Sta. AG-1443, 1950), pp. 73 and 78.

These estimates involve four assumptions, that soil fertility is at such a level at the outset that soil tests show no deficiencies in available phosphorus and potassium; that later some commercial fertilizer is used to supply nutrients removed by the crops; that weather and growing conditions are normal; and that no hay is removed.

In determining how much commercial fertilizer is required annually for each crop rotation, credit is given for the nitrogen returned to the soil by the clover crop.[1] For this reason, the amount of commercial fertilizer required per rotation acre decreases as the percentage of land in clover increases. Credit is also given for the nitrogen, phosphoric acid, and potash returned to the soil by livestock.[2]

Tables 1, 2, and 3 also show that as the percentage of land in forage increases, the need for conservation practices (terracing, strip cropping, and contouring) decreases.

Only a competitive relationship between grain and forage appears in the rotations considered.[3] The lack of a complementary relationship between grain and forage in the rotations considered is due to the high level of nitrogen assumed to be applied.

The man-hours required per rotation acre on each of the soils and slopes considered are also shown in Tables 1, 2, and 3. Because these requirements do not include labor involved in harvesting forage, man-hours per rotation acre decrease as the percent of land in forage increases.

Livestock Enterprises

A large number of livestock enterprises can be considered by the method of linear programming. In this study, however, only livestock enterprises commonly found on farms on Muscatine and Tama are included.

The following livestock enterprises, which involve certain assumptions, were selected and should be considered in relation to Table 4.

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[1] In the tables, rotations having a catch crop of clover have clover designated as (*Cl*). Those having a standover crop of clover have clover designated as *Cl*.

[2] Credits for manure are based on the table appearing in *Planning the Farm Business* (College of Agriculture, University of Illinois, Oct. 1947), p. 23. Hogs and cattle — the only livestock included in the livestock enterprises — differ in the amount of plant nutrients they restore to the soil.

[3] Production relationships between two crops may be complementary, competitive, or supplementary. If, on a given acreage, two crops are grown in the rotation and an increase in the production (yields times acreage) of the first crop augments the production of the second crop, the relationship is complementary. If the production of the second crop decreases, the relationship is competitive. If the production of the second crop remains unchanged, the relationship is supplementary.

Table 1. — Estimated Annual Yields and Fertilizer and Labor Required for 8 Crop Rotations
(Muscatine silt loam, 2-percent slope)

Item	Rotation and conservation practice							
	C-C-O (Cl) (contour)	C-C-Sb-O (Cl) (contour)	C-Sb-O (Cl) (strip crop)	C-C-Sb-O-Cl (contour)	C-C-O-Cl (contour)	C-O-Cl (none)	C-C-O-Cl-Cl (none)	C-O-Cl-Cl (none)
Yields per acre								
Corn, bu.	85	85	87	90	90	95	92	95
Soybeans, bu.	0	35	33	35	0	0	0	0
Oats, bu.	59	60	62	63	63	65	63	68
Clover, ton	0	0	0	3.0	3.0	3.0	3.5	3.5
Corn equivalent per rotation acre, lb.[a]	3,724	3,634	3,248	3,035	2,962	2,380	2,413	1,736
Fertilizer required per rotation acre, lb.								
N	39	30	14	11	14	0	7	0
P_2O_5	26	27	26	22	21	17	17	13
K_2O	17	22	23	19	14	12	11	9
Percent of land in:								
Grain	100	100	100	80	75	67	60	50
Clover	0	0	0	20	25	33	40	50
Man-hours required per rotation acre[b]								
Jan. 15–Feb. 14	0	0	0	0	0	0	0	0
Feb. 15–March 14	.3	.3	.3	.2	.2	.2	.2	.2
March 15–April 14	.5	.6	.6	.4	.4	.4	.3	.3
April 15–May 14	.9	1.0	.9	.8	.7	.5	.5	.3
May 15–June 14	1.0	1.0	.8	.8	.8	.5	.6	.4
June 15–July 14	1.2	1.0	1.1	.8	.9	1.0	.7	.7
July 15–Aug. 14	1.1	.8	1.0	.7	.8	.9	.6	.7
Aug. 15–Sept. 14	.3	.2	.2	.2	.2	.2	.2	.1
Sept. 15–Oct. 14	.8	.9	.7	.7	.6	.4	.5	.3
Oct. 15–Nov. 14	1.3	1.4	1.2	1.1	1.0	.7	.8	.5
Nov. 15–Dec. 14	.8	.7	.6	.6	.6	.4	.5	.3
Dec. 15–Jan. 14	.2	.1	.1	.1	.1	.1	.1	.1
Total	8.4	8.0	7.5	6.4	6.3	5.3	5.0	3.9
Pasture days per rotation acre[c]								
April 15–June 14	0	0	0	12.8	15.9	21.2	26.2	37.2
June 15–Aug. 14	0	0	0	13.5	16.9	22.5	31.5	39.4
Aug. 15–Oct. 14	10.2	7.5	10.0	11.2	14.1	18.8	29.8	32.8
Total	10.2	7.5	10.0	37.5	46.9	62.5	87.5	109.4

[a] Oats and soybeans were converted to corn equivalent on the following basis: 2 bushels oats = 1 bushel corn; 0.58 bushel soybeans = 1 bushel corn.
[b] Adapted from Table 17 in the Supplement to *Planning the Farm Business* (College of Agriculture, University of Illinois, Sept. 1953).
[c] Pasture may be converted to hay at this rate: 3⅛ pasture days = 100 pounds of hay.

Table 2. — Estimated Annual Yields and Fertilizer and Labor Required for 8 Crop Rotations
(Tama silt loam, 3.5-percent slope)

Item	Rotation and conservation practice							
	C-C-O (Cl) (strip crop)	C-C-Sb-O (Cl) (strip crop)	C-Sb-O (Cl) (strip crop)	C-C-Sb-O-Cl (strip crop)	C-C-O-Cl (contour)	C-O-Cl (contour)	C-C-O-Cl-Cl (contour)	C-O-Cl-Cl (contour)
Yields per acre								
Corn, bu.	79	79	80	83	85	89	87	89
Soybeans, bu.	0	30	30	30	0	0	0	0
Oats, bu.	58	58	58	58	63	65	63	68
Clover, ton	0	0	0	3.0	3.0	3.0	3.5	3.5
Corn equivalent per rotation acre, lb.[a]	3,488	3,332	2,984	2,755	2,822	2,268	2,301	1,724
Fertilizer required per rotation acre, lb.								
N	35	27	11	8	11	0	5	0
P_2O_5	24	25	23	20	20	16	16	13
K_2O	16	20	21	17	13	11	11	9
Percent of land in:								
Grain	100	100	100	80	75	67	60	50
Clover	0	0	0	20	25	33	40	50
Man-hours required per rotation acre[b]								
Jan. 15–Feb. 14	0	0	0	0	0	0	0	0
Feb. 15–March 14	.3	.3	.3	.2	.2	.2	.2	.2
March 15–April 14	.5	.6	.6	.4	.4	.4	.3	.3
April 15–May 14	.9	1.0	.9	.8	.7	.5	.5	.3
May 15–June 14	1.0	1.0	.8	.8	.8	.5	.6	.4
June 15–July 14	1.2	1.0	1.1	.8	.9	1.0	.7	.7
July 15–Aug. 14	1.1	.8	1.0	.7	.8	.9	.6	.7
Aug. 15–Sept. 14	.3	.2	.2	.2	.2	.2	.2	.1
Sept. 15–Oct. 14	.8	.9	.7	.7	.6	.4	.5	.3
Oct. 15–Nov. 14	1.3	1.4	1.2	1.1	1.0	.7	.8	.5
Nov. 15–Dec. 14	.8	.7	.6	.6	.6	.4	.5	.3
Dec. 15–Jan. 14	.2	.1	.1	.1	.1	.1	.1	.1
Total	8.4	8.0	7.5	6.4	6.3	5.3	5.0	3.9
Pasture days[c]								
April 15–June 14	0	0	0	12.8	15.9	21.2	26.2	37.2
June 15–Aug. 14	0	0	0	13.5	16.9	22.5	31.5	39.4
Aug. 15–Oct. 14	10.0	7.5	10.0	11.2	14.1	18.8	29.8	32.8
Total	10.0	7.5	10.0	37.5	46.9	62.5	87.5	109.4

[a] Oats and soybeans were converted to corn equivalent on the following basis: 2 bushels oats = 1 bushel corn; 0.58 bushel soybeans = 1 bushel corn.
[b] Adapted from Table 17 in the Supplement to *Planning the Farm Business* (College of Agriculture, University of Illinois, Sept. 1953).
[c] Pasture may be converted to hay at this rate: 3⅛ pasture days = 100 pounds of hay.

Table 3. — Estimated Annual Yields and Fertilizer and Labor Required for 8 Crop Rotations
(Tama silt loam, 7-percent slope)

Item	Rotation and conservation practice							
	C-C-O (Cl) (terrace)	C-C-Sb-O (Cl) (terrace)	C-Sb-O (Cl) (terrace)	C-C-Sb-O-Cl (terrace)	C-C-O-Cl (terrace)	C-O-Cl (strip crop)	C-C-O-Cl-Cl (strip crop)	C-O-Cl-Cl (contour)
Yields per acre								
Corn, bu.	73	73	73	75	78	78	78	80
Soybeans, bu.	0	28	28	28	0	0	0	0
Oats, bu.	50	50	50	50	50	55	50	60
Clover, ton	0	0	0	2.8	2.8	2.8	3.3	3.3
Corn equivalent per rotation acre, lb.[a]	3,192	3,057	2,716	2,492	2,531	1,971	2,027	1,540
Fertilizer required per rotation acre, lb.								
N	30	22	7	3	6	0	0	0
P_2O_5	22	23	21	18	18	14	14	11
K_2O	15	20	18	16	11	10	9	8
Percent of land in:								
Grain	100	100	100	80	75	67	60	50
Clover	0	0	0	20	25	33	40	50
Man-hours required per rotation acre[b]								
Jan. 15–Feb. 14	0	0	0	0	0	0	0	0
Feb. 15–March 14	.3	.3	.3	.2	.2	.2	.2	.2
March 15–April 14	.5	.6	.6	.5	.4	.4	.3	.3
April 15–May 14	.9	1.1	1.0	.8	.7	.5	.5	.3
May 15–June 14	1.1	1.1	.9	.9	.8	.5	.6	.4
June 15–July 14	1.3	1.0	1.1	.8	1.0	1.0	.7	.7
July 15–Aug. 14	1.1	.9	1.0	.7	.8	.9	.6	.7
Aug. 15–Sept. 14	.4	.3	.2	.2	.3	.2	.2	.1
Sept. 15–Oct. 14	.9	.9	.2	.7	.7	.4	.5	.3
Oct. 15–Nov. 14	1.4	1.5	1.2	1.2	1.1	.7	.8	.5
Nov. 15–Dec. 14	.9	.8	.6	.6	.7	.4	.5	.3
Dec. 15–Jan. 14	.2	.1	.1	.1	.1	.1	.1	.1
Total	9.0	8.6	7.2	6.7	6.8	5.3	5.0	3.9
Pasture days[c]								
April 15–June 14	0	0	0	11.9	14.9	19.8	28.0	35.1
June 15–Aug. 14	0	0	0	12.6	15.8	21.0	29.7	37.1
Aug. 15–Oct. 14	10.0	7.5	10.0	10.5	13.1	17.5	24.8	30.9
Total	10.0	7.5	10.0	35.0	43.8	58.3	82.5	103.1

[a] Oats and soybeans were converted to corn equivalent on the following basis: 2 bushels oats = 1 bushel corn; 0.58 bushel soybeans = 1 bushel corn.
[b] Adapted from Table 17 in the Supplement to *Planning the Farm Business* (College of Agriculture, University of Illinois, Sept. 1953).
[c] Pasture may be converted to hay at this rate: 3⅛ pasture days = 100 pounds of hay.

Hogs

Two-litter system (spring and fall). Gilts farrow in March and September; there are 6 pigs per litter; hogs are marketed at 225 pounds in September and March.

One-litter system (spring). Gilts farrow in March; there are 6 pigs per litter; hogs are marketed at 225 pounds in September.

One-litter system (fall). Gilts farrow in September; there are 6 pigs per litter; hogs are marketed at 225 pounds in March.

One-litter system (summer). Gilts farrow in June; there are 6 pigs per litter; hogs are marketed at 225 pounds in December.

Choice feeding cattle

Steer calves weighing 400 pounds are bought in October, roughed through winter, full-fed grain on pasture, and sold the following October at 950 pounds.

Steer calves weighing 400 pounds are bought in October, roughed through winter, full-fed grain in drylot, and sold in September at 900 pounds.

Yearling steers weighing 650 pounds are bought in November, roughed through winter, full-fed grain on pasture, and sold in September at 1,050 pounds.

Yearling steers weighing 650 pounds are bought in November, roughed through winter, full-fed grain in drylot, and sold in September at 1,050 pounds.

Yearling heifers weighing 600 pounds are bought in November, full-fed grain in drylot, and sold in March at 900 pounds.

Beef cow herd

The calf is sold in October at 400 pounds or transferred to one of the two feeding systems for steer calves described above; **cows** are replaced after they have produced 8 calves.

Dairy cow herd

Seven thousand pounds of 4-percent milk is produced annually; **cows** are replaced after 5 lactation periods; and the **calf** is vealed at 200 pounds.

Labor

Table 4 shows the estimated number of man-hours required per unit of production as well as the distribution of man-hours for the 12

Table 4. — Estimated Annual Labor and Feed Required for 11 Livestock Enterprises[a]
(Average level of management)

Item	Hogs				Choice feeding cattle					Beef cow herd	Dairy cow herd
	Two-litter system	One-litter system			Steer calves		Yearling steers		Yearling heifers		
	spring and fall	spring	fall	summer	on pasture	in drylot	on pasture	in drylot	in drylot		
	Man-hours per unit of production										
	(2,700 lb. produced)	(1,350 lb. produced)	(1,350 lb. produced)	(1,350 lb. produced)	(550-lb. gains)	(500-lb. gains)	(400-lb. gains)	(400-lb. gains)	(300-lb. gains)	(400-lb. calf produced)	(7,000 lb. of 4% milk and 200-lb. veal calf produced)
Jan. 15–Feb. 14	4.7	1.6	3.1	2.4	1.4	1.0	1.4	.4	2.1	1.6	12.0
Feb. 15–March 14	5.9	4.2	2.7	1.5	1.4	1.0	1.4	.4	1.5	1.6	12.0
March 15–April 14	5.8	4.7	1.1	1.5	1.4	1.1	1.4	1.9	.6	2.1	12.0
April 15–May 14	4.4	2.7	1.7	4.4	1.6	1.8	1.4	1.9	0	2.4	10.2
May 15–June 14	4.1	2.4	1.7	4.2	1.0	2.2	.7	1.9	0	1.4	8.4
June 15–July 14	3.2	1.9	1.4	1.0	1.0	2.2	.7	1.9	0	.4	8.4
July 15–Aug. 14	3.8	1.6	4.3	1.6	1.0	2.2	1.1	1.9	0	.4	8.4
Aug. 15–Sept. 14	4.7	2.2	4.5	2.2	1.0	1.1	.5	1.0	0	.4	8.4
Sept. 15–Oct. 14	3.5	2.2	3.4	2.0	1.0	.5	0	0	.9	1.1	8.4
Oct. 15–Nov. 14	2.8	1.6	2.2	1.8	1.4	1.0	.4	.2	1.1	1.6	9.0
Nov. 15–Dec. 14	3.3	1.7	2.6	1.8	1.4	1.0	1.4	.4	1.4	1.6	10.8
Dec. 15–Jan. 14	3.7	1.4	3.3	2.5	1.4	1.0	1.4	.4	1.4	1.6	12.0
Total	49.9	28.2	32.0	26.9	15.0	16.1	11.8	12.3	9.0	16.2	120.0
	Feed required per 100 lb. of production[b]										
Corn, lb.	371	417	382	417	560	600	633	700	560	266	432
Supplement, lb.	44	34	60	34	30	47	70	78	60	0	31
Hay, lb.	0	0	0	0	291	300	375	750	367	5,700	631
Pasture, days	2.2	4.4	0	0	9.1	0	12.5	0	5.7	224	25

[a] Based on Appendices III and IV in *Principles of Farm Management*, by H. C. M. Case and Paul E. Johnston (J. B. Lippincott Co., New York, 1953); *Detailed Cost Report for Northwestern and Western Illinois, 1949*, by R. H. Wilcox and A. C. Ruwe (College of Agriculture, University of Illinois, June, 1951; *Fourteenth Annual Report of Feeder Cattle Fed During the Feeding Years 1951-52 and 1952-53*, by A. G. Mueller and F. J. Reiss (College of Agriculture, University of Illinois, Sept. 1953). See page 4 of this bulletin for a detailed description of these livestock enterprises.

[b] For the beef-cow herd, the feed requirement is for one cow and replacement stock. For the dairy-cow herd, the feed requirement is for 1,000 pounds of milk.

labor periods of the year. These estimates are based on detailed cost records and surveys of livestock enterprises.

Feed

Table 4 shows the estimated amounts of feed required annually per unit of production under an average level of management by these livestock enterprises. These estimates are based on Illinois farm records and feeding experiments.

Prices and Costs

To arrive at prices and costs that would be reliable in planning highest return farming systems, past relationships among agricultural products were investigated. On the basis of these relationships, the following price and cost structure was devised, which should be considered in relation to Table 5.

Crop production costs (corn, oats, soybeans, hay): Based on 1949 detailed cost records for northwestern Illinois.[1]

Hay-harvesting costs: A crew of four men with a one-man baler is assumed to do the harvesting. Since two full-time men are available for any one of the farming systems considered, two additional men have to be hired when and if hay is harvested. The cost of harvesting hay, including this additional labor, is $7.86 a ton.

Fertilizer costs (nitrogen, phosphorus, potassium): Based on 1948-1952 average Illinois prices for straight materials.

Soybean meal costs: Based on 1948-1952 average Illinois prices.

Grain prices (corn, oats, soybeans): Based on 1948-1952 average Illinois prices.

Hog prices, butcher, Chicago: Based on a 12 to 1 instead of a 13 to 1 hog-corn ratio, which was the average hog-corn ratio for the United States for 1943-1952. There are two reasons for this: in planning, farmers may view the hog-corn ratio as the ratio of hog prices to government-supported corn prices rather than to the open-market corn prices; second, farmers may also consider that returns from hogs are more uncertain when they feed their corn to hogs than when corn is sold at government-supported prices.

[1] *Detailed Cost Report for Northwestern and Western Illinois, 1949,* by R. H. Wilcox and A. C. Ruwe (College of Agriculture, University of Illinois, June, 1951). Crop production costs are restricted to those which vary with the rotation. All costs which remain constant, whatever rotation is adopted — taxes, labor, and interest, for example — are excluded.

Cattle prices, slaughter, choice, Chicago (steer calves, yearling steers, yearling heifers, commercial cows, vealers): During 1944-1952, the average price per pound of 1,000-pound choice slaughter steers was 33 percent higher than the average price per pound of 225-pound butcher hogs. This relationship was used to develop the cattle prices. These prices are 76.9 percent of their average 1948-1952 level.

Feeder-cattle prices, choice, Kansas City (steer calves, yearling steers, yearling heifers): Price margins on feeding operations were based on studies of feeder cattle conducted at the University of Illinois. Feed margins were checked by valuing hay at $20 a ton.

Butterfat prices: Based on 1948-1952 average Illinois prices.

Table 5. — Prices of Products and Costs of Inputs[a]

Item	Weight (lb.)	Date bought or sold	Unit	Price per unit
Crop production costs[b]				
Corn	....	....	Acre	$31.59
Oats	....	....	Acre	13.23
Soybeans	....	....	Acre	18.09
Hay: growing cost	....	....	Acre	8.88
harvesting cost[c]	....	....	Acre	13.74
Fertilizer costs				
Nitrogen (33-0-0)	....	Bought at average annual price	Ton	87.12
Phosphorus (0-20-0)	....		Ton	38.40
Potassium (0-0-50)	....		Ton	55.00
Soybean meal	....	Bought at average annual price	Cwt.	4.58
Grain prices				
Corn	....	Sold at average annual price	Bu.	1.48[d]
Oats	....		Bu.	.77
Soybeans	....		Bu.	2.53
Hog prices, butcher, Chicago				
....	225	Sold Sept. 1	Cwt.	18.50
....	225	Sold March 1	Cwt.	16.88
....	225	Sold Dec. 1	Cwt.	15.85
Cattle prices, slaughter, choice, Chicago				
Steer calves	950	Sold Oct. 1	Cwt.	24.43
Steer calves	1,000	Sold Sept. 1	Cwt.	24.64
Yearling steers	1,050	Sold Sept. 1	Cwt.	24.64
Yearling heifers	900	Sold March 15	Cwt.	21.00
Commercial cows	1,100	Sold at average annual price	Cwt.	16.20
Vealers	200	Sold May 1	Cwt.	24.69
Feeder-cattle prices, choice, Kansas City				
Steer calves	400	Bought Oct. 1	Cwt.	22.00
Yearling steers	650	Bought Nov. 1	Cwt.	21.00
Yearling heifers	600	Bought Sept. 15	Cwt.	18.00
Butterfat	....	Sold at average annual price	Lb.	.65

[a] For the bases of these prices and costs, see page 10 and above.

[b] Does not include costs that remain constant whatever rotation is adopted — taxes, labor, and interest, for example — but does include the cost of terracing on those rotations requiring terracing.

[c] The cost of harvesting hay was included in the calculation of returns only when hay was harvested. This cost was set at $7.86 a ton, which includes the cost of hired labor other than that provided by the two men assumed to be available.

[d] Instead of feeding only home-grown corn to livestock, corn could be bought at a slightly higher price.

HIGHEST RETURN FARMING SYSTEMS

With these eight crop rotations and eleven livestock enterprises set forth, and the assumptions and conditions they involve made explicit, those combinations or systems that yield the highest returns to labor, capital, and management can now be presented.

Two basic situations are considered: first, 240-acre farms; second, 480-acre farms. Each of these farms is assumed to have two full-time men who furnish 480 man-hours in each of the twelve labor periods of the year. These two situations are assumed to exist first under an average level of livestock management, then under varying levels of livestock management.[1]

Comparison of Highest Return Farming Systems on 240-Acre Farms Under Average Level of Livestock Management

Table 6 compares the highest return farming systems for each of the soils and slopes under consideration. On less productive soils,[2] highest return farming systems require more acreage in standover clover, more cattle, and slightly fewer hogs. This, of course, decreases the annual expenditure for fertilizer. The highest return farming system for Tama, 7-percent slope, for example, requires no expenditures for nitrogen.

If the number of unused man-hours in each labor period is subtracted from the 480 man-hours assumed to be available each month, the monthly distribution of labor required by each system can be determined. The lower the productivity of the soil, the higher is the number of man-hours required. For even though soils with lower productivity have smaller acreages in grain, they have larger cattle enterprises.

Under all three systems, most of the hay is harvested in the first (May 15-June 14) and third (August 15-September 14) periods, because labor requirements for the other crops are lower during these periods than during the second period (June 15-July 14).

Returns to labor, capital, and management on Muscatine are roughly $1,000 higher than on Tama soil, 3.5-percent slope. Returns to labor, capital, and management on Tama soil, with 3.5-percent slope are about

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[1] Average requirements per unit of production (feed-to-gain ratio) are used to indicate the level of livestock management, and are based on Illinois farm records.

[2] Muscatine, 2-percent slope, is most productive; Tama, 7-percent slope, is least productive.

$2,000 higher than on Tama soil with 7-percent slope. These differences in returns are not wholly due to differences in productivity of the soil. They are also due to the fact that each system involves a somewhat different combination of capital investment. Only if capital investment is assumed to be fixed, and adequate for operating any of these systems, can the differences in returns be attributed in the main to differences in productivity of the soil.

Table 6. — Highest Return Farming Systems Under Average Level of Management[a] for Muscatine and Tama Silt Loam
(240-acre farms, 2 full-time men)

Item	Muscatine, 2-percent slope	Tama, 3.5-percent slope	Tama, 7-percent slope
Hogs (litters)			
Two-litter system (spring and fall)	50	43	41
Cattle (head)			
Steer calves fed on pasture	29	40	33
Yearling steers fed on pasture	28	48	60
Yearling heifers	12	23	25
Crop rotations (acres)			
C-C-O (Cl)	68	0	0
C-C-O-Cl	172	228	198
C-C-O-Cl-Cl	0	12	42
Hay harvested (tons)			
May 15–June 14	15.8	28.6	30.1
June 15–July 14	0	8.8	10.1
Aug. 15–Sept. 14	27.1	31.9	34.5
Fertilizer expenditure (annual)			
N	$1,453	$ 578	$ 0
P_2O_5	1,596	1,545	1,338
K_2O	548	517	398
Unused man-hours (monthly)			
Jan. 15–Feb. 14	139	106	103
Feb. 15–March 14	28	15	15
March 15–April 14	0	0	3
April 15–May 14	0	0	0
May 15–June 14	1	0	0
June 15–July 14	24	29	33
July 15–Aug. 14	19	32	36
Aug. 15–Sept. 14	90	100	104
Sept. 15–Oct. 14	98	117	124
Oct. 15–Nov. 14	1	0	0
Nov. 15–Dec. 14	42	15	0
Dec. 15–Jan. 14	154	143	107
Used man-hours (annual total)	5,284	5,407	5,444
Unused pasture days			
April 15–June 14	0	0	0
June 15–Aug. 14	0	0	0
Aug. 15–Oct. 14	0	0	0
Supplement bought (cwt.)	721	713	700
Corn equivalent bought (cwt.)	0	0	659
Corn equivalent sold (cwt.)	1,150	90	0
Returns to labor, capital, and management (annual)	$23,090	$22,240	$20,123

[a] Feed-to-gain ratio is used as an index of livestock management.

Table 7. — Highest Return Farming Systems for Five Levels of Livestock Management[a]

(240-acre farm, 2 full-time men, Muscatine silt loam, 2-percent slope)

Item	Level of livestock management				
	20 percent above average	10 percent above average	Average[b]	10 percent below average	20 percent below average
Hogs (litters)					
Two-litter system (spring and fall)	44	44	50	53	52
One-litter system (fall)	5	7	0	0	0
Cattle (head)					
Steer calves fed on pasture	5	12	29	35	54
Yearling steers fed on pasture	65	60	28	13	0
Yearling heifers	22	22	12	8	0
Crop rotations (acres)					
C-C-O (Cl)	83	50	68	65	37
C-C-O-Cl	157	190	172	175	203
Hay harvested (tons)					
May 15–June 14	12.8	17.8	15.8	12.4	13.7
June 15–July 14	2.2	4.5	0	0	0
Aug. 15–Sept. 14	33.4	32.6	27.1	24.6	23.2
Fertilizer expenditure (annual)					
N	$1,790	$1,414	$1,453	$1,348	$1,009
P_2O_5	1,646	1,625	1,596	1,567	1,546
K_2O	575	562	548	531	519
Unused man-hours (monthly)					
Jan. 15–Feb. 14	110	102	139	147	162
Feb. 15–March 14	12	7	28	30	43
March 15–April 14	1	1	0	0	0
April 15–May 14	1	0	0	0	0
May 15–June 14	17	10	1	0	0
June 15–July 14	27	27	24	20	21
July 15–Aug. 14	1	0	19	18	23
Aug. 15–Sept. 14	91	81	90	81	77
Sept. 15–Oct. 14	115	108	98	85	82
Oct. 15–Nov. 14	0	0	1	0	8
Nov. 15–Dec. 14	0	0	42	0	0
Dec. 15–Jan. 14	115	107	154	167	184
Used man-hours (annual total)	5,402	5,471	5,284	5,316	5,258
Unused pasture days					
April 15–June 14	0	0	0	286	587
June 15–Aug. 14	0	0	0	0	0
Aug. 15–Oct. 14	0	0	0	0	0
Supplement bought (cwt.)	582	673	721	807	867
Corn equivalent bought (cwt.)	0	0	0	0	460
Corn equivalent sold (cwt.)	2,585	1,532	1,150	395	0
Returns to labor, capital, and management (annual)	$27,240	$25,580	$23,090	$20,975	$18,890

[a] Variations in the level of feed-to-gain ratio are used to show differences in livestock management. When the same gains are achieved by using smaller quantities of grain, supplement, and pasture days, a higher level of livestock management is indicated. For example, the average level of feed-to-gain ratio shown in Table 4 is 371 pounds of grain, 44 pounds of supplement, and 2.2 pasture days. A decrease in this level to 297 pounds of grain, 35 pounds of supplement, and 1.8 pasture days represents a level of livestock management 20 percent above average.

[b] Average level of management is the same as that shown in Table 6.

Comparison of Highest Return Farming Systems on 240-Acre Farms Under Varying Levels of Livestock Management

Analysis of Illinois farm records indicates a wide variation in livestock management.[1] This variation is due to many factors such as sani-

[1] For a study of this point, see "Variability of Returns From the Hog Enterprise," by Earl R. Swanson, *Journal of Farm Economics, 37*: 736-739 (Nov. 1955).

Table 8. — Highest Return Farming Systems for Five Levels of Livestock Management[a]

(240-acre farm, 2 full-time men, Tama silt loam, 3.5-percent slope)

Item	Level of livestock management				
	20 percent above average	10 percent above average	Average[b]	10 percent below average	20 percent below average
Hogs (litters)					
Two-litter system (spring and fall)	42	40	43	21	20
Cattle (head)					
Steer calves fed on pasture......	35	39	40	148	152
Yearling steers fed on pasture...	57	58	48	0	0
Yearling heifers................	26	26	23	0	0
Crop rotations (acres)					
C-C-O (Cl)....................	0	0	0	12	32
C-C-O-Cl......................	240	240	228	116	35
C-C-O-Cl-Cl...................	0	0	12	112	173
Hay harvested (tons)					
May 15–June 14...............	30.4	28.5	28.6	43.7	45.3
June 15–July 14...............	0	8.9	8.8	1.0	0
Aug. 15–Sept. 14..............	29.0	32.2	31.9	48.9	59.6
Fertilizer expenditure (annual)					
N............................	$ 813	$ 749	$ 578	$ 403	$ 323
P_2O_5......................	1,601	1,576	1,545	1,535	1,503
K_2O........................	550	534	517	514	496
Unused man-hours (monthly)					
Jan. 15–Feb. 14...............	96	100	106	186	180
Feb. 15–March 14..............	8	14	15	112	108
March 15–April 14.............	0	3	0	78	75
April 15–May 14...............	0	0	0	2	0
May 15–June 14................	0	5	0	2	77
June 15–July 14...............	43	31	29	53	56
July 15–Aug. 14...............	29	32	32	71	71
Aug. 15–Sept. 14..............	109	109	100	92	73
Sept. 15–Oct. 14..............	121	124	117	115	115
Oct. 15–Nov. 14...............	0	0	0	2	2
Nov. 15–Dec. 14...............	0	0	15	75	73
Dec. 15–Jan. 14...............	102	104	143	179	174
Used man-hours (annual total)....	5,417	5,434	5,407	5,055	5,051
Unused pasture days					
April 15–June 14..............	128	0	0	0	0
June 15–Aug. 14...............	1,049	0	0	0	0
Aug. 15–Oct. 14...............	342	0	0	0	0
Supplement bought (cwt.).........	571	628	713	588	636
Corn equivalent bought (cwt.).....	0	0	0	0	814
Corn equivalent sold (cwt.)........	1,473	884	90	0	0
Returns to labor, capital, and management (annual).......	$26,410	$24,390	$22,240	$20,274	$17,949

[a] See footnote *a* to Table 7.
[b] See footnote *b* to Table 7.

tation practices, skill in feeding livestock, and the breed and quality of the livestock fed. To examine the effects of livestock management upon highest return farming systems, only Muscatine, 2-percent slope, and Tama, 3.5-percent slope, are considered. To vary levels of livestock management, a percentage increase and decrease was made for *all* feeds.[1] The two higher levels of livestock management shown in

[1] The feed-to-gain ratio may be affected by the substitution of one feed for another. For example, the grain required per 100 pounds of beef produced will be affected by the roughage in the ration. In this study, livestock-management levels were specified by taking a given percentage of all feeds.

Tables 7 and 8 represent a 10- and 20-percent decrease in the average feed requirements. The two lower levels represent a 10- and 20-percent increase in the average feed requirements. The average level is also shown in Table 6. The range from 20 percent above to 20 percent below average includes the management levels of most farmers.

In order to maintain the highest return farming system, whatever the level of livestock management, the crop and livestock enterprises had to be modified somewhat. In these situations, the modifications are of far less consequence in their effect on returns to capital, labor, and management than changes in the level of livestock management.

Table 7 presents the highest return farming systems for each of five levels of livestock management on 240-acre farms on Muscatine. The differences in returns range as high as $8,350. Table 8 presents the highest return farming systems for each of five levels of livestock management on 240-acre farms on Tama. The differences in returns range as high as $8,461.

On both Muscatine and Tama, the highest return farming systems for the levels of livestock management considered are principally livestock systems. There are more cattle on Tama than on Muscatine, because grain yields relative to forage yields are higher on Muscatine. Even though returns from livestock decrease with a decrease in the level of livestock management, returns from the entire farming system are higher when there are livestock than when there are none, because labor is more fully utilized.

Comparison of Highest Return Farming Systems on 480-Acre Farms Under Varying Levels of Livestock Management

Tables 9 and 10 present the highest return farming systems for three levels of livestock management on 480-acre farms on Muscatine and Tama. Again, the crop and livestock enterprises had to be modified somewhat in order to maintain the highest return farming system. This time, changes in the level of livestock management, and the resulting modifications of the systems, had little effect upon returns to labor, capital, and management, because the value of livestock production is minor compared with the value of cash-grain production. No hogs appear in these systems and cattle numbers change little with changes in the level of livestock management.

Not only does the value of livestock production decrease in relation to the value of cash-grain production, but actual cattle numbers are smaller on 480-acre farms than on 240-acre farms.

The differences in returns to labor, capital, and management on Muscatine and Tama indicate differences in soil productivity.

More labor is used by any of the highest return farming systems on Tama than by any of those on Muscatine, because the systems on Tama include more cattle. The reason that the systems on Tama include more cattle is that grain yields relative to forage yields are higher on Muscatine than on Tama.

Comparison of Highest Return Farming Systems That Include Livestock With Highest Return Cash-Grain Systems That Exclude Livestock on 240- and 480-Acre Farms

The highest return farming systems that include livestock can now be compared with the highest return cash-grain systems that exclude

Table 9. — Highest Return Farming Systems for Three Levels of Livestock Management[a]

(480-acre farm, 2 full-time men, Muscatine silt loam, 2-percent slope)

Item	Level of livestock management		
	Average	10 percent below average	20 percent below average
Cattle (head)			
Steer calves fed on pasture	0	0	0
Yearling steers fed on pasture	52	47	49
Yearling heifers	20	18	19
Crop rotations (acres)			
C-C-O (Cl)	240	246	243
C-C-Sb-O (Cl)	82	83	82
C-Sb-O (Cl)	38	59	50
C-C-O-Cl	120	92	105
Hay harvested (tons)			
May 15–June 14	0	0	0
June 15–July 14	0	0	0
Aug. 15–Sept. 14	47	47	54
Fertilizer expenditure (annual)			
N	$5,940	$5,983	$5,949
P_2O_5	3,811	3,817	3,801
K_2O	1,539	1,555	1,542
Unused man-hours (monthly)			
Jan. 15–Feb. 14	363	375	370
Feb. 15–March 14	243	251	247
March 15–April 14	156	159	157
April 15–May 14	0	0	0
May 15–June 14	0	0	0
June 15–July 14	25	23	24
July 15–Aug. 14	0	0	0
Aug. 15–Sept. 14	239	242	229
Sept. 15–Oct. 14	88	86	87
Oct. 15–Nov. 14	0	0	0
Nov. 15–Dec. 14	0	11	6
Dec. 15–Jan. 14	289	301	296
Used man-hours (annual total)	4,744	4,687	4,725
Unused pasture days			
April 15–June 14	868	426	486
June 15–Aug. 14	472	0	0
Aug. 15–Oct. 14	1,810	1,682	1,287
Supplement bought (cwt.)	126	126	144
Corn equivalent bought (cwt.)	0	0	0
Corn equivalent sold (cwt.)	154	155	152
Returns to labor, capital, and management (annual)	$31,870	$31,420	$31,000

[a] See footnote *a* to Table 7.

livestock. The two basic situations still remain 240- and 480-acre farms, each with two full-time men, on Muscatine and Tama. Table 11 presents the systems without livestock; Tables 7, 8, and 9 present the systems with livestock.

240-acre farms on Muscatine

The returns from the system without livestock on the 240-acre farm on Muscatine are $15,440 (Table 11); the returns from the system with livestock on the same soil and size of farm are $23,090 (Table 7). This difference is largely due to the fact that labor is better

Table 10. — Highest Return Farming Systems for Three Levels of Livestock Management[a]

(480-acre farm, 2 full-time men, Tama silt loam, 3.5-percent slope)

Item	Level of livestock management		
	Average	10 percent below average	20 percent below average
Cattle (head)			
Steer calves fed on pasture	59	0	0
Yearling steers fed on pasture	19	60	60
Yearling heifers	15	15	15
Crop rotations (acres)			
C-C-O (Cl)	172	228	228
C-C-Sb-O (Cl)	0	81	81
C-C-O-Cl	308	171	171
Hay harvested (tons)			
May 15–June 14	1	0	0
June 15–July 14	12	15	0
Aug. 15–Sept. 14	44	41	61
Fertilizer expenditure (annual)			
N	$3,639	$5,207	$5,195
P_2O_5	3,445	3,590	3,583
K_2O	1,274	1,455	1,401
Unused man-hours (monthly)			
Jan. 15–Feb. 14	342	363	362
Feb. 15–March 14	227	241	241
March 15–April 14	155	155	155
April 15–May 14	0	0	0
May 15–June 14	0	0	0
June 15–July 14	0	4	29
July 15–Aug. 14	0	0	0
Aug. 15–Sept. 14	200	243	210
Sept. 15–Oct. 14	69	99	99
Oct. 15–Nov. 14	0	17	17
Nov. 15–Dec. 14	0	0	0
Dec. 15–Jan. 14	270	288	288
Used man-hours (annual total)	4,942	4,825	4,838
Unused pasture days			
April 15–June 14	3,882	1,396	1,276
June 15–Aug. 14	2,120	0	727
Aug. 15–Oct. 14	2,477	2,461	1,224
Supplement bought (cwt.)	174	146	159
Corn equivalent bought (cwt.)	0	0	0
Corn equivalent sold (cwt.)	126	139	137
Returns to labor, capital, and management (annual)	$29,440	$28,900	$28,460

[a] See footnote *a* to Table 7.

Table 11. — Returns to Labor, Capital, and Management and Labor Required for Highest Return Cash-Grain Systems

(240- and 480-acre farms on Muscatine silt loam, 2-percent slope, and Tama silt loam, 3.5-percent slope)

	Muscatine, 2-percent slope		Tama, 3.5-percent slope	
	240 acres	480 acres	240 acres	480 acres
Crop rotation (acres)				
C-C-O (Cl)	0	0	240	480
C-C-Sb-O (Cl)	240	480	0	0
Corn equivalent sold (cwt.)	87	174	84	168
Man-hours used	1,894	3,788	2,040	4,080
Returns to labor, capital, and management	$15,440	$30,880	$14,100	$28,200

utilized by the system with livestock than by the system without livestock. Even under a livestock management 20 percent below average, returns are $3,450 more on a system with livestock than on one without livestock.

In considering these comparisons, it should be recognized that the cost of buildings and equipment required in livestock production and not present in cash-grain production has not been deducted. However, for cattle and hogs — the only livestock included in the livestock enterprises — this cost is not substantial. The annual cost for the added buildings and equipment is about 5 percent of the feed cost.[1]

240-acre farms on Tama

Similar differences may be observed in comparing these two kinds of systems on 240-acre farms on Tama (Tables 8 and 11). Irrespective of the level of livestock management, returns are higher from the system with livestock than from the system without livestock.

480-acre farms on Muscatine and Tama

Similarities rather than differences in returns from the systems with livestock (Tables 9 and 10) and those without livestock (Table 11) appear when 480-acre farms are compared. This is to be expected, as the two systems are similar. Since crops on a 480-acre farm almost completely utilize the labor of the two men available, there are no hogs and only few cattle. Because the returns from these two systems are almost equal, farmers need to consider whether adding livestock to the cash-grain system is worthwhile. They may find the added labor required by the livestock to be disproportionate to the added returns.

[1] *Detailed Cost Report for Northwestern and Western Illinois*, by R. H. Wilcox and A. C. Ruwe (College of Agriculture, University of Illinois, June, 1951), Tables 20 and 22.

SUMMARY

The purpose of this bulletin was to present the highest return farming systems for 240- and 480-acre farms on Tama and Muscatine soils under average and varying levels of livestock management (feed-to-gain ratio) and with two full-time men available for each farm.

By the method of linear programming, the following conclusions were derived:

On 240-acre farms under average level of livestock management. The highest return farming systems are essentially livestock systems. On less productive soils, more acreage is devoted to standover clover and there are more cattle and fewer hogs. Returns are higher on Muscatine than those on Tama.

On 240-acre farms under varying levels of livestock management. To vary the level of livestock management, a 10- and 20-percent increase and decrease in the average level was made. Then, in order to maintain the highest return farming system for each of these levels of livestock management, the basic systems were slightly modified. The level of livestock management proved to have far more effect on returns than the modifications of the systems.

On 480-acre farms under varying levels of livestock management. Compared with the highest return farming systems on 240-acre farms, those on 480-acre farms have fewer cattle and no hogs. As a consequence, changes in the level of livestock management proved to have less effect on returns than changes in the level of livestock management on 240-acre farms. Again, returns are higher on Muscatine than on Tama.

On 240-acre farms with and without livestock. Highest return farming systems that include livestock have higher returns than those that exclude livestock, regardless of the level of livestock management.

On 480-acre farms with and without livestock. Highest return farming systems that include livestock have returns only slightly higher than those that exclude livestock.

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