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Re-integrating Crops and Livestock in Maine: An Economic Analysis of the Potential for and Profitability of Integrated Agricultural Production

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RE-INTEGRATING CROPS AND LIVESTOCK IN MAINE: AN ECONOMIC ANALYSIS OF THE POTENTIAL FOR AND PROFITABILITY OF INTEGRATED AGRICULTURAL PRODUCTION

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A THESIS

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Thesis Advisor: Dr. Stewart N. Smith

An Abstract of the Thesis Presented
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This thesis examines the profitability of and sustainability indicators for potato and dairy farms in Maine integrating crops and livestock in two different ways. The first is inter-farm *coupling*, where two or more specialized producers are close enough to exchange manure applications for crops used as livestock feed. Land base is shared between farmers. The second is where farms are *on-farm integrated*. Here crops and livestock are raised on the same farm and manure is applied to cash crops and livestock feed crops. Face-to-face interviews with Maine producers were used to construct integrated and non-integrated representative budgets.

Assuming potato farms expanded and dairy farms did not, net farm income for central Maine and Aroostook County coupled potato and dairy agricultural systems compared to non-integrated systems improved from increased potato acreage in the short term ($46/acre), and manure nutrient credits ($36/acre) and a 5% increase in potato yields ($75/acre) assumed in the long term.

Use of the dairy farm's cultivated acreage during coupling allowed potato farms to expand potato acreage. Short-term coupled potato farms were able to grow more potatoes, a more profitable cash crop while keeping the same rotation sequence. Profitability improved for dairy farms if forage acreage and herd size could be expanded from coupling. Coupled dairy farms that relocated to Aroostook County had increased profitability due to lower land ownership and rental costs.

On-farm integrated dairy farms growing concentrated livestock feed crops were more profitable than conventional dairy farms in both central Maine and Aroostook County. Growing and processing concentrated feed crops was cheaper than buying such feed at typical market prices assuming land was available to grow these crops. Sustainability indicators also improved for coupled and on-farm integrated systems compared to conventional systems.

Both integration types are not prevalent in Maine despite short- and long-term economic benefits. Challenges to adopting integrated crop and livestock systems include distance between potential couplers, establishing and maintaining successful coupled relationships, management of inter-farm coupling and other crops, land availability, and the terms of processing potato contracts. Integration in Aroostook County is also challenged by a lack of infrastructure for dairy farms.

DEDICATION

for Tokiko and Henry,
my Mom and Dad

I wish you were here with me.
I love you very much.

and

for Kristie L. Miner
and Elijah Henry Miner Hoshide
for giving me much support

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I would like to thank all of the cooperating potato, dairy, and beef farmers in Aroostook, Franklin, Lincoln, Oxford, Penobscot, and in York Counties in Maine that participated in this project. Without their patience, time, willingness to teach an inexperienced graduate student, and provision of data used in this study, this dissertation would not have been possible. Their breadth and depth of knowledge about their operations and industry are impressive. It has been a pleasure working with and learning from all of them. Phil Gassman and Todd Campbell at Iowa State helped with i-EPIC. Dr. Jimmy Williams at Texas A&M assisted calibration of the EPIC model for Maine.

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Chapter 1

INTRODUCTION

Crops and livestock historically were integrated in Maine, often being produced on the same farm. Integration involves exchanges of manure, livestock feed, and other activities between specialized crop and livestock farms or within a farm with both crop and livestock enterprises. Farms have become larger and more specialized, focusing exclusively on the production of either crop or livestock products. Crop and livestock industries have also become more consolidated. Potential environmental problems result from specialization and concentration of crop and livestock systems. For specialized crop farms, soils are depleted of organic matter, reducing fertility. Specialized crop production requires increased amounts of chemical fertilizer, which may run-off into watersheds or leach into groundwater. For specialized livestock producers, imported feeds concentrate manure nutrients in industrial animal production facilities. Manure nutrients generated from livestock increasingly exceed assimilation capacity of nearby cropland. This may also result in non-point source pollution.

Specialization and consolidation of crop and livestock industries have made integrating crops and livestock more difficult for two main reasons. First, the prevalence of on-farm integration of crops and livestock on the same farm has diminished as farms specialize into either crops or livestock. Second, geographic areas tend to specialize in different commodities resulting in a spatial separation of crops and livestock. Despite these challenges to integration, some potato, dairy, and beef farms in Maine have experimented with both *coupled* and *on-farm integration.* This has generated interest in the potential for such integration to improve profitability and to encourage tighter nutrient cycling. Unlike on-farm integrated farms that have both livestock and diversified crop enterprises within a single farm unit, coupled farms involve the integration of crop and livestock produced on separate farms engaged in a complementary relationship.

This thesis examines the profitability of and performance indicators for potato and dairy integration in Maine. These performance indicators measured both profitability and sustainability. This analysis first looked at coupled farms in central Maine, which constituted the majority of integrated producers that were surveyed. Profitability and performance indicators for integrated compared to non-integrated farms were also examined for potential potato and dairy couplers in Aroostook County, as well as for dairy farms growing their own concentrated feed crops. Profitability was compared using enterprise and whole-farm budgets. Financial impacts and sustainability indicators were measured for systems that have been coupled for two years (short term) and for more than ten years (long term). Also, the long-term impacts on crop yields were estimated using bio-economic modeling of conventional and integrated cropping systems. Model simulations were run using the Environmental Policy Integrated Climate (EPIC) program.

It is important to examine profitability and sustainability indicators and to conduct simulation modeling of integrated crop and livestock systems in Maine. Farms may be interested in adopting integrated crop and livestock systems, but are unsure of the benefits and costs associated with transitioning to these types of systems. Possible benefits may include increased crop[1] yields, reduced fertilizer use, improved soil quality, options for crop and herd expansion, and enhanced management skills by interaction with another producer. However, integrating systems may be costly due to increased time

[1] Potatoes (*Solanum tuberosum* L.), grain and silage corn (*Zea mays* L.), alfalfa (*Medicago sativa* L.), barley (*Hordeum vulgare* L.), soybeans (*Glycine max*), and mixed forage grass (Family *Poaceae*).

required to manage these more complex systems (Files and S.N. Smith, 2001). Potential agronomic benefits from integration such as increased crop yields and soil quality, improved nutrient cycling, and reduced nutrient loading should be modeled since these benefits are more difficult to measure.

Coupled crop and livestock systems should be more profitable than non-integrated agricultural systems. First, coupled crop and livestock farms may both expand if land base is shared. Second, profitability should increase if manure nutrient credits are taken since fertilizer applications decrease. Third, manure application may increase crop yields, especially in the long-term. For example, previous field research suggested a higher likelihood of increased potato yields from long-term manure amendment, especially in dry years (Gallandt et al., 1998).

On-farm integrated dairy farms growing forage and crops processed into concentrated livestock feed may be more profitable than farms growing only forage. This may happen if growing and processing crops for concentrated feed is cheaper than purchasing bulk feeds processed from crops raised in the Midwest. Crop diversification in integrated systems can also reduce risk from producing a limited set of commodities.

Integrated systems should also have more favorable performance indicator values than non-integrated systems due to higher net farm income and lower purchased fertilizer inputs. Both factors improve values of many measured indicators. Computer simulation of non-integrated and integrated crop rotations should show that integrated systems have higher crop yields compared to non-integrated systems, especially in the long term. However, validating the EPIC model with Aroostook County research farm data may be challenging with less studied crops like potatoes.

Chapter 2

BACKGROUND

This thesis investigates two types of integrated farms, coupled and on-farm integrated. Coupled farms are involved in manure for feed exchanges with another farm, but this it is difficult to accomplish with potato and dairy industries in Maine that are usually spatially separate. Potato farms are clustered in Aroostook County, while dairy farms are found primarily in central and southern Maine. This may inhibit coupling between these types of farms. On-farm integrated farms raise livestock, cash crops, livestock forage, and crops for concentrated feed plus spread manure on cropland. Cooperating integrated Maine producers are also described in this chapter.

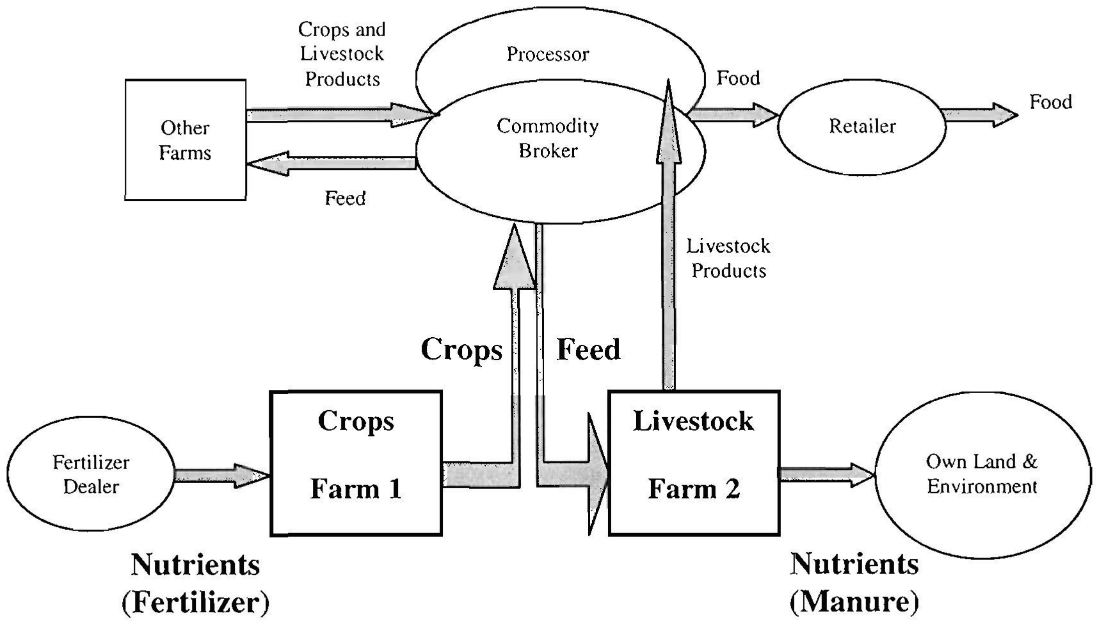
Crop and Livestock Integration Types

Farms that are not integrated are considered decoupled and in this analysis are referred to as conventional, having nutrient cycles that are not as tight as those of integrated farms. Conventional crop farms rely almost exclusively on non-farm generated fertilizer usually purchased from a fertilizer dealer. Some conventional farms may use legume cover crops as a nitrogen source. Crops produced are generally marketed to a commodity broker or processor further down the food supply chain. Feed crops sold to commodity brokers are resold to livestock farms. Conventional livestock farms purchase a large proportion of their feed from commodity brokers. Livestock generate manure that on large farms can result in nutrient overloading of the soil. Nutrient overloading can result in non-point source pollution (Figure 2.1).

Integrated farms tend to have tighter nutrient cycles than conventional. Coupled farmers are specialized crop or livestock producers that exchange feed crops for manure

Figure 2.1. Conventional and coupled farm systems (Adapted from Leibman, 2002).

Conventional or Decoupled Farms



Coupled Farms

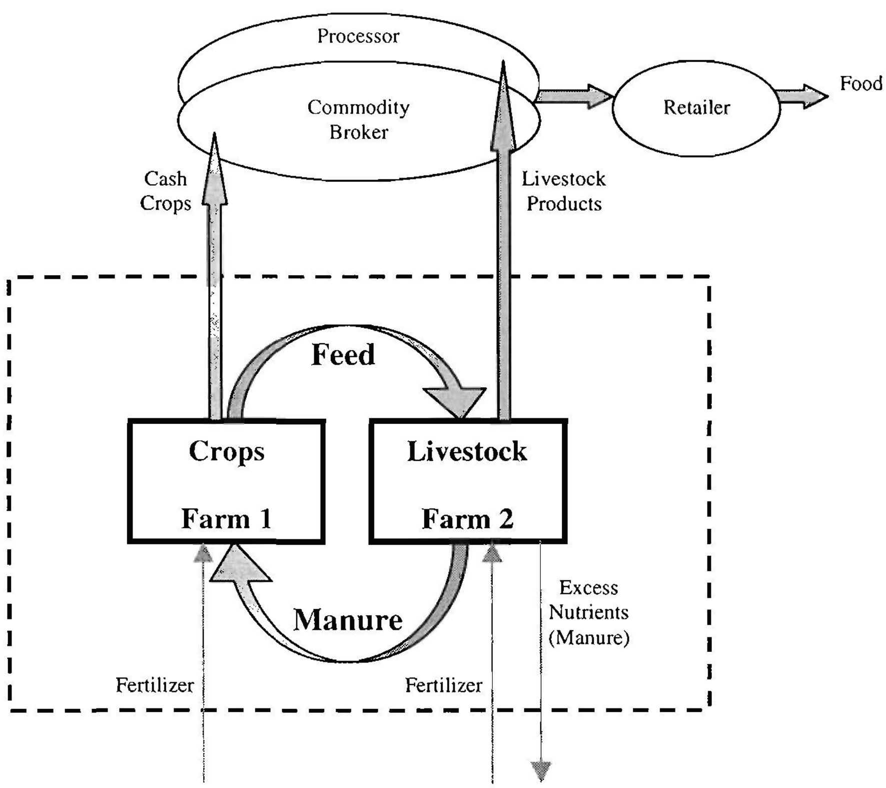
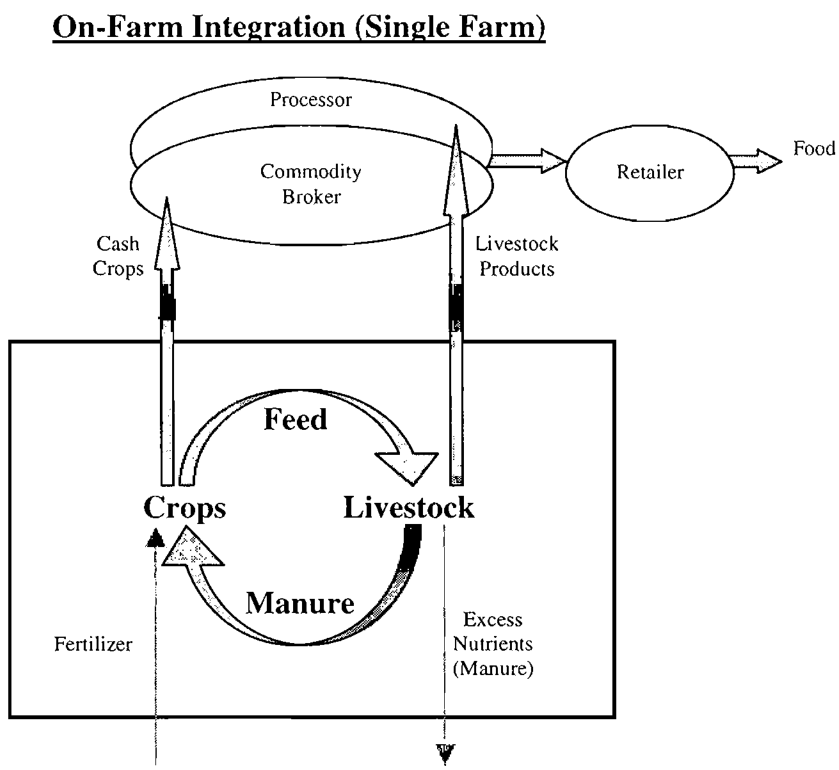


Figure 2.2. On-farm integrated system (Adapted from Leibman, 2002).

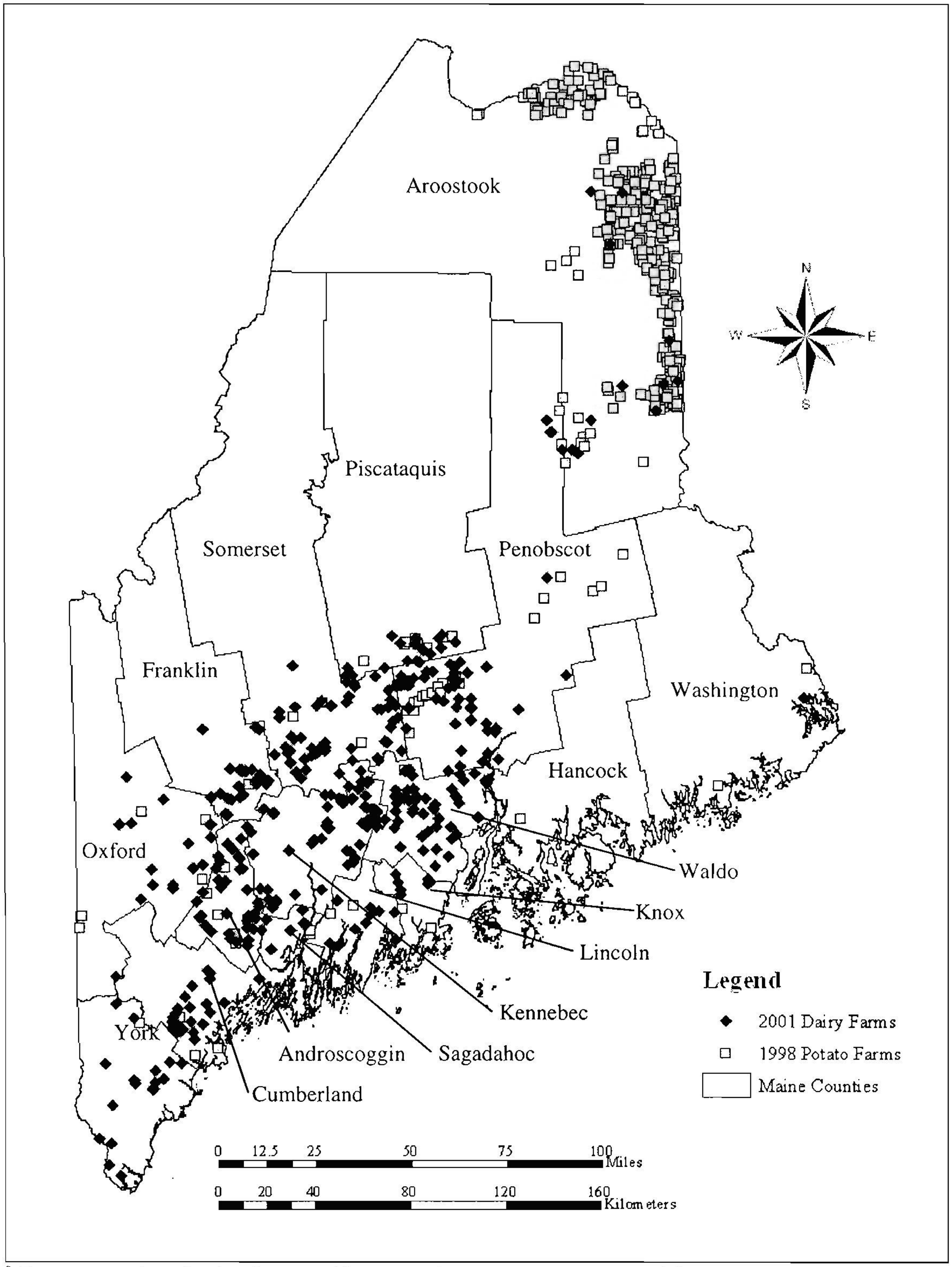


and allow crop acre reallocations. Cropland is usually exchanged between couplers. For crop farms, rotation cropland is exchanged for cash crop or feed crop acreage. For livestock farms, exchanged land may be used to grow forage and/or concentrated feed. Manure produced by the coupled livestock farm is distributed over cropland used for both cash crops and feed crops. Additionally, crops grown by the crop farm can be used as feed by the livestock farm. Both crop and livestock farms may still sell cash crops and livestock products to processors and both may still purchase fertilizer. However, fertilizer purchases as well as nutrient pollution may be more limited compared to conventional (Figure 2.1). The coupled relationship can range from being as simple as a land exchange to involving shared equipment, labor, and other production inputs (Files and S.N. Smith, 2001).

On-farm integrators have both crop and livestock enterprises. A high proportion of livestock feed is grown on-farm and manure is applied to crops. Specialized crop farms that grow a wide variety of cash and feed crops and that have a livestock enterprise can be on-farm integrated. On-farm integrators can also be livestock farms that raise both forage and concentrated feed. Like the coupled case, on-farm integrators have tighter nutrient cycles compared to conventional. The major difference between on-farm integration and farm coupling is that integration occurs under the management of one farm rather than two or more farms. Like coupled farms, on-farm integrators may sell cash crops and livestock products to processors, may purchase fertilizer, and have nutrient management challenges. Increased farm specialization that focuses on either crop or livestock systems discourages the on-farm integration of these systems.

Couplers and on-farm integrators can be integrated to varying degrees both within and between integration categorizations. For example, in Maine most conventional dairy farms raise their own forage but purchase concentrated feed. These farms are on-farm integrated to a certain level since livestock forage is raised and manure is spread on the farm's forage cropland. However, few dairy farms in Maine raise their own concentrated feed in addition to forage. The on-farm integrator depicted in Figure 2.2 would more closely represent dairy farms raising all their feed. A farm can also be both on-farm integrated and coupled as long as some manure is exchanged for livestock feed.

Figure 2.3. Maine potato farms in 1998 and dairy farms in 2001.[a]



[a] Farms were plotted using farmer addresses and may not represent actual farm centers.

Maine Potato, Dairy, and Beef Farms

Potato farms are concentrated in Aroostook County, while the bulk of the dairy industry is in the dairy belt in central and south-central Maine (Figure 2.3). The 495 potato farms[2] shown in Figure 2.3 were geo-coded in Arc View using a 1998 mailing list obtained from the Resource and Economics and Policy (REP) department at the University of Maine, while a total of 437 Maine dairy farms in 2001 were address matched by Aimee Rioux (2001). Geo-coded points for both dairy and potato farms were farmer addresses and may not correspond precisely with actual farm centers. Address matched farms were less than cited in the 1997 Census of Agriculture. According to the 1997 Census, Maine had 586 potato farms and 685 dairy farms.

Potato Farms

The number of potato farms in Maine has declined over the past few decades. From 1964 to 1997, the number of Maine potato farms decreased from approximately 4052 to 586 according to the 1997 Agricultural Census (Table 2.1). Total harvested acreage also decreased from about 131,000 to 73,000 acres from 1964 to 1997. During this same time, annual potato production dropped from about 35,250,000 to 19,490,000 cwt (USDA-NEASS, 1997). Average potato acreage per farm increased during this time from about 32 to 125 acres. When farms with revenues greater than $10,000 were considered, average acreage for Maine potato farms in 1997 increased to 145 acres.

Potato farms by county from the 1997 Census of Agriculture were compared to potato farmers from the 1998 REP mailing list and those successfully geo-coded. Farmer addresses overestimated Census numbers in Aroostook County, while underestimating

[2] Of the initial 582 potato farmers on the 1998 mailing list, 495 were successfully geo-coded.

Table 2.1. Maine potato farms and acreages from the 1997 Census.

County	County Totals Farms[a] (1997)	Farmers[b] (1998)	Geo-coded Farmers (1998)	Potato Farm Cropland[ac] (acres)	Potatoes[a] (acres)	Potato Farm Avg Crops[ac] (acres)	Potato Acreage[a]
Androscoggin	12	6	6	196	196	16	16
Aroostook	416	514	433	112,864	65,454	271	157
Cumberland	9	4	4	26	D	3	D
Franklin	5	1	1	22	22	4	4
Hancock	12	1	1	30	11	3	1
Kennebec	14	1	1	691	9	49	1
Knox	4	2	2	D	D	D	D
Lincoln	8	3	3	29	7	4	1
Oxford	18	6	6	2,878	1,919	160	107
Penobscot	34	29	23	7,133	4,007	210	118
Piscataquis	12	8	8	543	444	45	37
Sagadahoc	3	-	-	D	D	D	D
Somerset	4	3	3	619	D	155	D
Waldo	9	2	2	16	16	2	2
Washington	11	2	2	28	28	3	3
York	15	-	-	13	D	1	D
MAINE	586	582	495	127,216	73,085	217	125

[a] Data from 1997 Agricultural Census for all surveyed farms (USDA-NEASS, 1997).
[b] Data from University of Maine Resource Economics and Policy mailing list.
[c] Cropland included potatoes, barley, oats, and grain corn. Wheat and rye grain not included since acreage for these crops were minimal. Some crops not included in sum due to disclosure (D).

them in all other counties. Total farm and potato acreages, average farm size, and average potato farm acreages were estimated (Table 2.1). Adding acreages for barley, oats, and grain corn to potato acreages approximated total potato farm cropland.

According to Census data, about 78% of the potato farms and about 90% of the potato acreage in Maine were in Aroostook County. Penobscot County was second with about 5% of farms and acreage. Farm averages for size and potato acreage were simply estimated by dividing total potato farm cropland and acreages by the number of farms in each county. Average potato acreages for farms were largest for Aroostook, Penobscot, and Oxford Counties (Table 2.1).

Dairy Farms

Dairy farms in Maine have also declined over the past few decades. From 1964 to 1997, the number of dairy farms decreased from approximately 5414 to 685 according to the 1997 Agricultural Census. Between 1964 and 1997, the number of milk cows decreased from 75,582 to 40,749 (USDA-NEASS, 1997; Figure 2.4), while total Maine milk production decreased slightly from approximately 6,600,000 to 6,540,000 cwt from 1965 to 2001 (MSPO, 2003). Average number of cows per farm increased during this time from about 14 to 59. Stable milk production with fewer cows was attributed to higher productivity per cow. Herd averages also increased during this time.

Maine dairy farms, milking cows, annual fluid milk output (cwt), average cow numbers per farm, and herd averages were summarized for all counties in 2001 (Table 2.2). Farm numbers decreased in all counties from 1997 to 2001. Dairy farms were concentrated in Kennebec, Penobscot, Somerset, Waldo, and Androscoggin counties. Aggregate milk output corresponded to farm numbers with the exception of Franklin and

Figure 2.4. Maine dairy and beef cow numbers, 1964 to 1997 (USDA-NEASS, 1997).

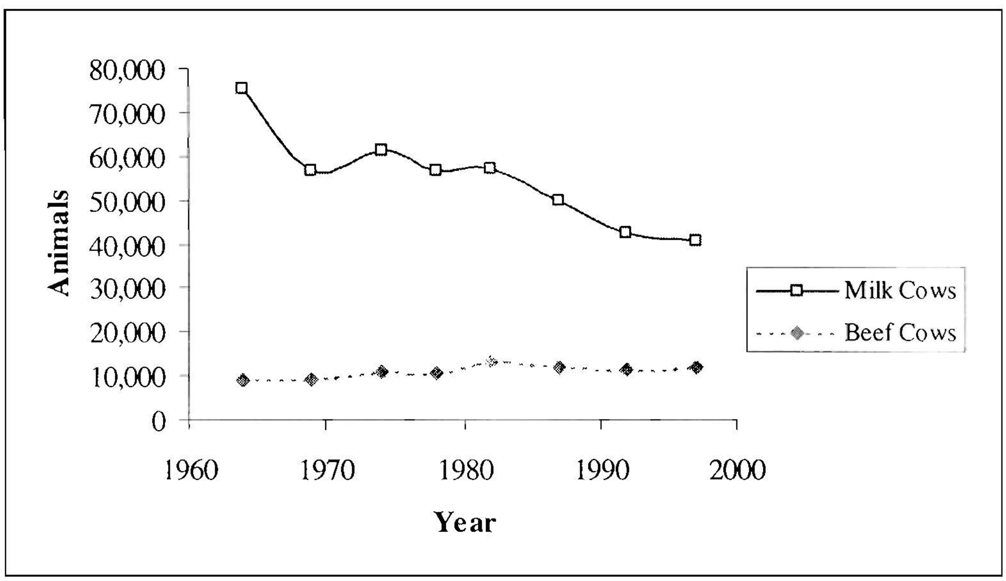


Table 2.2. Dairy farm numbers, milk output, milking cows, average number of cows per farm, and herd average for Maine counties in 2001.

	County Totals					Dairy Farm Avg.		
County	Farms[a] (1997)	Farms[b] (2001)	Dairy Farm Cropland[c] (acres)	Milk Cows[b]	Annual Milk Output[b] (cwt)	Crops[c] (acres)	Milk Cows[b]	Herd Avg.[b] (cwt)
Androscoggin	67	39	7,282	2,853	579,620	187	73	203
Aroostook	47	12	1,945	762	161,609	162	64	212
Cumberland	42	23	2,851	1,117	220,130	124	49	197
Franklin	44	27	2,757	1,080	188,513	102	40	175
Hancock	2	-	-	-	-	-	-	-
Kennebec	84	73	17,254	6,760	1,535,920	236	93	227
Knox	12	8	707	277	58,765	88	35	212
Lincoln	21	12	1,728	677	116,800	144	56	173
Oxford	37	20	2,453	961	200,069	123	48	208
Penobscot	91	63	14,498	5,680	1,231,636	230	90	217
Piscataquis	31	19	2,889	1,132	273,445	152	60	242
Sagadahoc	15	7	1,059	415	79,935	151	59	193
Somerset	81	60	12,479	4,889	1,224,923	208	81	251
Waldo	76	56	9,947	3,897	809,499	178	70	208
Washington	4	1	153	60	5,475	153	60	91
York	31	17	2,047	802	164,250	120	47	205
MAINE	685	437	80,049	31,292	6,850,589	183	72	218

[a] Data from 1997 Agricultural Census for all surveyed farms (USDA-NEASS, 1997).
[b] Data from 2001 Maine Milk Commission data.
[c] County dairy farm cropland and average cropland were estimated assuming a requirement of 2.55 acres of corn silage, haylage, and hay per milk cow. Numbers of milk cows in 2001 were used.

Piscataquis counties. Piscataquis County with 19 farms had about 45% higher aggregate milk production than Franklin County with 27 farms due to the relatively larger herd average in Piscataquis compared to Franklin County. Herd averages were highest in Somerset County followed by Piscataquis, Kennebec, and Penobscot.

Beef Farms

Beef farm numbers in Maine have remained relatively stable over the past few decades. From 1964 to 1997, the number of Maine beef farms decreased from approximately 1295 to 1035 according to the 1997 Census of Agriculture. Over the same time, the number of beef cows increased from 9167 to 11,782 (USDA-NEASS, 1997; Figure 2.4). Average number of beef cows per farm increased from 7 to 11 over this

Table 2.3. Beef farm numbers, cows, and average number of cows per farm for Maine counties in 1997.

County	---------- County Totals ----------			-- Beef Farm Avg. --	
	Farms[a] (1997)	Beef Farm Cropland[b] (acres)	Beef Cows[a]	Crops[b] (acres)	Beef Cows[a]
Androscoggin	58	1,022	511	18	9
Aroostook	147	5,790	2,895	39	20
Cumberland	100	2,864	1,432	29	14
Franklin	52	896	448	17	9
Hancock	34	D	D	D	D
Kennebec	103	2,208	1,104	21	11
Knox	31	848	424	27	14
Lincoln	39	728	364	19	9
Oxford	90	1,426	713	16	8
Penobscot	73	1,394	697	19	10
Piscataquis	24	770	385	32	16
Sagadahoc	27	850	425	31	16
Somerset	73	1,676	838	23	11
Waldo	52	984	492	19	9
Washington	22	D	D	D	D
York	110	1,536	768	14	7
MAINE	1,035	23,564	11,782	23	11

[a] Data from 1997 Agricultural Census for all surveyed farms (USDA-NEASS, 1997).
[b] County beef farm cropland and average cropland were estimated assuming a requirement of 2 acres of haylage, hay, and pasture per beef cow and that no concentrated feeds were grown on farm.

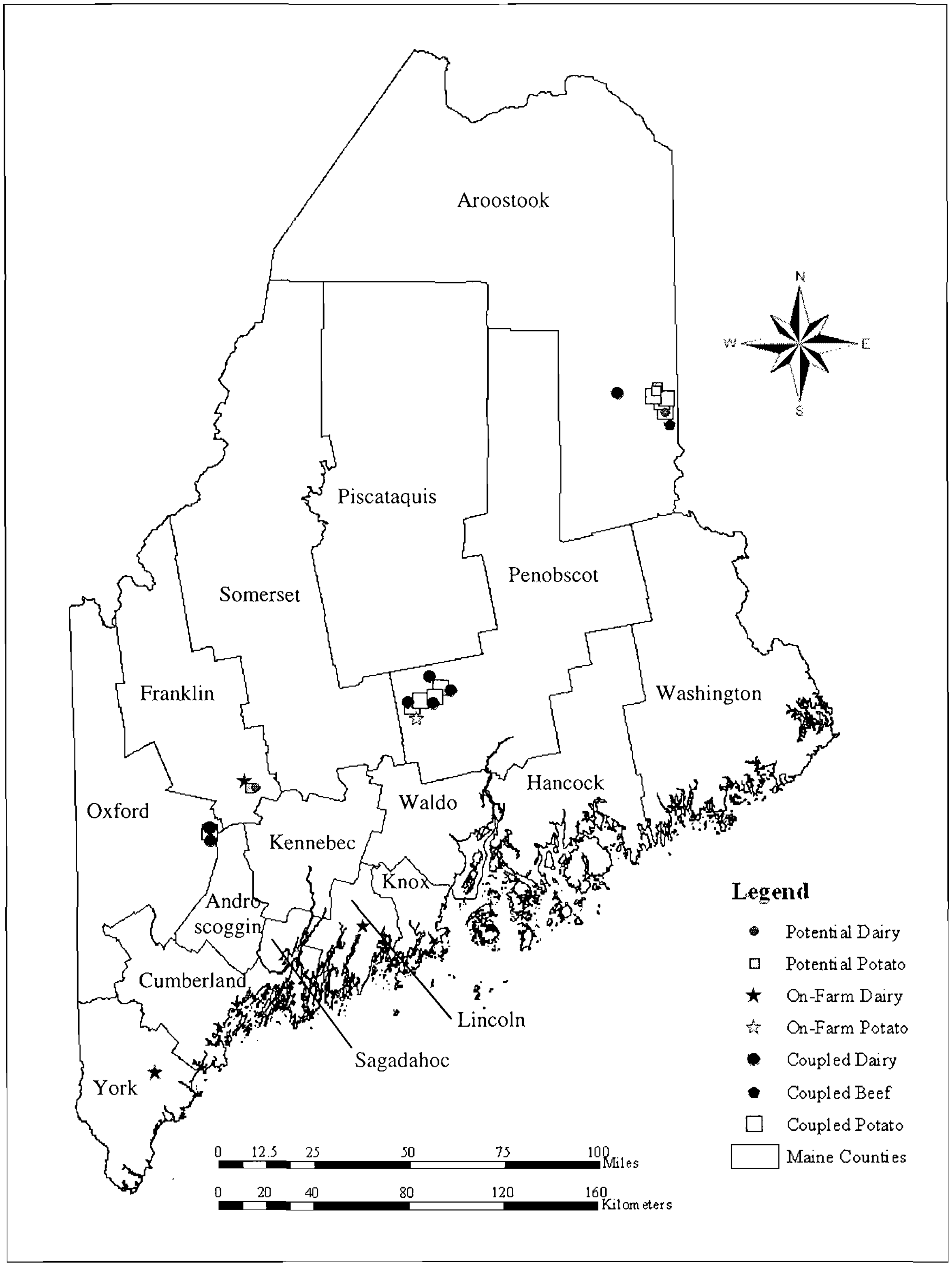
period. Maine county data on beef farms, cows, and estimated cropland were summarized (Table 2.3).

Beef farm numbers were highest in Aroostook, York, Kennebec, and Cumberland Counties. However, Aroostook beef farms had the largest number of cows and herd size compared to all other Maine counties (Table 2.3). Maine beef farms can be classified as one or a combination of three different farm production types. Following the growth and development of beef cows, these beef farm categorizations are cow/calf operations, stockers, and finishers (Giustra, 2003).

Maine Cooperating Integrated Farms

The 26 cooperating producers in Maine that were integrated or that had explored integration in the past were clustered in central Maine and southern Aroostook County

Figure 2.5. Maine cooperating farms classified as coupled, on-farm integrated,[a] or potentially interested in crop and livestock integration.



[a] The on-farm integrated classification represented the farm's dominant enterprise.

Table 2.4. Integrated farm categorizations, manure type, milk cows, and acreages.

Integrated Farm Type	Commodity	Size	Manure	Farms	Cows	----------- Average Acreage ----------- Total[a]	Crops[b]	Cultiv.	Potato	Int.[c]	% Int.[d]
Coupled	Dairy	S	Dairy, Hen (S)	3	67	318	184	86	-	57	66
		M	Dairy (L/S)	2	145	714	532	322	-	45	14
		L	Dairy (L)	3	434	961	584	434	-	180	42
	Beef	M	Beef (S)	1	D[e]	D	D	D	D	D	9
	Potato	S	Dairy (L) Beef (S)	2	-	925	763	499	160	321	64
		M	Dairy (L/S)	3	-	931	590	501	316	141	28
		L	Dairy (L)	1	-	D	D	D	D	D	19
On-farm	Dairy[f]	S/M	Dairy (S)	3	110	1142	650	317	-	262	83
	Potato[g]	L	Dairy (S)	1	D	D	D	D	D	D	28
			Integrated Total[h]	19	2,189	16,151	11,003	7,672	2,592	3,062	40
			Integrated Avg.		182[i]	850	579	404	370[j]	161	40

[a] Average total farm acreage included forested and developed land.
[b] Crops included cultivated ground, hay land, and pasture.
[c] Average farm acreage that was integrated.
[d] Percent of cultivated acreage that was integrated.
[e] Data not disclosed (D) since only one farm was in size class.
[f] Dairy and mixed vegetable farm components.
[g] Potato farm with livestock component.
[h] Not including two potential integrators and a coupled potato farm with insufficient data.
[i] Milking cows averaged only for dairy farms.
[j] Potato acreage averaged only for potato farms.

where both potato and dairy farms were prevalent (Figures 2.3 and 2.5). Integrated farms were categorized as coupled, on-farm integrated, and potential integrators. Coupled farms were either specialized potato or livestock farms exchanging manure for forage in addition to land. On-farm integrators were dairy operations with diversified crop production or a potato farm with a livestock component. Potential integrators were potato and dairy farmers interested in integration even though actual implementation had been limited.

The 26 cooperating producers recommended by extension educators were aggregated into small-, medium-, and large-sized representative farms. Relative acreages and livestock numbers used for representative coupled and on-farm integrated farms were from 2001 (Table 2.4). The 19 integrated farms in Table 2.4 did not include 4 potential integrators and 3 coupled farms with insufficient data. These 19 farms provided adequate data and were composed of 15 coupled farms and 4 on-farm integrators. Production data from the 15 coupled farms were used to construct representative budgets. Manures generated and/or used on farm were categorized as solid (S) or liquid (L). All hen manure was from large egg facilities. Hen and beef manure were solid. Dairy manure was solid, liquid, or a combination of liquid and solid (L/S).

Total farm, cultivated, and potato acreages were listed along with the amount and percent of cultivated land that was integrated on each type of farm (Table 2.4). Size classes for representative farms were based on cow numbers for dairy farms and potato acreage for potato farms. Representative farms are further described in Appendix A and Hoshide and Dalton (2003). Total farm acreage included forested and developed land. Crops included cash crops, rotation crops, and livestock feed crops (including pasture).

For coupled dairy and potato farms, the amount and percentage of cultivated acreage that was designated as integrated corresponded to the proportion of potato acreage that was integrated. One exception was a potato farm that grew forage for the coupled dairy farm where integrated land included both potato and corn silage acreage. For on-farm integrated farms, integrated cropland included acreages of silage corn, concentrated feed crops, and mixed vegetables.

Coupled farms had integrated varying amounts of their cultivated land. Cultivated land included tilled cash crops like potatoes, grain corn, and barley. Livestock forage such as hay and haylage was not cultivated. Nine coupled farms had integrated more than one-third of their cultivated acreage, including three pairs of large coupled potato and dairy farms as well as three small dairy farms. These small dairy farms had most of their silage corn coupled with a single potato farm. This was an unusual situation with higher transaction costs for the potato farmer but which still appeared profitable.

Six coupled farms were integrated on less than one-third of tillable acreage. One was a dairy farm that coupled with a potato farm integrated on more than a third of its potato acreage. A second pair of potato and dairy farms was coupled on another farm's land. The only cooperating beef farm was integrated with two potato farms. Of the four on-farm integrators, one was a potato farm with a dairy component. The other three were dairy farms that grew varying amounts of sweet corn and mixed vegetables in addition to forage and crops for concentrated feed. Four potential integrated farms had limited past integration or had expressed interest in integration. Two of these farms experimented with integrating potatoes and silage corn at a plot level a few years ago. The other two farms had never been integrated but had discussed this possibility.

Representative whole-farm budgets in Appendices B and C were based on the integration classifications in Table 2.4. Production information for farms in each category were averaged or generalized and did not represent specific cooperating farms. Farms with only one farm falling in a classification category are described in Appendix A in a generalized fashion so as not to disclose confidential production data about that specific farm. These included a coupled beef, a large-coupled potato, and an on-farm-integrated potato farm with a dairy component (Table 2.4; Appendix A).

Chapter 3

LITERATURE REVIEW

Productivity in conventional agricultural systems is maintained using pesticides and chemical fertilizers. Integrated systems can displace pesticides with technologies highlighting biodiversity such as crop rotation, inter-cropping, and predatory insects. Chemical fertilizers can be displaced with increased nutrient cycling from decomposing organic matter such as manure, green manures, and crop residues (C.A. Edwards et al., 1993). Integrated farming systems tend to have greater crop diversity (Cutforth et al., 2001) combined with more prevalent livestock (Taylor and Dobbs, 1991). Integration takes place under different spatial scales of nutrient cycling and varying types of agricultural production systems. Integration can also be found in agricultural production systems using different intensities of crop inputs such as land, labor, and capital.

Most literature on crop and livestock integration focuses on on-farm integrated systems. Many potential benefits and challenges to on-farm integration are applicable to inter-farm coupling. Possible agronomic benefits are higher crop yields and quality, improved soil quality, and reduced fertilizer and pesticide use. Economic benefits for integrated systems include greater profitability, diversification, and risk reduction. Environmental benefits to integration include tighter nutrient cycling and reductions in non-point source pollution. Inter-farm coupling in particular may enhance farm management and efficiency and facilitate livestock expansion. Integration is challenging to manage since it is more complex, requiring greater knowledge about different types of agricultural enterprises. At the farm-level, integrating crop and livestock systems may be limited by agricultural specialization, economies of scale, access to land and infrastructure, crop production problems, and markets. Consolidation and vertical coordination of farm and non-farm firms in crop and livestock industries also limit adoption of integrated systems. Widespread inter-farm coupling is further limited by spatial separation of crops and livestock industries.

Integration Structure, Scale, and Input Use

Magdoff et al. (1997) differentiated crop and livestock integration from non-integrated production with respect to changes in the spatial structure of food trophic pyramids. Close proximity of plants, animals, and humans to each other characterized pre-industrial revolution agricultural production. Nutrients from human and animal wastes were composted and applied back on the land for crops. Subsequent urbanization separated many people from the agricultural land base, limiting nutrient cycling to animal manure used in integrated crop and livestock systems. Recent industrialization and specialization of agriculture separated the production of crops and livestock, further limiting opportunities to cycle nutrients between agricultural plants and animals.

Integrated systems occur across different spatial scales of nutrient cycling. Nutrient cycling happens at the field and farm-level and at regional and global scales. Integration at one spatial scale does not necessarily imply a high degree of integration at other scales. For example, coupled farms may have certain fields that are not integrated. Likewise, coupled farms may be in regions or countries that are net importers or exporters of crop nutrients. Global trade of agricultural commodities and products may concentrate nutrients in certain areas of the world at the expense of other regions.

Schiere et al. (2002) also distinguished different types of crop and livestock integration depending on the type of agricultural production system used. Agricultural production systems vary by their use of inputs such as land, labor, and capital. Farms that manage most integrated acreage in Maine would be classified as high-input. Both integrated and non-integrated systems can also be found in expansion, low-input, and new conservation forms of agriculture. Grazing livestock on common frontier land demonstrates integrated expansion agriculture. Low-input agricultural integration is typified by West African agro-pastoral systems. An example of new conservation agricultural integration in Maine would be an on-farm integrated dairy farm growing all required forage and crops used for concentrated feed.

Integration Benefits

Potential socio-economic, agronomic, and environmental advantages to integrating crop and livestock systems are numerous. This section describes possible benefits for integrated farms in general that may be applicable to on-farm integration and/or inter-farm coupling. Potential benefits specific to coupled farms are explored, motivated by cooperating potato and dairy producers in Maine.

Integrated Farms

On-farm integration of crops and livestock can be encouraged by numerous socio-economic factors related to agricultural production and consumer preferences. The USDA's Conservation Reserve Program (CRP) offers incentives to growers to establish perennial cover on highly erodible land for ten years. After this period, CRP land could be grazed. Livestock can control weeds on farmland and utilize failed crops, crop residues, and wasteland. Technological advances in animal fencing may reduce grazing costs. Consumer preferences for humane livestock production practices common under on-farm integration such as intensive grazing, reduction in hormone and antibiotic use, and less reliance on confinement (Hardesty and Tiedeman, 1996) may cause a shift to this type of a system.

Integrated crop and livestock systems can have higher crop yields and quality. This may or may not translate to greater profitability. Profitability aside, integrated systems may provide diversification and risk reduction (Krall and Schuman, 1996). Integration may lower cash and capital inputs and distribute production activities more evenly throughout the year (Bender, 1994). Integrated systems raise forage and/or crops used for concentrated livestock feed. Past on-farm integration in southern Minnesota demonstrated moderate agronomic and economic benefits and was encouraged where low-value forage was prevalent (Keith, 1952).

On-farm integration using forage legume rotation crops may enhance profitability. Linear programming (LP) confirmed greater yields and profitability for on-farm integrated livestock systems using forage legumes in both the highlands of Ethiopia (Kassie et al., 1999) and in northern Syria (Thomson et al., 1995; Thomson and Bahhady, 1995a and 1995b). LP also demonstrated integrated Cameroon crop and livestock systems were more profitable than non-integrated ones due to "better use of intermediate farm resources such as manure, draft power, and crop residues" (Ngambeki et al., 1992).

Unlike developing nations, modern agriculture does not use draft livestock. However, manure application may increase crop yields and soil quality. This was shown for potatoes, especially under dry conditions, in locations such as Prince Edward Island, Canada (Black and White, 1973) and Shimla and Punjab, India (Sharma and Grewal, 1986; Sharma and Arora, 1987; Grewal and Trehan, 1988). Maine Potato Ecosystem

Project (MPEP)[3] potato yields for soils amended with compost and solid manure were greater than unamended, especially in dry years. Yields tended to be more stable for amended. Short-term profitability measured by return over variable costs (ROVC) were 34% lower for amended due to higher costs for manure and compost plus no returns from peas/vetch/oats rotation from 1993 to 1996. However, if manure was not paid for and if compost was produced on-farm, ROVC for amended was only 7% lower than unamended (Gallandt et al., 1998).

Organic matter and water stable aggregates, both measures of soil quality, were higher and thus more favorable for amended soils in the MPEP after only two years. Levels of phosphorus and potassium were also greater for amended (Gallandt et al., 1998; Porter and McBurnie, 1996). Potato farms in central Maine integrated for more than ten years have noticed gradual improvements in soil quality. Unamended soil that used to crust over became easier to till after long-term integration with nearby dairy farms (Files and S.N. Smith, 2001). Black and White (1973), Sharma and Grewal (1986), and Grewal and Trehan (1988) showed increased organic carbon and/or nutrient availability for manured potatoes. Improvements in similar soil quality measures from manure application were shown in sub-Saharan Africa (J.W. Smith et al., 1997). In addition to improving soil quality, longer rotations with livestock forage may reduce the potential for soil erosion (Bender, 1994).

Integration may provide opportunities to reduce fertilizer and herbicide use. Nutrient release from manure can be slower than chemical fertilizer, which can favor large-seeded crops over smaller-seeded weeds. Additionally when integrated systems

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[3] The Maine Potato Ecosystem Project has analyzed agronomic and economic effects of conventional and alternative pest and soil management systems on potato production since 1991 (Marra, 1996).

utilize more diverse rotations due to inclusion of annual and perennial livestock forage, weed growth may be compromised from "resource competition and niche disruption" (Liebman and Davis, 2000). Fertilizer reductions save energy needed to manufacture, mine, and/or process chemical nitrogen, phosphorus, and potassium.

Fertilizer use for potatoes in the MPEP was reduced by about half (Gallandt et al., 1998). Integrated beef and forage systems in Virginia that had longer rotations and that utilized more intensive grazing used less fertilizer and herbicides than conventional systems with simpler rotations. Manure and inclusion of alfalfa as a rotation crop helped reduce fertilizer requirements. Herbicide use was reduced using integrated pest management (Luna et al., 1994). Longer crop rotations in integrated systems from forage may also reduce pest problems (Krall and Schuman, 1996).

In addition to socio-economic and agronomic factors promoting integration, possible environmental benefits include tighter nutrient cycling and reduced non-point source pollution. Non-integrated, specialized crop and livestock systems have more wasteful, linear nutrient flows. Specialized crop farms rely on chemical fertilizers for fertility and generally sell to commodity markets. Non-integrated livestock farms grow less of their own feed, instead importing it from commodity brokers. Thus, manure may get concentrated on farmland, potentially causing water and air pollution. Manure nutrients may also be exported to non-agricultural areas. For example, North Carolina hog producers volatilize manure in lagoons and then irrigate coastal Bermuda grass with remaining nutrients (Hoag and Roka, 1995). Integration allows more efficient nutrient cycling, which can improve nutrient conservation, reduce crop fertilizer use, mitigate externalities of livestock farming, and maintain wild plant species diversity (Tilman, 1999).

On the crop side, integrating crops and livestock may decrease the amount of chemical fertilizer required for crops. Reduced chemical fertilizer use may reduce non-point source pollution since less fertilizer is present in the soil profile. However, excess manure nutrients can also run off into watersheds and leach into groundwater. Examples of non-point source pollution are phosphorus run-off causing algal blooms and hypoxic watershed conditions and nitrates contaminating drinking water (Ribaudo et al., 1999).

On the livestock side, integration can also mitigate non-point source pollution.[4] For very large livestock farms, nutrients from nearby manure spreading may become overly concentrated in the soil. For example, South Dakota beef feedlots typically apply manure nutrients in excess of crop requirements, resulting in nutrient loading. Nitrogen and phosphorus loading was greater for larger feedlots (Taylor and Rickerl, 1998). Like chemical fertilizers, excess soil nitrogen and phosphorus from manure can contaminate watersheds and groundwater (Jongbloed and Lenis, 1998). Integrated livestock facilities have access to greater land base from more diverse crops or from inter-farm coupling. Nutrients can be distributed over larger areas so as not to exceed plant uptake and aggravate environmental problems related to nutrient loading.

National estimates of county-level nutrient production and uptake demonstrate the potential for non-point source pollution problems in certain areas of the U.S. such as the southeast and southwest. In these regions, production of nutrients from concentrated livestock facilities exceeded possible plant uptake from nearby agricultural land in many

[4] In addition to nitrogen and phosphorus, livestock facilities produce air pollutants such as ammonia, methane and other greenhouse gases, and odors (Jongbloed and Lenis, 1998).

counties (Lander et al., 1998; Gollehon and Caswell, 2000; Gollehon et al., 2001). The Environmental Protection Agency requires all confined animal facilities with over one thousand animal units[5] to file manure discharge permits to monitor manure runoff. Compliance is variable by state (Sullivan et al., 2000). Increased compliance stringency in the future may encourage certain producers to consider integration.

Coupled Farms

There are potential farm management benefits to inter-farm coupling. Integration is possible under inter-farm coupling without having to "learn new management skills or expand production" required when transitioning to on-farm integration (Files and S.N. Smith, 2001). One pair of cooperating producers in central Maine cited enhanced management and efficiency from inter-farm coupling. After more than ten years of coupling, both crop and livestock farmers said their management skills were enhanced by closely observing how another farmer runs an operation different from their own. Coupled farms usually are integrated on exchanged land, which may reduce land rental costs. Shared equipment and labor characteristic of more involved coupled relationships was also cited as a benefit.

The dairy producer in this pair also listed the ability to expand herd size as another potential benefit. Livestock farms may have limited land base relative to the number of animals they are looking to add. Coupling allowed this dairy farm to grow without purchasing additional land. This coupled potato and dairy pair grew forage together, allowing the dairy farmer more time to manage cows and milk production (Ibid.). Integration could be encouraged in areas where dairy farms are rapidly

[5] An animal unit is 1000 lb of animal. One animal unit is approximately equivalent to one beef cow, 0.7 dairy cow, 2.5 hogs, 18 turkeys, or 100 chickens (Ribaudo et al., 1999).

expanding or looking to expand their herds. Increased land base under coupling provides greater opportunities for livestock waste disposal for expanding dairy farms (Fulhage, 1997).

Integration Challenges

Although there are many benefits to integrating crops and livestock systems, numerous socio-economic challenges exist. There are fewer concerns of an agronomic and environmental nature. This section describes potential challenges that may be applicable to on-farm integration and/or inter-farm coupling. In particular, challenges to integration faced by coupled farms in Maine are explored.

Integrated Farms

Numerous socio-economic factors limit integration of crop and livestock systems. Integration involves growing more diverse crops such as livestock forage, concentrated feed crops, various field crops, and/or mixed vegetables. The added complexity of these systems requires greater knowledge and management. Some producers may not be able to devote time to learning about and managing integrated systems. Increased management requirements for integrated systems can limit livestock expansion, which may reduce benefits achieved through economies of scale.

Livestock facilities require buildings and other infrastructure whose cost may inhibit crop farms diversifying into livestock. Other production challenges include land availability, conflicting labor requirements for crops and livestock, and meeting seasonal forage needs. Livestock used in integrated systems need to have lucrative markets (Hardesty and Tiedeman, 1996). Tradition and livestock transportation are other challenges (Krall and Schuman, 1996). Integration may also be limited by government policies and marketing organizations (DeLuca and DeLuca, 1997).

Specialization and consolidation of crop and livestock industries have diminished potential for on-farm integration and have made inter-farm coupling more difficult. The challenge of spatial separation of crop and livestock industries is discussed in the next section of this chapter on coupled farms. Additionally, adoption of sustainable practices such as crop and livestock integration may be limited by vertical coordination in livestock industries. Vertical coordination contributes to consolidation of these industries as agribusiness firms handle more production and marketing elements. Examples of livestock industries with high degrees of vertical coordination are poultry, hogs, and feedlot beef. Farmers contracted to raise these animals may have limited control over production decisions such as feeding farm-grown feed (Hinrichs and Welsh, 2003).

Crop and livestock integration presents specific agronomic challenges such as potential disease problems. Although manure amendments are generally regarded as beneficial to cropping systems, manure can encourage tuber diseases in potatoes such as powdery scab (Porter, 2003). However in Maine, incidence of other diseases such as early and late blight and black scurf were not higher for amended potatoes receiving manure compared to unamended potatoes (Lambert and Salas, 1996; Gallandt et al., 1998). Recent research suggested that potato verticillium wilt, scab, and microbial populations might be dependent on various conditions including manure and soil type and time of amendment (Conn and Lazarovits, 1999). Also, nutrient balancing can be a difficult process for livestock producers even with specialized software (Eigenberg et al., 1998). Pesticides used for crops may be incompatible with livestock production (Hardesty and Tiedeman, 1996).

Manure may cause non-point source pollution if not properly applied. This is generally considered to be more an artifact of the large quantities of manure that must be managed under large-scale livestock farming. Proper manure management and composting may actually reduce nitrate leaching and subsequent contamination of watersheds compared to raw manure applications on frozen ground (Koepf, 1985; DeLuca and DeLuca, 1997). Non-point source manure pollution can be limited if manure nutrients applied do not exceed those required for crop growth. Also, application of manures with high amounts of available nitrogen and phosphorus such as slurries and hen manure should be avoided during the fall and winter (Chambers et al., 2000).

Other technologies for possible non-point source pollution reduction may be more attractive to large livestock producers than integration. Historically, expanding dairy farmers have relied on technologies such as milking parlors, free-stall cow housing, horizontal silos, and modern manure management facilities to expand their herds in order to boost efficiency (Stahl et al., 1999). Dairy cow milk production efficiency may be increased with technologies such as recombinant bovine somatotropin, three times a day milking, and artificial lighting. Increasing efficiency of milk production theoretically should reduce nutrient loading for a given level of milk produced (Dunlap et al., 2000). This may or may not translate into actual reductions in non-point source pollution.

Coupled Farms

Files and S.N. Smith (2001) highlighted several challenges to inter-farm coupling. One challenge was spatial proximity between producers. Coupling between potato and dairy farms in Maine usually occurred within fifteen miles of the dairy farm. The current potential for integration in Maine may be limited given the spatial separation of the potato and dairy industries. Additionally, the added management time required for coordinating with one or more coupled farms might not be appealing to certain farmers. Coordination arrangements between couplers varied in Maine. The simplest arrangements were those where management of production activities were still specialized. Couplers just decided what crop acreage was going to be exchanged by integration. Inter-farm coupling could evolve into more complex relationships where labor, equipment, and inputs were exchanged, blurring the distinction between specialized crop and livestock producers. Increased management time required for coupled agricultural systems may also limit expansion.

Long-term integrators in Maine stressed that successful integration required both couplers to worry less about which farmer was currently making out better and to instead focus on potential future benefits. Two pairs of couplers in central Maine reiterated that they did not keep track of who owed each other what in their coupled relationship. On some days, the livestock farmer may have been making out better. On other days, it may have been the crop producer. Couplers needed to have faith that their operations were benefiting in the long run. Some farmers may not have enough trust in the integration process and potential couplers to successfully integrate. These farmers may require more tangible economic benefits or incentives to consider crop and livestock integration.

Chapter 4

REPRESENTATIVE FARMS FOR CENTRAL MAINE

Cooperating integrated Maine farmers provided the basis for developing classifications and representative budgets of potato and dairy integration. Integrated farms are classified as on-farm integrated or (inter-farm) coupled. Three types of relationships exist between inter-farm couplers. In the first type, the dairy farm grows forage on the potato farm's land. In the second, the dairy farm contracts the potato farm to grow forage. In the third type, production operations and ownership as well as land may be shared. Production characteristics and assumptions are presented for small and medium-large sized potato and dairy farms that are integrated for two years (short term) and for more than ten years (long term).

Integration Classifications

On-farm integrators were dairy farms with diverse crop production or a potato farm with a livestock component. Coupled farms were two or more specialized crop and livestock farms that exchanged some combination of land, feed, and other inputs (Table 4.1) and are land-coupled (L), land/feed-coupled (LF), and land/feed/input-coupled (LFI).

Table 4.1. On-farm and coupled integration types.

Integration Type	Farms Involved	Description
On-Farm	1	Livestock & crops raised; Crops raised for livestock feed
		Livestock manure applied to crops
Coupled	≥ 2	Specialized crop & livestock farms exchange feed and manure
Land (L)	≥ 2	Livestock farm raises feed on crop farm's land
		Crop farm uses livestock farm's land for crops
Land/Feed (LF)	≥ 2	Crop farm contracted by livestock farm to grow feed
		Crop farm uses both own land & livestock farm's land
Land/Feed/Input (LFI)	≥ 2	Production operations & ownership as well as land may be shared

Table 4.2. Division of production responsibilities and asset ownership for coupled farms.

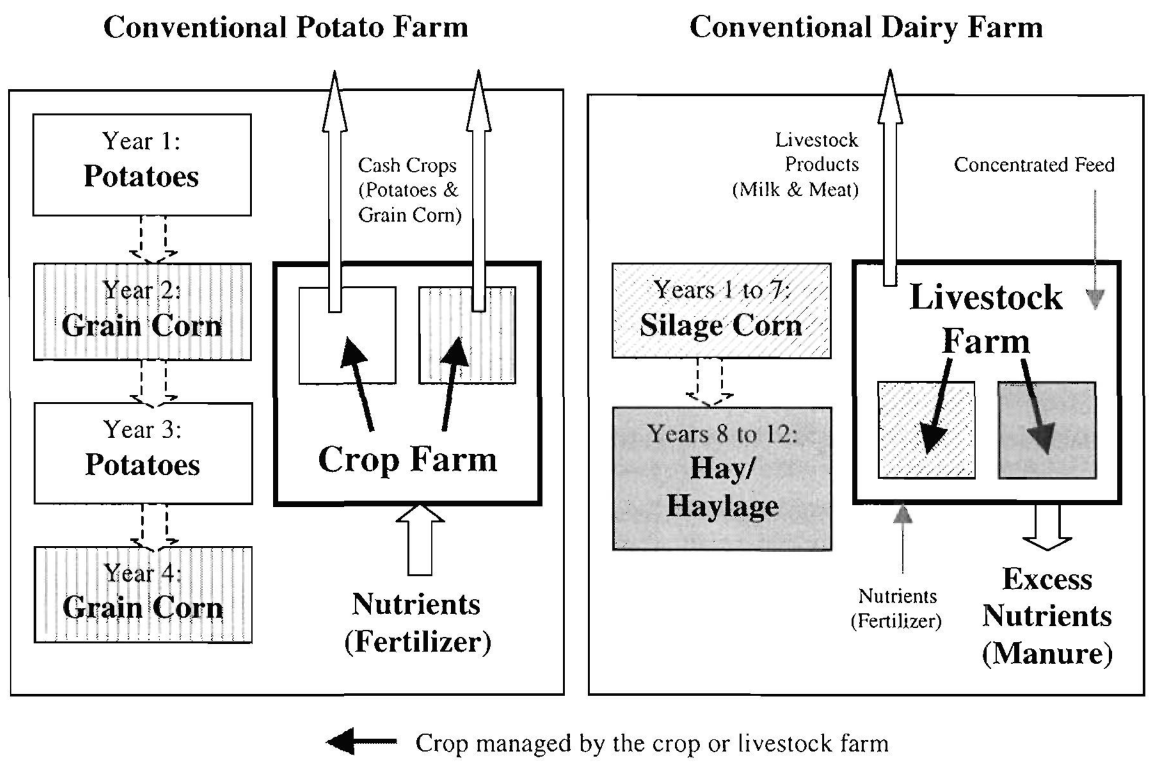
	Coupled Farm Types		
Activities	Land	Land/Feed	Land/Feed/Input
Operations			
Grow and harvest potatoes	Potato	Potato	Potato/Dairy
Grow and harvest forage crops	Dairy	Potato	Potato/Dairy
Grow concentrates[a]	None	None	None
Spreads dairy manure	Dairy	Potato	Potato/Dairy
Purchases concentrates	Dairy	Dairy	Dairy
Manages dairy herd	Dairy	Dairy	Dairy
Ownership			
Potato production equipment	Potato	Potato	Potato
Forage production equipment	Dairy	Potato	Potato/Dairy
Manure spreading equipment	Dairy	Dairy	Potato/Dairy
Manure storages	Dairy	Dairy	Dairy
Livestock feed storages	Dairy	Dairy	Potato/Dairy
Potato and corn cropland	Potato/Dairy	Potato/Dairy	Potato/Dairy

[a] Maine dairy farms do not typically grow crops used for concentrated feed (Dalton and Bragg 2003).

Enterprise production operations and asset ownership for the three types of coupled farms are quite different (Table 4.2). The relationship between coupled crop and livestock farms can evolve from simple exchanging of cropland (land-coupled) to more complex arrangements where land and feed are exchanged (land/feed-coupled) or to even more complexity where land, feed, and production inputs such as labor, fertilizer, and equipment are shared (land/feed/input-coupled). This analysis focused on land-coupled and land/feed-coupled farms common in central Maine. Although two pairs of central Maine coupled farms were land/feed/input-coupled, this case was not analyzed due to the many ways production inputs can be shared.

Typical rotations and crop management for conventional (non-integrated), land-coupled, and land/feed coupled potato and dairy farms in central Maine are illustrated in Figures 4.1 to 4.4. Conventional potato farms manage potatoes and grain corn in a two year rotation. Conventional dairy farms manage silage corn and hay or haylage, growing

Figure 4.1. Central Maine conventional potato and dairy farm crop management before coupling.



this forage in a long-term rotation such as seven years of silage corn followed by five years of hay/haylage. Dairy manure is applied to forage, while forage is used as livestock feed (Figure 4.1). Most Maine dairy farms grow forage and purchase concentrated feed (Dalton and Bragg, 2003).

Land-coupled (L-coupled) potato and dairy farms exchange cropland. Dairy farms manage silage corn grown on potato farmland. Potato farms manage potatoes grown on dairy farmland (Figures 4.2 and 4.3). Thus the potato farm pays no production costs for silage corn. Like conventional, the L-coupled dairy farm covers the costs of forage storage and manure-spreading.

Figures 4.2 and 4.3 illustrate a situation where the potato farm continues to grow grain corn and silage corn acreage is not expanded. This happens when the dairy farm's

Figure 4.2. Central Maine land-coupled crop management where potato farm expanded.

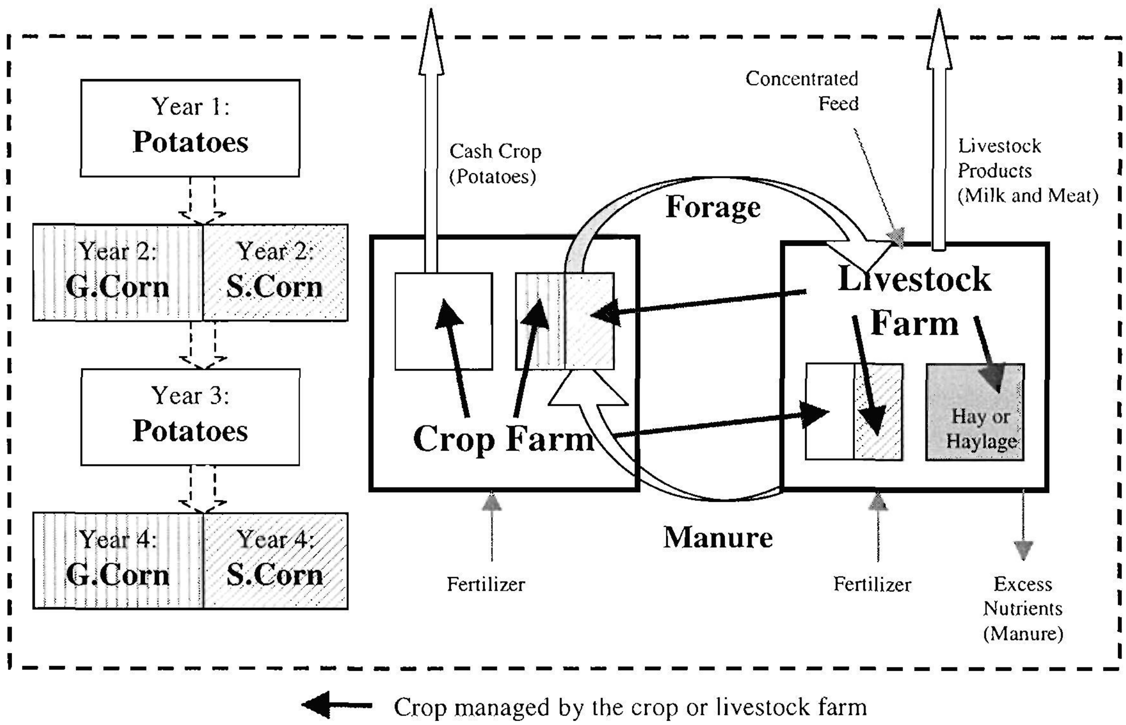


Figure 4.3. Central Maine land-coupled crop management where dairy farm expanded.

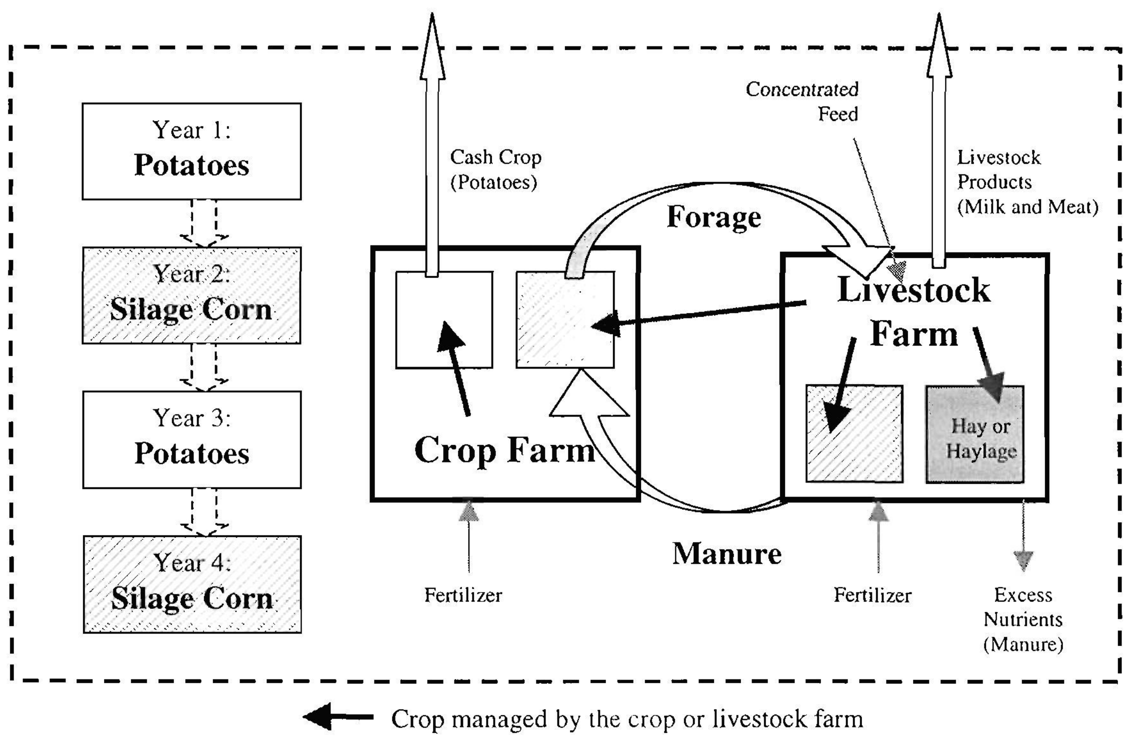
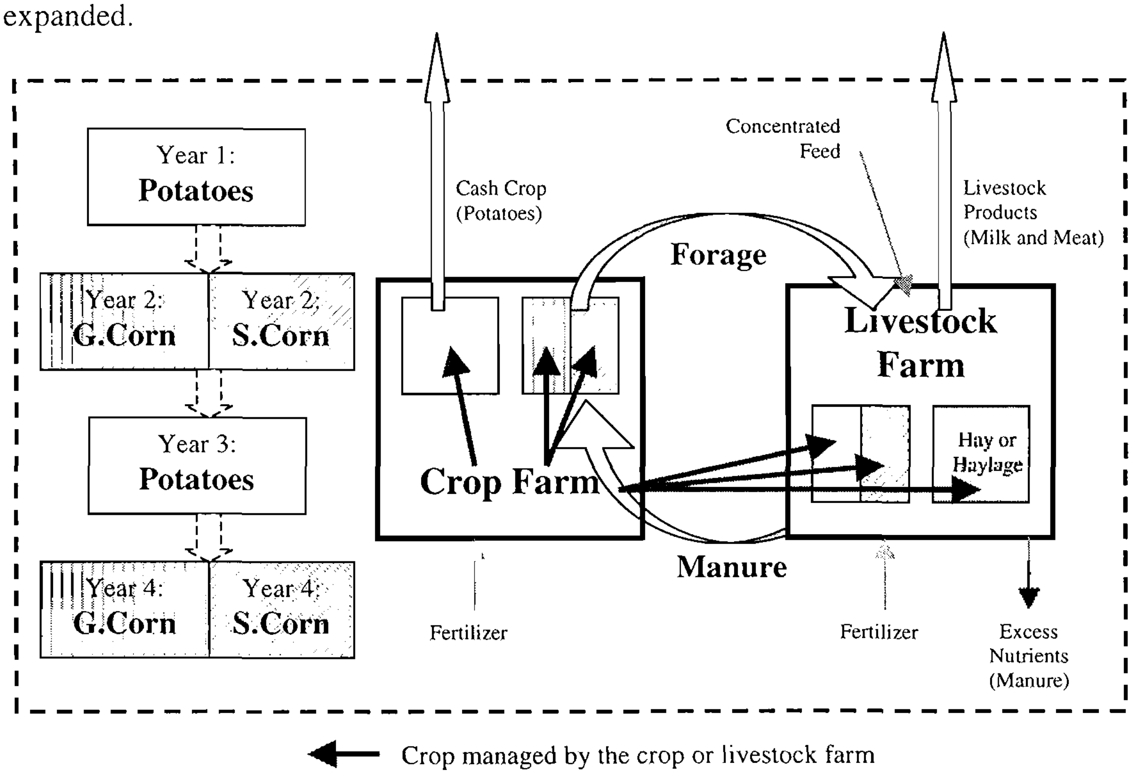


Figure 4.4. Central Maine land/feed-coupled crop management where potato farm expanded.



required silage corn acreage is less than one-half of the sum of potato plus grain and silage corn acreages for the coupled system. If the dairy farm's required silage corn acreage equals at least one-half of the sum of potato plus rotation crop acreage, potato and silage corn acreages expand equally (not shown). These expansions allowed the coupled potato farm to grow more potatoes than it could before integrating with the dairy farm (Figure 4.2). Figure 4.3 illustrates the case where the dairy farm expands and potato production is not increased. In all cases, cropland expansion occurs on both the dairy farm's cultivated acreage and the potato farm's rotation acreage.

Land/feed-coupled (LF-coupled) farms also expand and exchange land since the potato farm operates all cropland of both farms. The LF-coupled potato farm manages potatoes and rotation crops such as grain corn and/or livestock forage (Figure 4.4), while the dairy farm still provides forage and manure storages as well as manure-spreading

Table 4.3. Central Maine enterprise budget crop yields and prices and farm acreages.

					-- Potato Farm Acres[b] --						Dairy Farm Acres[b]		
			Yield				L-		LF-		Conv.&		LF-
		Price	(cwt/	Price	Conv.		Coup.		Coup.		L-Coup.		Coup.
Crop	Yield/Acre[a]	($/unit)	acre)	($/cwt)	S	ML	S	ML	S	ML	S	ML	S & ML
Potato	240 cwt	$6.88	240	$6.88	160	320	209	480	209	480	-	-	-
Grain Corn	100 bu	$2.50	56	$4.46	160	320	111	160	111	160	-	-	-
Silage Corn	15 tons	$25.00	300	$1.25	-	-	-	-	98	320	98	320	-
Dry Hay[c]	3.5 tons	$64.50	70	$3.23	-	-	-	-	73	-	73	-	-
Haylage[d]	6 tons	$32.55	120	$1.63	-	-	-	-	-	200	-	200	-

[a] Forage yields per acre shown as harvested tons and not tons of dry matter.
[b] Farm acres were operated crop acres, not owned and rented crop acres.
[c] First cut harvested as round bales and second cut harvested as square bales.
[d] First cut haylage and 90% haylage and 10% square bales for second cut.

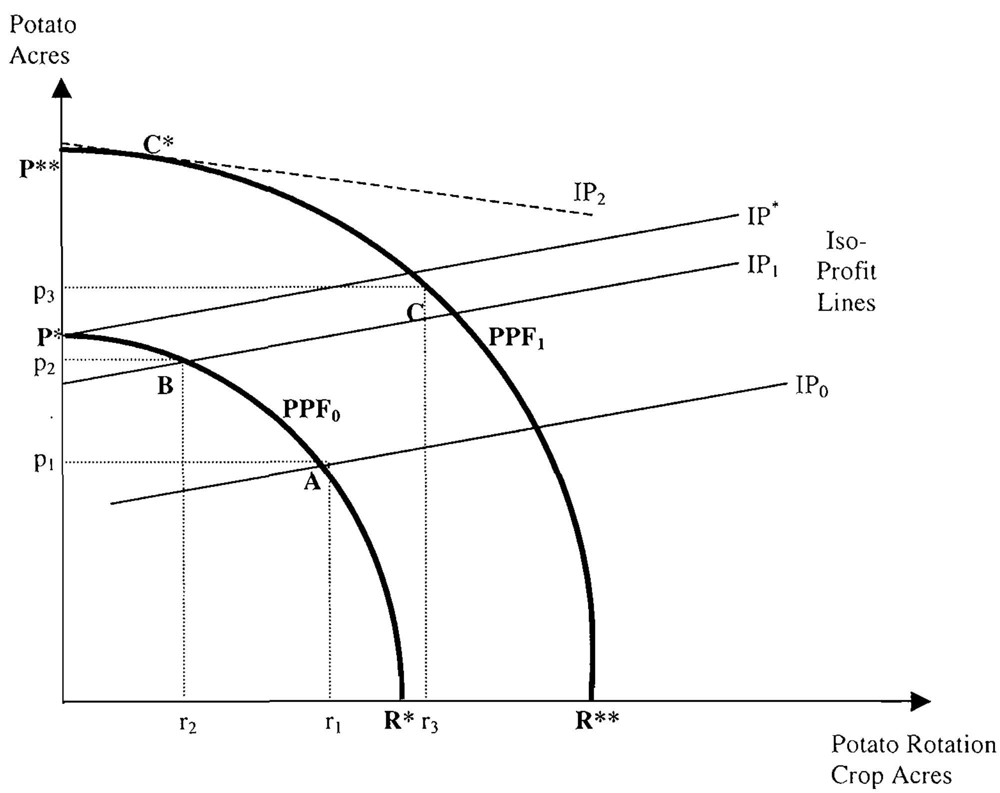
equipment. Potato farms grow forage for sale to the coupled dairy farm at typical market prices (Table 4.3). The potato farm pays for all other crop production costs. LF-coupled farms are not as common in Maine.[6] Like L-coupled, LF-coupled farms have different crop allocations depending on whether the potato and/or dairy farm expanded.

Expansion of potato farm crop acres during coupling (described previously) can also be demonstrated using production economics concepts (Beattie and Taylor, 1985). Positive impacts on potato farms occur through 1) substitution of the potato rotation crop with potatoes during L-coupling and 2) the expansion of potato farm acreages during LF-coupling where forage is grown by the potato farm in addition to the potato rotation crop and/or potatoes.

Figure 4.5 displays a production possibility frontier (PPF_0) for potato farms, defining all possible acreages of either potatoes or potato rotation crop(s) that can be grown given a fixed amount of cropland. The lines IP_0, IP_1, and IP* represent iso-profit lines (line of equal profits) where any combination of potatoes and rotation crop acres

[6] Only two pairs of cooperating farms were LF-coupled, selling and purchasing forage slightly below market prices since the LF-coupled dairy farm conducted some crop production operations.

Figure 4.5. Potato farm crop substitution and expansion during coupling.



produce the same profits. Note that in these cases where the potato farmer is growing their traditional rotation crop, the iso-profit lines are positively sloped since profits from this rotation crop are negative and must be compensated by growing more potatoes, which have positive profitability. When the potato farm grows dairy forage, which has positive profits, the iso-profit line becomes negatively sloped (IP_2), although the slope is less than -1 since dairy forage is still less profitable than potatoes.

Points P* and R* represent unconstrained corner solutions where the farm grows nothing but potatoes and potato rotation crop(s), respectively. Potato farmers cannot grow continuous potatoes at P* since they need to rotate potatoes with other crops. Instead they produce potatoes in a one-to-one rotation at point A, which is intersected by the iso-profit line IP_0.

L-coupling does not change the total amount of crops the potato farmer grows. Instead, it allows the potato farm to increase potato acreage while still keeping the same potato rotation since the dairy farm's forage acreage replaces all or some of the potato farm's rotation crop acreage during coupling. L-coupling allows the potato farm to shift the crop mix from point A to point P* if dairy farm crop acres are equal to or greater than potato farm crop acres. At P*, the potato farmer has moved up from iso-profit line IP_0 to the higher iso-profit line IP*.

If dairy farm crop acres are less than potato farm crop acres and there is a requirement for a one-to-one potato rotation, potatoes cannot exceed one-half of the total crop acres for both farms. In this case, the crop mix is point B because potato farm crop acres exceed dairy farm crop acres by 2 times r_2. This shift moves the farm to a higher iso-profit line from IP_0 to IP_1, although IP_1 is lower than IP*.

LF-coupling shifts the PPF outward from PPF_0 to PPF_1 since the potato farm operates both potato and dairy farm crop acreage. The new unconstrained optimal crop mix for the potato farm is now C* on PPF_1, the point tangent to IP_2. However at C*, potato acres are not sufficient to neither meet dairy farm needs nor maintain a one-to-one potato rotation. Consequently, potato production is constrained to the sub-optimal solution point C, which satisfies these two requirements. Point C is on a higher iso-profit line (not shown) than the constrained L-coupled case at point B.

Integrated and Conventional Farm Characteristics

Representative farm budgets were developed for integrated and non-integrated agricultural production. This section describes production characteristics of conventional (non-integrated) and coupled (integrated) potato and dairy farms in two size classes, small and medium-large (ML). Both integrated and non-integrated representative budgets were developed using data from previous studies of the Maine potato (Dalton et al., 2003, 2004) and dairy (Dalton and Bragg, 2003) industries in addition to 2001 production data from cooperating farms. Crop acreages for conventional and coupled farms were representative of both types (Table 4.3). Silage corn, dry hay,[7] and haylage[8] yields and prices were typical for cooperating producers in central Maine.

Coupled farms represented cooperating producers that were integrated in a two-year rotation of potatoes and silage corn. Coupling occurred on the potato farm's rotational acreage and the dairy farm's silage corn land. It was assumed manure was spread in the corn rotation year during the spring and that 25% of farmland was rented.

Both conventional and coupled potato and dairy farms had common base production activities for crops (Table 4.4) and livestock (Table 4.5). Production assumptions were based on the most common practices of cooperating farms and were

Table 4.4. Central Maine base crop production assumptions for potato and dairy farms.

		--- Pesticide Applications ---						Lime
Farm Crop	Manure Applied	Herbi-cides	Insecti-cides	Fungi-cides	Sprout Inhibit.[a]	Top Kill[b]	Times Harvested	Applied (tons/acre)
Potato	No	2	2	8	1	2	1	0.50
Grain Corn	No	1	-	-	-	-	1	0.61
Silage Corn	Yes	1	-	-	-	-	1	0.61
Hay	Yes	-	-	-	-	-	2	0.50
Haylage	Yes	-	-	-	-	-	2	0.50

[a] Applied to 50% of potato acres for late storage varieties.
[b] Applied to 75% of potato acres for storage varieties since 25% of acres were harvested fresh out of field.

[7] Dry hay was cut, dried, and baled as round bales for first cut (2.1 tons/acre) and as square bales for second cut (1.4 tons/acre). Dry hay price was a weighted average of surveyed prices of $22.50 and $1.88/bale for round (1000 lb) and square (40 lb) bales, respectively, and may not reflect current market prices.
[8] First and second cut haylage yielded 3.6 and 2.4 tons, respectively. The haylage price was a weighted average of haylage packed into horizontal silos and covered ($30/ton) with 10% of second cut baled as square bales ($1.88/bale) for calves.

Table 4.5. Base livestock assumptions for dairy farms.

Farm Type	Size	Livestock Numbers: Milk Cows	Heif-ers	Calves	Bulls	Herd Avg. (cwt)	Manure: Type	Bedding	Storage
Dairy	S	66	28	26	1	159	Solid	Sawdust	Stack
	ML	200	90	90	3	210	Liquid	Sand/ Sawdust	Pit/ Stack

used to derive representative budgets. Crop and livestock production activities may have been different for particular cooperating producers. Crop management practices may have also varied from year to year.

Representative conventional and coupled potato farms raised potatoes and grain corn. LF-coupled potato farms and L-coupled dairy farms grew silage corn and dry hay or haylage. LF-coupled dairy farms did not raise any crops, focusing instead on milk production. Prices were those generally received by cooperating farmers (Table 4.3). Common manure and fertilizer applications were assumed for conventional and coupled farms (Table 4.6). Manure and fertilizer assumptions were the same for both types of coupled farms. Major nutrients, nitrogen (N), phosphorus (P), and potassium (K), applied as manure, fertilizer, and in total are also shown for each crop.

Potato Farms

Representative potato farms used a two-year rotation of potatoes and rotation crop. Grain corn was a typical rotation crop in central Maine. Coupled potato farms grew more potatoes and less grain corn than conventional farms with similar acreage since dairy farm crop acreage increased land available for a one-to-one rotation with potatoes. Farm budgets used an average contract price for chipping potatoes of $6.88/cwt (Table 4.3). Although most cooperating potato farms used some irrigation, irrigation was

Table 4.6. Manure, fertilizer, and nutrient applications and fertilizer cost for conventional and coupled farms in central Maine.

Farm				Manure	Fertilizer			Nutrients Applied as (lb/acre)								
				Applied	Type	Applied	Cost	Manure			Fertilizer			Total		
Type	Industry	Size	Crop	per Acre[a]	(Analysis)	(lb/acre)	($/ton)	N	P	K	N	P	K	N	P	K
Conventional	Potato	S & ML	Potato	-	Potato Blend (10-10-10)	1204	$210	-	-	-	120	120	120	178	120	120
					Side Dress[b] (46-0-0)	126	$230	-	-	-	58	-	-			
			Grain Corn	-	Gr. Corn Starter (16-20-0)	270	$220	-	-	-	43	54	-	144	54	78
					Side Dress[b] (46-0-0)	220	$230	-	-	-	101	-	-			
					Muriate of Potash[b] (0-0-60)	130	$160	-	-	-	-	-	78			
	Dairy	S	Silage Corn	22.5 ton	Side Dress (46-0-0)	125	$230	165	41	148	58	-	-	223	41	148
			Hay	12.5 ton	Top Dress (46-0-0)	100	$230	92	23	82	46	-	-	138	23	82
		ML	Silage Corn	5500 gal	Side Dress (46-0-0)	125	$230	139	83	113	58	-	-	197	83	113
			Haylage	4000 gal	Top Dress (10-20-10)	200	$220	101	60	82	20	40	20	158	100	102
					Top Dress (46-0-0)	80	$230	-	-	-	37	-	-			
Coupled (Short-term)	Potato	S & ML	Potato	-	Potato Blend (10-10-10)	1204	$210	-	-	-	120	120	120	178	120	120
					Side Dress[b] (46-0-0)	126	$230	-	-	-	58	-	-			
	Pot. & Dairy	S	Silage Corn	22.5 ton	Side Dress (46-0-0)	125	$230	165	41	148	58	-	-	223	41	148
		ML		5500 gal	Side Dress (46-0-0)	125	$230	139	83	113	58	-	-	197	83	113
		S	Hay	12.5 ton	Top Dress (46-0-0)	100	$230	92	23	82	46	-	-	138	23	82
		ML	Haylage	4000 gal	Top Dress (10-20-10)	200	$220	101	60	82	20	40	20	158	100	102
					Top Dress (46-0-0)	80	$230	-	-	-	37	-	-			
Coupled (Long-term)	Potato	S & ML	Potato	-	Potato Blend (10-10-10)	320	$210	-	-	-	32	32	32	69	32	32
					Side Dress[b] (46-0-0)	80	$230	-	-	-	37	-	-			
	Pot. & Dairy	S	Silage Corn	22.5 ton	Side Dress (46-0-0)	100	$230	165	41	148	46	-	-	211	41	148
		ML		5500 gal	Side Dress (46-0-0)	100	$230	139	83	113	46	-	-	185	83	113
		S	Hay	12.5 ton	Top Dress (46-0-0)	100	$230	92	23	82	46	-	-	138	23	82
		ML	Haylage	4000 gal	Top Dress (10-20-10)	200	$220	101	60	82	20	40	20	158	100	102
					Top Dress (46-0-0)	80	$230	-	-	-	37	-	-			

[a] Small farms used solid dairy manure (tons/acre) while medium-large (ML) farms used liquid dairy manure (gallons/acre).
[b] Separate application from at-plant fertilizer.

not included in budgets due to a lack of reliable data for potato yield response to irrigation and amendment for central Maine. Non-irrigated marketable potato yields for all farms was assumed to be 240 cwt/acre, a typical average for central Maine producers obtained from an agronomist used by several cooperating potato growers (Titus, 2003).

It was assumed that the L-coupled potato farm grew just potatoes and grain corn, while the LF-coupled potato farm also handled all forage production for the coupled dairy farm. The LF-coupled dairy farm provided manure-spreading equipment as well as feed crop and manure storages. Although small dairy farms generated only solid manure, all small cooperating dairy farms used a combination of both solid dairy and hen[9] manure. Therefore, it was assumed that the same nutrient credit used for liquid manure in the case of medium-large coupled farms was taken for solid manure for small coupled farms. Most prices and crop yields were based on cooperating farms. Both family and hired labor were used. However, family labor was not entered as an explicit cost due to lack of these data for potato farms. Thus returns to family labor were captured in net farm income, and the labor expense shown was only hired labor.

Crop management practices used in developing representative budgets were typical for cooperating farms in central Maine (Table 4.4). Two herbicide applications of Sencor 75DF were applied with Matrix for grass. Insecticide applications included Admire in furrow and an early summer Asana XL spray. There were an average of eight fungicide applications of Dithane DF and Curzate. Actual fungicide applications can vary depending on the weather. Half of potato acreage was treated with sprout inhibitor such as Sprout Stop (MH). Potatoes were top killed twice with diquat or other chemical

[9] Poultry were not part of the operation but hen manure was supplied by large egg facilities.

products. Crops required typical amounts of lime. Chemical fertilizer use shown in Table 4.6 varied depending on duration of integration.

Manure was not applied to conventional potatoes and grain corn or to potatoes on coupled farms. Instead for both coupled potato and dairy farms, manure was typically applied in the spring to silage corn during the coupled rotation year and was also applied to hay/haylage during mid-summer. Farms took no manure-nutrient credit for potatoes grown by short-term integrators.

For long-term coupled potato farms, starter and side dress fertilizer on potatoes was reduced by taking manure-nutrient credits amounting to roughly a 61% reduction in nitrogen and a 73% reduction in both phosphorus and potassium compared to conventional applications. These manure-nutrient credits were based on observed fertilizer reductions by cooperating potato farmers. Long-term coupled potato farms reduced the application of 46-0-0 side-dressed fertilizer on potatoes by about 37% compared to conventional and short-term coupled farms (Table 4.6).

Dairy Farms

Dairy farms grew forage such as silage corn and grass in a long-term rotation. Dairy farms purchased all concentrated feed[10]. For coupled farms, silage corn acreage was integrated with a potato farm. Dairy budgets were based on Dalton and Bragg (2003), where their small- and medium-sized dairy farms were aggregated to form the conventional small size class, while their large farm was used for the medium-large class, better representing the farm sizes of cooperating farmers. Coupled dairy budgets were updated with data collected from cooperating dairy farms.

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[10] Only one cooperating coupled dairy farm grew crops used for concentrated feed.

L-coupled dairy farms raised silage corn and hay/haylage on the potato farms' rotation land. The LF-coupled dairy farm purchased all forage from the potato farm at market prices (Table 4.3) and focused on milk production. Cooperating farms in each coupled size class provided the basis for most input and output quantities and prices. A milk price of $15.16/cwt (Appendices C) was used for dairy budgets in central Maine and Aroostook County, consistent with the 1998 to 2002 average for Maine farms (USDA, NASS, 2004b). To be consistent with potato farms, family labor on dairy farms was not included explicitly in budgets and returns to family labor were captured in net farm income.

Dairy farms stored and spread manure. In general, small dairy farms generated solid manure bedded with sawdust, while medium-large farms mainly produced liquid manure bedded with sand. Liquid manure was stored in pits and was agitated prior to loading into spreader trucks. Larger dairy facilities also produced some solid manure from young stock, which was bedded with sawdust and was spread with a solid spreader. Some medium-large farms used sand as bedding year round, while others bedded with sawdust during the winter and sand during the remainder of the year.

Typical crop management for silage corn involved one herbicide application with no insecticide or fungicide applications. Hay and haylage received no pesticides and were cut twice a season. Silage corn, hay, and haylage were limed (Table 4.4). Forage yields, prices, and acreages were representative of the industry (Table 4.3). The dry hay price used on small farms included labor costs for transporting and storing bales. Larger dairy operations used lower-valued haylage, which was packed into horizontal silos with a tractor, covered with plastic and tires, and stored. Manure and fertilizer applications for forage were based on typical rates used by cooperating farms (Table 4.6).

Dairy farms spread manure on silage corn acreage during the spring before planting or during the fall following harvest. For silage corn fertilization, it was assumed manure was spring applied. For hay or haylage, conventional fertilizer was top dressed prior to first cut. Manure was then spread during the mid-summer after first cut. Typical manure and fertilizer applications and analysis were used (Table 4.6). Short-term integrated dairy farms had been coupled for about two years and took no more manure-nutrient credits for silage corn than before coupling. Long-term coupled farms took the same 20% manure-nutrient credit for silage corn as LF-coupled potato. Conventional and coupled hay fertilization was assumed to be the same.

Chapter 5

COUPLED AND CONVENTIONAL REPRESENTATIVE BUDGETS FOR CENTRAL MAINE

The profitability of integrated compared to conventional agricultural systems in Maine was analyzed using crop enterprise and whole-farm budgets. Crop and livestock integration occurred primarily in central Maine between coupled potato and dairy farms involved in rotation of potatoes and silage corn. Representative enterprise and whole-farm potato and dairy budgets of coupled and conventional systems in central Maine were constructed to compare the relative profitability of these systems.

Budget Background and Methodology

Representative enterprise and whole-farm budgets for coupled potato and dairy farms were constructed. These integrated budgets were compared to conventional non-integrated budgets derived from previous analyses of the Maine dairy (Dalton and Bragg, 2003) and potato (Dalton et al., 2003; 2004) industries. Data from cooperating farmers and from these previous studies were used to create budgets for each cooperating farm. Individual budgets were then generalized to produce representative budgets for different sizes and types of integrators.

Enterprise budgets indicate the relative profitability of different crop or livestock enterprises that represent one aspect of a farming operation. Enterprise budgets show gross income from the enterprise, production costs, net farm income, and return-over-variable costs and can be used for break-even analysis. Whole-farm budgets represent all farm crop and/or livestock operations and can be used to compare profitability between different farm plans (Kay, 1986). Representative whole-farm budgets are provided in

Appendices B-1, B-2, C-1, and C-2. Potato whole-farm budgets included a potato enterprise with a rotation crop or crops. Dairy whole-farm budgets included silage corn and dry hay or haylage enterprises in addition to fluid milk.

Conventional and coupled equipment inventories were updated and enterprise budgets for potato rotation crops and dairy forage were added. Budget revenues used typical marketable yields and prices. Most quantities and costs for inputs and outputs were obtained from cooperating farmers and were verified with University of Maine researchers and extension personnel. Farm operating costs were itemized as seed, fertilizer, lime, chemicals, labor, fuel and oil, maintenance, supplies, insurance, miscellaneous costs, and interest. To be consistent with potato budgets, dairy budgets were presented using only hired labor. Returns to family labor were included in net farm income. Ownership costs included depreciation, interest, tax and insurance on farm equipment, buildings, and land. Equipment costs shared by two or more crops were weighted based on total seasonal equipment operation time.

Conventional and L-coupled budgets assumed the dairy farm grew silage corn and hay or haylage, while the LF-coupled farm budgets assumed the potato farm grew this forage. Budgets were checked with 2000 Farm Credit data for dairy (Stafford et al., 2001) and with 2001 data for potatoes (Kenney, 2003). Potato enterprise budgets were also compared with a previous study of potato rotations in Aroostook County (Westra and Boyle, 1991). Enterprise budgets for grain corn, silage corn, dry hay, and haylage were verified against existing budgets (PSU, 2004).

Coupled and Conventional Budget Results

Representative whole-farm budgets were constructed for both short- and long-term coupling. Coupled whole-farm budgets in Appendices B-1, B-2, C-1, and C-2 represented integration lasting more than ten years (long term) where fertilizer use was reduced. Although short-term whole-farm budgets were not shown in this thesis, farms coupled for only two years (short term) took less manure-nutrient credits. Conventional and coupled farms had similar crop equipment inventories. The relative profitability of potato yield response from integration was analyzed. In addition to enterprise and whole-farm budgets, conventional and coupled agricultural systems were also compared.

Potato Farms

Whole-farm budget return-over-variable costs (ROVC) and net farm income (NFI) per acre of owned and rented cropland was greater for coupled compared to conventional (Table 5.1) assuming marketable potato yields were the same. For LF-coupled potato farms, returns per acre were calculated using the same total potato and grain corn acreage as L-coupled and conventional farms. Revenues, costs, and returns were summarized for potatoes and rotation crops (Table 5.2). Profitability was compared at the whole-farm level (Appendices B-1 and B-2) and for potato (Tables 5.3 to 5.6) and grain corn, hay, and haylage (Appendices D-1 and D-2) enterprises.

In general, profitability improved going from short- to long-term coupling. The scenarios outlined in Table 5.1 assumed that the dairy farm remained the same size. The larger coupled cropland base allowed the potato farm to increase potato acreage while maintaining the same rotation and current silage corn production by reducing the acreage devoted to grain corn. In the case where a two-year potato-corn rotation was maintained,

Table 5.1. Relative profitability of conventional and coupled potato farms for central Maine.

Profit Measure	Size	Conventional[b]	Short Term L-Coupled[c]	Short Term LF-Coupled[d]	Long Term L-Coupled[c]	Long Term LF-Coupled[d]
ROVC[a]	S	$200	$262	$335	$327	$402
	ML	$225	$334	$443	$409	$520
NFI[a]	S	-$51	$12	$57	$76	$124
	ML	$18	$127	$208	$203	$285

[a] Return over variable costs (ROVC) and net farm income (NFI) were in $/acre of potatoes and grain corn. Acreage in denominator did not include forage for LF-coupled.
[b] Small (S) conventional farms grew 160 acres of potatoes and 160 acres of grain corn for a total of 320 crop acres. Medium-large (ML) crop acreages were doubled.
[c] Small L-coupled raised 209 acres of potatoes and 111 acres of grain corn, while ML grew 480 acres of potatoes and 160 acres of grain corn. Total crop acreages were the same as conventional farms.
[d] LF-coupled crop acreages used to calculate per acre returns were the same as L-coupled. Additional crops raised were 98 acres of silage corn and 73 acres of hay for small and 320 acres of silage corn and 200 acres of haylage for ML.

Table 5.2. Central Maine crop enterprise budget summary for conventional and coupled potato farms.

Potato Size	Coup. Hist.[a]	Farm Type	Potato[b] Acres	Potato[b] Rev.	Potato[b] Oper. Costs	Potato[b] Own. Costs	Potato[b] ROVC	Potato[b] NFI	Rotation[bc] Acres	Rotation[bc] Rev.	Rotation[bc] Oper. Costs	Rotation[bc] Own. Costs	Rotation[bc] ROVC	Rotation[bc] NFI
S	None	Conv.	160	$1,650	$1,247	$340	$403	$63	160	$250	$253	$163	-$3	-$166
	ST	L-Coup.	209	$1,650	$1,247	$289	$403	$114	111	$250	$255	$179	-$5	-$184
		LF-Coup.	209	$1,650	$1,247	$252	$403	$151	111	$250	$251	$151	-$1	-$152
									98	$375	$211	$113	$164	$51
									73	$226	$130	$114	$96	-$18
	LT	L-Coup.	209	$1,650	$1,146	$289	$504	$215	111	$250	$255	$179	-$5	-$184
		LF-Coup.	209	$1,650	$1,146	$252	$504	$252	111	$250	$251	$151	-$1	-$152
									98	$375	$208	$113	$167	$54
									73	$226	$130	$114	$96	-$18
ML	None	Conv.	320	$1,650	$1,206	$300	$444	$144	320	$250	$244	$114	$6	-$108
	ST	L-Coup.	480	$1,650	$1,206	$229	$444	$215	160	$250	$247	$138	$3	-$135
		LF-Coup.	480	$1,650	$1,206	$196	$444	$248	160	$250	$243	$115	$7	-$108
									320	$375	$195	$75	$180	$105
									200	$195	$137	$71	$58	-$13
	LT	L-Coup.	480	$1,650	$1,105	$229	$545	$316	160	$250	$247	$138	$3	-$135
		LF-Coup.	480	$1,650	$1,105	$196	$545	$349	160	$250	$243	$115	$7	-$108
									320	$375	$192	$75	$183	$108
									200	$195	$137	$71	$58	-$13

[a] Short-term (ST) and long-term (LT) coupled.
[b] Revenue, costs, and returns in $/acre.
[c] Conventional and L-coupled potato rotation was grain corn. The order of budget summaries for LF-coupled potato rotation crops in this table is grain corn, silage corn, and then dry hay (S) or haylage (ML).

Table 5.3. Central Maine potato enterprise budget for a small conventional farm.[a]

	Total	Per Acre	Per Cwt
Number of Acres	160	-	-
Potato Yield (cwt)	38,400	240	-
Price ($/cwt)	$6.88	-	-
Annual Revenue	**$264,107**	**$1,650.67**	**$6.88**
Annual Operating Expenses			
Seed	$37,368	$233.55	$0.97
Fertilizer	$22,546	$140.91	$0.59
Lime	$1,600	$10.00	$0.04
Chemicals	$26,336	$164.60	$0.69
Labor	$36,688	$229.30	$0.96
Diesel Fuel and Oil	$12,058	$75.36	$0.31
Maintenance and Upkeep	$17,754	$110.96	$0.46
Supplies	$9,215	$57.59	$0.24
Insurance	$8,865	$55.40	$0.23
Miscellaneous			
Utilities	$6,101	$38.13	$0.16
Custom Hire	$0	$0	$0
Rent or Lease	$10,000	$62.50	$0.26
Freight and Trucking	$2,849	$17.81	$0.07
Storage and Warehousing	$1,879	$11.75	$0.05
Other Expenses	$960	$6.00	$0.03
Interest	$5,364	$33.52	$0.14
Total Operating Expenses	**$199,581**	**$1,247.38**	**$5.20**
Annual Ownership Expenses			
Depreciation and Interest	$51,305	$320.66	$1.34
Tax and Insurance	$3,133	$19.58	$0.08
Total Ownership Expenses	**$54,438**	**$340.24**	**$1.42**
Total Annual Cost	**$254,019**	**$1,587.62**	**$6.62**
Net Farm Income (NFI)	**$10,088**	**$63.05**	**$0.26**
Return over Variable Cost (ROVC)	**$64,526**	**$403.29**	**$1.68**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,587.62	$6.62
Short-run to Cover Operating Costs		$1,247.38	$5.20

[a] Numbers may not sum due to rounding.

Table 5.4. Central Maine potato enterprise budget for a small long-term land-coupled farm.[a]

	Total	Per Acre	Per Cwt
Number of Acres	209	-	-
Potato Yield (cwt)	50,160	240	-
Price ($/cwt)	$6.88	-	-
Annual Revenue	**$344,990**	**$1,650.67**	**$6.88**
Annual Operating Expenses			
Seed	$48,812	$233.55	$0.97
Fertilizer	$8,945	$42.80	$0.18
Lime	$2,090	$10.00	$0.04
Chemicals	$34,401	$164.60	$0.69
Labor	$47,924	$229.30	$0.96
Diesel Fuel and Oil	$15,750	$75.36	$0.31
Maintenance and Upkeep	$23,191	$110.96	$0.46
Supplies	$12,037	$57.59	$0.24
Insurance	$11,580	$55.40	$0.23
Miscellaneous			
Utilities	$7,969	$38.13	$0.16
Custom Hire	$0	$0	$0
Rent or Lease	$13,063	$62.50	$0.26
Freight and Trucking	$3,721	$17.81	$0.07
Storage and Warehousing	$2,455	$11.75	$0.05
Other Expenses	$1,254	$6.00	$0.03
Interest	$6,440	$30.81	$0.13
Total Operating Expenses	**$239,631**	**$1,146.56**	**$4.78**
Annual Ownership Expenses			
Depreciation and Interest	$56,921	$272.35	$1.13
Tax and Insurance	$3,584	$17.15	$0.07
Total Ownership Expenses	**$60,506**	**$289.50**	**$1.21**
Total Annual Cost	**$300,137**	**$1,436.06**	**$5.98**
Net Farm Income (NFI)	**$44,853**	**$214.61**	**$0.89**
Return over Variable Cost (ROVC)	**$105,358**	**$504.11**	**$2.10**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,436.06	$5.98
Short-run to Cover Operating Costs		$1,146.56	$4.78

[a] Numbers may not sum due to rounding.

Table 5.5. Central Maine potato enterprise budget for a medium-large conventional farm.[a]

	Total	Per Acre	Per Cwt
Number of Acres	320	-	-
Potato Yield (cwt)	76,800	240	-
Price ($/cwt)	$6.88	-	-
Annual Revenue	**$528,214**	**$1,650.67**	**$6.88**
Annual Operating Expenses			
Seed	$74,736	$233.55	$0.97
Fertilizer	$45,091	$140.91	$0.59
Lime	$3,200	$10.00	$0.04
Chemicals	$52,672	$164.60	$0.69
Labor	$64,925	$202.89	$0.85
Diesel Fuel and Oil	$21,878	$68.37	$0.28
Maintenance and Upkeep	$35,507	$110.96	$0.46
Supplies	$18,430	$57.59	$0.24
Insurance	$17,729	$55.40	$0.23
Miscellaneous			
Utilities	$12,202	$38.13	$0.16
Custom Hire	$0	$0	$0
Rent or Lease	$18,000	$56.25	$0.23
Freight and Trucking	$5,698	$17.81	$0.07
Storage and Warehousing	$3,759	$11.75	$0.05
Other Expenses	$1,920	$6.00	$0.03
Interest	$10,377	$32.43	$0.14
Total Operating Expenses	**$386,123**	**$1,206.64**	**$5.03**
Annual Ownership Expenses			
Depreciation and Interest	$90,345	$282.33	$1.18
Tax and Insurance	$5,603	$17.51	$0.07
Total Ownership Expenses	**$95,947**	**$299.84**	**$1.25**
Total Annual Cost	**$482,071**	**$1,506.47**	**$6.28**
Net Farm Income (NFI)	**$46,143**	**$144.20**	**$0.60**
Return over Variable Cost (ROVC)	**$142,090**	**$444.03**	**$1.85**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,506.47	$6.28
Short-run to Cover Operating Costs		$1,206.64	$5.03

[a] Numbers may not sum due to rounding.

Table 5.6. Central Maine potato enterprise budget for a medium-large long-term land-coupled farm.[a]

	Total	Per Acre	Per Cwt
Number of Acres	480	-	-
Potato Yield (cwt)	115,200	240	-
Price ($/cwt)	$6.88	-	-
Annual Revenue	**$792,320**	**$1,650.67**	**$6.88**
Annual Operating Expenses			
Seed	$112,104	$233.55	$0.97
Fertilizer	$20,544	$42.80	$0.18
Lime	$4,800	$10.00	$0.04
Chemicals	$79,008	$164.60	$0.69
Labor	$97,387	$202.89	$0.85
Diesel Fuel and Oil	$32,818	$68.37	$0.28
Maintenance and Upkeep	$53,261	$110.96	$0.46
Supplies	$27,645	$57.59	$0.24
Insurance	$26,594	$55.40	$0.23
Miscellaneous			
Utilities	$18,303	$38.13	$0.16
Custom Hire	$0	$0	$0
Rent or Lease	$27,000	$56.25	$0.23
Freight and Trucking	$8,546	$17.81	$0.07
Storage and Warehousing	$5,638	$11.75	$0.05
Other Expenses	$2,880	$6.00	$0.03
Interest	$14,264	$29.72	$0.12
Total Operating Expenses	**$530,792**	**$1,105.82**	**$4.61**
Annual Ownership Expenses			
Depreciation and Interest	$103,238	$215.08	$0.90
Tax and Insurance	$6,684	$13.92	$0.06
Total Ownership Expenses	**$109,922**	**$229.00**	**$0.95**
Total Annual Cost	**$640,714**	**$1,334.82**	**$5.56**
Net Farm Income (NFI)	**$151,606**	**$315.85**	**$1.32**
Return over Variable Cost (ROVC)	**$261,529**	**$544.85**	**$2.27**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,334.82	$5.56
Short-run to Cover Operating Costs		$1,105.82	$4.61

[a] Numbers may not sum due to rounding.

profitability increased from the expanded production of a cash crop (potato) and the reduced acreage of a less lucrative rotation crop (grain corn). ROVC and NFI increased from short-term coupling even if there was no increase in potato yields from integration and no manure-nutrient credits were taken.

When potato production did not expand, benefits were limited to shifting grain corn production to silage corn and to possible increases in potato yields from longer rotations. One cooperating potato farmer who increased to a three year rotation of potato, silage corn, and barley noted higher yields from the longer rotation. Longer potato rotations were not analyzed due to time limitations and potato yields were initially assumed to be the same for coupled and conventional. If L-coupled potato farms did not expand potato production and allowed the dairy farm to grow forage, profitability was still greater than conventional. NFI per acre of owned and rented cropland increased to -$14 and $43 for the small and medium-large size classes respectively (data not presented) compared to conventional NFI of -$51 and $18 per acre (Table 5.1). This demonstrated that grain corn was less profitable than growing forage for the dairy farm.

The profitability of grain corn as a rotation crop, however, may have been underestimated. First, the grain corn yields assumed for this study were typical for central Maine, but were low (100 bu/acre) compared to other areas in Maine further south. Second, grain corn prices may be higher than those used here. Third, grain corn budgets did not account for government commodity program payments. Fourth, grain corn leaves plant residues that are incorporated into the soil after harvest. While the organic matter in such residues has value, this value was not recognized in potato farm budgets.

LF-coupled potato farms were more profitable than L-coupled farms (Table 5.1) due to the added revenue from growing dairy forage in addition to potatoes and grain corn. LF-coupled potato farms were even more profitable if they grew dairy forage exclusively and not grain corn since grain corn was a less profitable enterprise than dairy forage. For short-term LF-coupled potato farms growing just silage corn and hay/haylage as rotation crops, ROVC per acre increased to $394 for small and $487 for medium-large farms, while NFI per acre increased to $136 for small and $265 for medium-large (data not presented). This scenario assumed expansion of the coupled dairy farm to utilize the additional forage.

Long-term coupling improved profitability even further compared to short-term coupling (Table 5.1) due to decreased fertilizer costs from manure-nutrient credits taken for potatoes and silage corn and the subsequent reduction of purchased chemical fertilizer (Tables 5.3 to 5.6). Fertilizer costs for long-term coupled potato ($43/acre) were about 70% less than conventional ($141/acre). Similarly, fertilizer costs for rotation crops were less for silage corn grown on long-term coupled farms, $12/acre, than for both grain corn grown on conventional farms, $65/acre, and silage corn grown on short-term coupled farms, $14/acre (Tables 5.10 to 5.13; Appendix D-1).

Some cooperating potato farms that were long-term coupled (over ten years) believed that their potato yields had increased from improved soil quality. However, they did not have records to establish the amount of potato yield increase. Although there is no experimental field data on integrated potato and corn systems in Maine, potato yields may increase from integration because of increased soil quality, especially in dry years

(Gallandt, 1998). However, there was some evidence that increased disease pressure could suppress yields (Porter, 2003).

Long-term potato yield impacts for manure applications were tested with the Environmental Policy Integrated Climate (EPIC) model for Presque Isle and Corinna, Maine. The EPIC model has been extensively used nationally and internationally to simulate crop yields, nutrient dynamics, and soil erosion for different crop rotations. Parameter values for Maine were incorporated into the model. However, EPIC results showed very little response in potato yields to manure applications (Appendix E).

The Maine Potato Ecosystem Project average (1991 to 2003) observed increase (6%) in marketable yield for potatoes amended with manure and compost compared to potatoes not receiving manure was assumed for central Maine. Annual marketable potato yield changes ranged from -13% to 31% (Porter, 2004). Potato yield response to amendment for central Maine may be less than Aroostook research farm results since manure was only applied during the potato rotation year.

To test the impact of this potential yield variability, NFI was estimated for coupled potato farms at various yields ranging between -25% and +25% from the base yield of 240 cwt/acre. These yield differences were assumed to be from soil quality changes as a result of integration and not from additional fertilizer. Harvest labor, truck fuel, and storage costs were adjusted in proportion to yield changes. The potato contract price has not changed recently so this was not adjusted in the sensitivity analysis.

Table 5.7 shows the actual NFI's for these yields for both coupling arrangements compared to conventional potato farms where NFI/acre was -$51 for small farms and $18 for medium-large farms. Conventional farms assumed a base yield of 240 cwt/acre.

Table 5.7. Net farm income for central Maine whole-farm budgets of coupled potato farms with yield response for potatoes ranging from -25% to 25%.

	Marketable		NFI ($/acre)[b]							
	---- Yield ----		Short-Term Integration				Long-Term Integration			
			S		ML		S		ML	
Potato Farm Type	% Increase	cwt/ acre	Land	Land/ Feed	Land	Land/ Feed	Land	Land/ Feed	Land	Land/ Feed
Coupled[a]	-25%	180	-$257	-$209	-$179	-$98	-$191	-$143	-$103	-$21
	-20%	192	-$203	-$156	-$117	-$37	-$137	-$89	-$42	**$40**
	-15%	204	-$150	-$103	-$56	$24	-$84	**-$36**	**$19**	**$101**
	-10%	216	-$97	**-$50**	$5	**$85**	**-$31**	**$17**	**$81**	**$162**
	-5%	228	**-$43**	**$4**	**$66**	**$147**	**$23**	**$71**	**$142**	**$224**
	0%	240	**$12**	**$57**	**$127**	**$208**	**$76**	**$124**	**$203**	**$285**
	5%	252	**$63**	**$110**	**$189**	**$269**	**$129**	**$177**	**$264**	**$346**
	10%	264	**$117**	**$164**	**$250**	**$330**	**$183**	**$230**	**$326**	**$407**
	15%	276	**$170**	**$217**	**$311**	**$391**	**$236**	**$284**	**$387**	**$469**
	20%	288	**$223**	**$270**	**$372**	**$453**	**$289**	**$337**	**$448**	**$530**
	25%	300	**$277**	**$324**	**$434**	**$514**	**$343**	**$390**	**$509**	**$591**

[a] Coupled NFI per acre in bold face was greater than or equal to conventional NFI per acre of -$51 for small (S) and $18 for medium-large (ML).
[b] Acreage in denominator was potatoes and grain corn. Forage not used in denominator for LF-coupled.

There were gains of up to $328 per acre for long-term integrators over conventional if potato yields increased by 5%. On the other hand, larger sized long-term integrators were no worse off than equivalent sized conventional farms with yield losses of 15% to 20%. The bold face profits in Table 5.7 show where NFI of integrators was superior to the conventional base cases at various differences and demonstrate that long-term integrators can withstand yield losses of up to 20% and be as well off as conventional farms.

Dairy Farms

Whole-farm and enterprise budgets were compared for conventional and coupled small- and medium-large-sized dairy farms. Profitability for coupled and conventional dairy farms was also summarized (Table 5.8). Whole-farm conventional and coupled budgets are shown in Appendices C-1 and C-2. Revenues, costs, and returns for forage are summarized in Table 5.9. Crop enterprise budgets were constructed for silage corn (Tables 5.10 to 5.13) and for hay and haylage (Appendix D-2).

Table 5.8. Relative profitability of central Maine conventional and coupled dairy farms.

Profit Measures	Size	Conventional[b]	Short Term L-Coupled[c]	Short Term LF-Coupled[d]	Long Term L-Coupled[c]	Long Term LF-Coupled[d]
ROVC[a]	S	$148	$148	$44	$150	$44
	ML	$319	$319	$187	$321	$187
NFI[a]	S	-$245	-$245	-$295	-$243	-$295
	ML	-$9	-$9	-$109	-$7	-$109

[a] ROVC and NFI in $/acre of silage corn and hay/haylage cropland. Crop acreage did not include pasture.
[b] Small (S) conventional dairy farms grew 98 acres of silage corn and 73 acres of hay for a total of 171 crop acres. Medium-large (ML) conventional dairy farms grew 320 acres of silage corn and 200 acres of haylage for a total of 520 crop acres. The 29 and 43 acres of pasture for S and ML dairy farms, respectively, were not included as crop acres.
[c] L-coupled farms raised the same crop acreages as conventional farms.
[d] LF-coupled dairy farms did not raise forage since the LF-coupled potato farms grew these. However, returns were calculated using the same crop acres as conventional and L-coupled farms.

Table 5.9. Central Maine crop enterprise budget summary for conventional and coupled dairy farms.

Dairy Size	Coup. History[a]	Farm Type	Silage Corn[b] Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI	Hay/Haylage[bc] Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI
S	None	Conv.	98	$375	$220	$181	$155	-$26	73	$226	$139	$165	$87	-$78
	ST	L-Coup.	98	$375	$220	$181	$155	-$26	73	$226	$139	$165	$87	-$78
		LF-Coup.	0	-	-	-	-	-	0	-	-	-	-	-
	LT	L-Coup.	98	$375	$217	$181	$158	-$23	73	$226	$139	$165	$87	-$78
		LF-Coup.	0	-	-	-	-	-	0	-	-	-	-	-
ML	None	Conv.	320	$375	$202	$137	$173	$36	200	$195	$140	$96	$55	-$41
	ST	L-Coup.	320	$375	$202	$137	$173	$36	200	$195	$140	$96	$55	-$41
		LF-Coup.	0	-	-	-	-	-	0	-	-	-	-	-
	LT	L-Coup.	320	$375	$199	$137	$176	$39	200	$195	$140	$96	$55	-$41
		LF-Coup.	0	-	-	-	-	-	0	-	-	-	-	-

[a] Short-term (ST) and long-term (LT) coupled.
[b] Revenue, costs, and returns in $/acre.
[c] The small dairy farm grew dry hay, while the medium-large (ML) farm raised primarily haylage.

If potato farms expanded potato acreage during coupling and the dairy farm did not increase herd size, benefits were minimal for L-coupled dairy farms[11]. In the short-term, ROVC and NFI were identical to conventional farms. Long-term coupled farms

[11] Some cooperating dairy farmers believed their silage corn yields increased from lengthening crop rotation during coupling. In this analysis, representative dairy budgets assumed silage corn yields did not increase from coupling and economic benefits from such yield increases were not studied.

Table 5.10. Central Maine silage corn enterprise budget for a small conventional dairy farm.[a]

	Total	Per Acre	Per Ton
Number of Acres	98	-	-
Silage Corn Yield (tons)	1,470	15	-
Price ($/ton)	$25	-	-
Annual Revenue	**$36,750**	**$375.00**	**$25.00**
Annual Operating Expenses			
Seed	$3,234	$33.00	$2.20
Fertilizer	$1,409	$14.38	$0.96
Lime	$1,189	$12.13	$0.81
Chemicals	$2,390	$24.39	$1.63
Labor	$5,675	$57.90	$3.86
Diesel Fuel and Oil	$1,558	$15.90	$1.06
Maintenance and Upkeep	$2,618	$26.71	$1.78
Supplies	$980	$10.00	$0.67
Insurance	$32	$0.33	$0.02
Miscellaneous			
Rent or Lease	$1,225	$12.50	$0.83
Storage and Warehousing	$196	$2.00	$0.13
Other Expenses	$490	$5.00	$0.33
Interest	$580	$5.92	$0.39
Total Operating Expenses	**$21,575**	**$220.16**	**$14.68**
Annual Ownership Expenses			
Depreciation and Interest	$16,480	$168.17	$11.21
Tax and Insurance	$1,233	$12.59	$0.84
Total Ownership Expenses	**$17,714**	**$180.75**	**$12.05**
Total Annual Cost	**$39,289**	**$400.91**	**$26.73**
Net Farm Income (NFI)	**-$2,539**	**-$25.91**	**-$1.73**
Return over Variable Cost (ROVC)	**$15,175**	**$154.84**	**$10.32**
Performance Measures			
Breakeven Revenue		$/acre	$/ton
Long-run to Cover All Costs		$400.91	$26.73
Short-run to Cover Operating Costs		$220.16	$14.68

[a] Numbers may not sum due to rounding.

Table 5.11. Central Maine silage corn enterprise budget for a small long-term land-coupled dairy farm.[a]

	Total	Per Acre	Per Ton
Number of Acres	98	-	-
Silage Corn Yield (tons)	1,470	15	-
Price ($/ton)	$25	-	-
Annual Revenue	**$36,750**	**$375.00**	**$25.00**
Annual Operating Expenses			
Seed	$3,234	$33.00	$2.20
Fertilizer	$1,127	$11.50	$0.77
Lime	$1,189	$12.13	$0.81
Chemicals	$2,390	$24.39	$1.63
Labor	$5,675	$57.90	$3.86
Diesel Fuel and Oil	$1,558	$15.90	$1.06
Maintenance and Upkeep	$2,618	$26.71	$1.78
Supplies	$980	$10.00	$0.67
Insurance	$32	$0.33	$0.02
Miscellaneous			
Rent or Lease	$1,225	$12.50	$0.83
Storage and Warehousing	$196	$2.00	$0.13
Other Expenses	$490	$5.00	$0.33
Interest	$572	$5.84	$0.39
Total Operating Expenses	**$21,286**	**$217.20**	**$14.48**
Annual Ownership Expenses			
Depreciation and Interest	$16,480	$168.17	$11.21
Tax and Insurance	$1,233	$12.59	$0.84
Total Ownership Expenses	**$17,714**	**$180.75**	**$12.05**
Total Annual Cost	**$39,000**	**$397.96**	**$26.53**
Net Farm Income (NFI)	**-$2,250**	**-$22.96**	**-$1.53**
Return over Variable Cost (ROVC)	**$15,464**	**$157.80**	**$10.52**
Performance Measures			
Breakeven Revenue		$/acre	$/ton
Long-run to Cover All Costs		$397.96	$26.53
Short-run to Cover Operating Costs		$217.20	$14.48

[a] Numbers may not sum due to rounding.

Table 5.12. Central Maine silage corn enterprise budget for a medium-large conventional dairy farm.[a]

	Total	Per Acre	Per Ton
Number of Acres	320	-	-
Silage Corn Yield (tons)	4,800	15	-
Price ($/ton)	$25	-	-
Annual Revenue	**$120,000**	**$375.00**	**$25.00**
Annual Operating Expenses			
Seed	$10,560	$33.00	$2.20
Fertilizer	$4,600	$14.38	$0.96
Lime	$3,882	$12.13	$0.81
Chemicals	$7,805	$24.39	$1.63
Labor	$15,366	$48.02	$3.20
Diesel Fuel and Oil	$5,088	$15.90	$1.06
Maintenance and Upkeep	$6,196	$19.36	$1.29
Supplies	$3,200	$10.00	$0.67
Insurance	$106	$0.33	$0.02
Miscellaneous			
Rent or Lease	$4,000	$12.50	$0.83
Storage and Warehousing	$640	$2.00	$0.13
Other Expenses	$1,600	$5.00	$0.33
Interest	$1,741	$5.44	$0.36
Total Operating Expenses	**$64,783**	**$202.45**	**$13.50**
Annual Ownership Expenses			
Depreciation and Interest	$40,841	$127.63	$8.51
Tax and Insurance	$3,044	$9.51	$0.63
Total Ownership Expenses	**$43,885**	**$137.14**	**$9.14**
Total Annual Cost	**$108,667**	**$339.59**	**$22.64**
Net Farm Income (NFI)	**$11,333**	**$35.41**	**$2.36**
Return over Variable Cost (ROVC)	**$55,217**	**$172.55**	**$11.50**
Performance Measures			
Breakeven Revenue		$/acre	$/ton
Long-run to Cover All Costs		$339.59	$22.64
Short-run to Cover Operating Costs		$202.45	$13.50

[a] Numbers may not sum due to rounding.

Table 5.13. Central Maine silage corn enterprise budget for a medium-large long-term land-coupled dairy farm.[a]

	Total	Per Acre	Per Ton
Number of Acres	320	-	-
Silage Corn Yield (tons)	4,800	15	-
Price ($/ton)	$25	-	-
Annual Revenue	**$120,000**	**$375.00**	**$25.00**
Annual Operating Expenses			
Seed	$10,560	$33.00	$2.20
Fertilizer	$3,680	$11.50	$0.77
Lime	$3,882	$12.13	$0.81
Chemicals	$7,805	$24.39	$1.63
Labor	$15,366	$48.02	$3.20
Diesel Fuel and Oil	$5,088	$15.90	$1.06
Maintenance and Upkeep	$6,196	$19.36	$1.29
Supplies	$3,200	$10.00	$0.67
Insurance	$106	$0.33	$0.02
Miscellaneous			
Rent or Lease	$4,000	$12.50	$0.83
Storage and Warehousing	$640	$2.00	$0.13
Other Expenses	$1,600	$5.00	$0.33
Interest	$1,716	$5.36	$0.36
Total Operating Expenses	**$63,837**	**$199.49**	**$13.30**
Annual Ownership Expenses			
Depreciation and Interest	$40,841	$127.63	$8.51
Tax and Insurance	$3,044	$9.51	$0.63
Total Ownership Expenses	**$43,885**	**$137.14**	**$9.14**
Total Annual Cost	**$107,722**	**$336.63**	**$22.44**
Net Farm Income (NFI)	**$12,278**	**$38.37**	**$2.56**
Return over Variable Cost (ROVC)	**$56,163**	**$175.51**	**$11.70**
Performance Measures			
Breakeven Revenue		$/acre	$/ton
Long-run to Cover All Costs		$336.63	$22.44
Short-run to Cover Operating Costs		$199.49	$13.30

[a] Numbers may not sum due to rounding.

had slightly greater profitability measures due to the small manure-nutrient credit assumed for silage corn on farms that had been integrated for more than ten years (Table 5.8). Silage corn enterprise budgets confirmed greater ROVC and NFI for long-term coupled dairy farms from this slight manure-nutrient credit for silage corn (Tables 5.9 to 5.13). Fertilizer costs for silage corn for long-term coupled dairy farms, $12/acre, was about 15% less than for conventional dairy farms at $14/acre (Tables 5.10 to 5.13).

LF-coupled dairy farms had lower profitability than conventional and L-coupled farms. Although there were no crop production expenses for LF-coupled dairy farms, the dairy farm did not eliminate all of the fixed costs allocated to forage crops. Profitability for LF-coupled dairy farms can be improved if prices paid to the potato farm for forage are reduced. Increased profitability from coupling in both the short term and long term may be limited for dairy farms unless they expand or unless management can be redirected from crop production to improve livestock productivity. Such potential increased profitability of the livestock enterprise was not directly reflected in budgets. Assuming increasing returns to scale, profitability should be greater if coupled dairy farms were able to expand herd size. Given the available data, however, dairy farm budgets were difficult to scale up continuously to exact herd and farm sizes for such hypothetical dairy farm expansions.

A hypothetical dairy farm expansion was demonstrated by transition from a small LF-coupled dairy farm to a medium-large LF-coupled dairy farm for which data was available. In this demonstration, the acreage of silage corn grown by the coupled potato farm increased from 98 to 258 acres to take advantage of all rotational acreage available from coupling. This scenario assumed the expanding dairy farm purchased the equivalent of an additional 62 acres of silage corn and 127 acres of haylage for increased feed needs beyond the increase provided by the coupling arrangement. ROVC and NFI under this scenario increased by $39/acre and $136/acre, respectively, compared to both the conventional and short-term L-coupled small dairy farm (Table 5.8). It is possible for both potato and dairy farms to benefit from coupling if dairy farms expand herd size while the potato farm increases potato acreage.

Potato and Dairy Systems

Coupled and conventional comparisons in previous sections focused on the potato or dairy side of the coupled relationship. This section compares conventional and coupled budgets as agricultural systems including both potato and dairy components. Acreages, revenues, and costs were aggregated to the farm-level. To compare segregated to integrated systems, an artificial combination of conventional systems was simulated.

For short-term integrated systems, ROVC and NFI were higher for L-coupled and LF-coupled compared to conventional farm systems (Table 5.14). This was mainly due

Table 5.14. Central Maine whole-farm budget summary for conventional and coupled systems.

			Crop Acres					System Budget[a]				
System Size	Coup. History	System Type	Potato	Grain Corn	Silage Corn	Hay/ Haylage	Total	Rev.	Oper. Costs	Own. Costs	ROVC	NFI
S	None	Conv.	160	160	98	73	491	$967	$769	$317	$198	-$119
	ST	L-Coup.	209	111	98	73	491	$1,107	$868	$317	$239	-$78
		LF-Coup.	209	111	98	73	491	$1,215	$965	$316	$250	-$66
	LT	L-Coup.	209	111	98	73	491	$1,107	$825	$317	$282	-$35
		LF-Coup.	209	111	98	73	491	$1,215	$922	$316	$294	-$22
ML	None	Conv.	320	320	320	200	1160	$1,088	$805	$277	$283	$6
	ST	L-Coup.	480	160	320	200	1160	$1,281	$938	$277	$343	$66
		LF-Coup.	480	160	320	200	1160	$1,418	$1,073	$279	$345	$66
	LT	L-Coup.	480	160	320	200	1160	$1,281	$895	$277	$386	$109
		LF-Coup.	480	160	320	200	1160	$1,418	$1,030	$279	$388	$109

[a] Revenue, costs, and returns in $/acre of total potato and dairy farm cropland, not including pasture.

Table 5.15. System profitability increases of component parts of coupling in central Maine (NFI in $/acre of potato and dairy farm cropland).

Coupling Components	Farm Size Small	Farm Size Medium-Large	Farm Size Average	Percent of Total w/o Yield Increase	Percent of Total w/ Yield Increase
Crop acreage changes	$41	$60	$50	51%	28%
Manure nutrient credits	$43	$43	$43	43%	23%
Coupling arrangement[a]	$12	$0	$6	6%	3%
Potato yield increase	$74	$94	$84		46%

[a] Shifting from land to land/feed coupled.

to the increased profitability from an increase in potato acreage. For long-term integrated systems, ROVC and NFI were greater than conventional systems for all coupled cases and sizes due to reductions in fertilizer use for both potatoes and silage corn in coupled systems. Differences in ownership and operating costs for L-coupled and LF-coupled cases were due to different machinery, equipment storages, and maintenance costs for potato compared to dairy farms. Thus profitability for L-coupled and LF-coupled systems was slightly different when comparing the same size and integration history.

Profitability of coupled systems in central Maine where the potato farm expanded and the dairy farm remained the same size was itemized into four separate components, 1) increased potato acreage, 2) manure nutrient credits, 3) shifting from land to land/feed coupled, and 4) a 5% assumed increase in potato yields. On average, gains in NFI were $50/acre from expansion of potato acreage during short-term coupling. In the long term if manure nutrient credits were taken, average gains were an additional $43/acre. Shifting from land to land/feed coupled provided relatively minimal system gains ($6/acre). If potato yields increased 5%, system NFI increased on average by an additional $84/acre (Table 5.15).

Chapter 6

COUPLED AND CONVENTIONAL PERFORMANCE INDICATORS FOR CENTRAL MAINE

The previous budget analysis indicates that integrated agricultural systems in Maine are more profitable than conventional systems. Integrated systems may also exhibit more favorable sustainability indicators than conventional, and sustainability indicators of farm and system performance should be important considerations when comparing agricultural systems. Economic and sustainability indicators were calculated for coupled and conventional potato and dairy farms and systems. Economic indicators included both profitability and efficiency measures. Sustainability indicators captured contributions to farm families, labor, and farmland as well as energy and machinery use, support for local families, and the balance of feed purchases and production on-farm.

Indicator Descriptions

Economic indicators were used to compare performance of conventional non-integrated systems and coupled integrated systems (Table 6.1). Most of these were standard indicators used to evaluate the financial performance of farms as proposed by the Farm Financial Standards Council (FFSC). The FFSC has identified 13 measures that are important when evaluating farm performance. The economic indicators listed in Table 6.1 include four of these measures. Return-over-variable costs is not an FFSC measure (FFSC, 1997). Five sustainability indicators were also used.

Economic indicators were calculated using representative budgets of integrated and conventional farms. Indicators for coupled and conventional farms were compared

Table 6.1. Economic and sustainability performance indicators.

Indicator Type	Indicator	Calculation	Description
1) Economic Profitability	a) Net Farm Income (NFI)	Revenue - Total Expenses	Return to farmer for unpaid labor, management, and owner equity
	b) Return over Variable Costs (ROVC)	Revenue - Variable Expenses	Return to farmer after all variable production costs are paid
	c) Profit over Revenues (POR)	Net Farm Income / Revenue	Proportion of revenues that is farm profit
Efficiency	d) Asset Turnover Ratio (ATR)	Revenue / Total Farm Assets	Efficiency of farm assets used to generate revenue
	e) Operating Expense Ratio (OER)	(Total operating expenses - Depreciation expense) / Revenue	Efficiency of adjusted farm operating expenses used to generate revenue
2) Sustainability			
	a) Farming Value Added (FVA)	Revenue - Costs Returned to Input Sector	Total systems revenue retained in the farming sector
	b) FVA as a Prop. of Prod. Share (FVA_p)	1 - (Costs Returned to Input Sector / Revenue)	Proportion of total systems revenue retained in the farming sector
	c) Energy and Machinery Use (NRG)	(Chemicals, Custom Hire, Deprec., Fertilizers, Lime, Gas, Fuel, Oil, Mach. Rent, Repairs, Utilities) / Revenue	Energy and machinery expenses purchased from non-farm sources as a proportion of farm revenue
	d) Support for Local Families (SLF)	(Employee Benefits Prog., Labor Hired, Pension and Profit Sharing, Net Farm Income) / Revenue	Proportion of farm revenue returned to farm families and farm workers
	e) Feed Balance (FB)	(Gross Income from Crops Sold - Feed Purchased) / Revenue	Difference between crops sold and feed purchased as a proportion of farm revenue

to each other for two farm size classes, small and medium-large. Indicators were measured on an economic basis for integrated compared to non-integrated systems.

<u>Economic Indicators</u>

Economic indicators were used to measure comparative profitability and efficiency of integrated and non-integrated representative farms. Net farm income, return-over-variable costs, and profit over revenues were the profitability indicators used in this study. The asset-turnover ratio and the operating-expense ratio were used to measure farm efficiency.

Net Farm Income (NFI) measures farm profitability in dollars per acre. NFI is total farm revenue minus all expenses including seed, fertilizer, lime, chemicals, labor, gas, fuel and oil, repairs, supplies, insurance, miscellaneous expenses, interest, property taxes, and depreciation. Integrated farms may have higher or lower NFI compared to non-integrated farms depending on how cost savings compare to revenues.

Return over Variable Costs (ROVC) measures short-run farm profitability in dollars per acre. ROVC is total farm revenue minus all variable expenses including seed, fertilizer, lime, chemicals, labor, gas, fuel and oil, repairs, supplies, insurance, miscellaneous expenses, and interest on production costs. Integrated farms may have higher ROVC compared to non-integrated farms due to fewer purchased inputs such as fertilizer.

Profit over Revenues (POR) normalizes farm profitability. A farm may have higher profits but a lower POR ratio. For example, a farm with an NFI of $10,000 and total revenue of $100,000 has a POR ratio of 0.10, whereas a farm with an NFI of $5,000 and a total revenue of $20,000 has a POR of 0.25. A higher POR implies that costs are a lower proportion of farm revenues. Integrated farms may have higher POR due to potentially lower fertilizer and feed costs. However, integrated farms may have higher labor costs plus higher equipment depreciation and interest, resulting in a lower POR.

Asset Turnover Ratio (ATR) measures the efficiency of the use of farm assets. As taken from the FFSC, ATR uses the farm's average annual total assets. The assets used to calculate ATR in this study included farm inventory at the end of the growing season, not the annual average value of farm inventory. Integrated farms may have higher or lower ATR depending on the value of farm revenues relative to assets.

Operating Expense Ratio (OER) measures adjusted operating costs per dollar of total farm revenue (FFSC 1997). An integrated farm may have a higher or lower OER compared to a non-integrated farm. This depends on the cost of external variable and fixed inputs relative to farm revenues.

Sustainability Indicators

Sustainability indicators include farming value added and farming value added as a proportion of producer's share. The three other sustainability indicators used in this study are found in Levins (1996). These include indicators that capture energy and machinery use, support for local families, and the balance of on-farm feed production and off-farm feed purchases. Data used for sustainability indicators were from representative farm budgets and IRS Schedule F information collected from cooperating farms.

Farming Value Added (FVA) is a measure of the contribution to all farm families, hired labor, and owned farmland. It is calculated as total farm revenue minus costs not returned to the farming sector and is measured in dollars per acre. FVA measures the returns to farming distinct from the input and marketing sectors of the agro-food system[12]. Total farm expenses include costs returned to input and farming sectors. Costs not returned to the farming sector include fertilizers, pesticides, equipment, services, and other items that are purchased from input sector firms. Costs returned to the farming

[12] The agro-food system consists of farming, input, and marketing sectors. The farming sector includes all on-farm activities generating farm production. Input sector firms produce fertilizers, pesticides, and farm machinery and provide credit and other services to farmers. Marketing sector firms take commodities or other products from the farming sector and transform them into consumer purchases (S.N. Smith, 1992).

sector include all directly paid farm labor and property taxes, plus the proportion of payments that remain in the farming sector that are paid to other farms.

Farm production expenses may consist of costs that produce proportionate returns to both the non-farming and farming sectors. Therefore, each itemized expense is adjusted by an appropriate FVA factor to determine the percentage of that expense that is returned to the farming sector (Table 6.2). For example, labor and property tax expenses directly paid by the farmer return all of their cost to the farming sector by definition. Thus labor and property taxes are direct impacts of FVA.

Indirect impacts of FVA, on the other hand, only contribute a proportion of their value to the farming sector. For example, repairs and maintenance to equipment and buildings, with an FVA factor of 20%, means that 20% of those costs are returned to the farming sector and 80% to the non-farm sector. Included in this indirect contribution to

Table 6.2. FVA factors for integrated and non-integrated Maine farms (Files, 1999).

Budget Line Items	FVA Factors (%)	Source
Direct impacts paid by farmer		
1) Labor	100	From definition of FVA
2) Property Taxes	100	From definition of FVA
Indirect impacts from purchases from other farmers		
3) Potato Seed	43	Based on average FVA ratio for conventional treatment of the MPEP[a]
4) Grain and Forage Seed	22	Barley and alfalfa seed used as proxy for grains and forage
5) Repairs and Maintenance (Equipment & Buildings)	20	Percentage of repairs and maintenance costs which are labor, as estimated by Langille Construction, Inc.
6) Miscellaneous:		
a) Rent or Lease:		
Vehicle/Mach./Equip.	20	Barley custom combine rental used as proxy
Land	100	If rented from other farmers
b) Custom Hire	20	Barley custom combine rental used as proxy
c) Feed Purchased	22	Seed used for grain and forage feed used as proxy

[a] The MPEP (Maine Potato Ecosystem Project) at the University of Maine has analyzed the agronomic and economic effects of conventional and alternative pest and soil management systems on potato production since 1991 (Marra, 1996).

FVA are the returns to other farm profits, labor, and property taxes from the purchase of inputs and services from these other farms. Further explanation of FVA calculations can be found in Files (1999) and Hoshide (2002).

Farming Value Added as a Proportion of Producer's Share (FVA_p) measures the returns to the farming sector as a proportion of farm revenues. FVA_p equals FVA divided by total farm revenue. Since FVA equals total farm revenue minus costs returned to the input sector, FVA_p is equal to 1 minus costs returned to the input sector divided by total farm revenue. Thus an FVA_p value of 0 indicates that no farm revenue is retained in the farming sector, while an FVA_p of 1 means that all farm revenue is retained in the farming sector. Negative FVA indicators mean that costs returned to the input sector exceed farm revenues.

Earlier research contrasted hypothetical integrated and non-integrated livestock and potato operations (Files, 1999). Files (1999) found that FVA_p was 7% greater for integrated dairy and potato operations using rotational grazing than for those using confined feeding. Large integrated dairy and potato operations using rotational grazing had 18% higher FVA_p than large non-integrated dairy and potato farms using confined feeding. Integrated farms should have higher FVA and FVA_p than non-integrated farms due to lower use of chemical fertilizers, which are not purchased from the farming sector.

Energy and Machinery Use (NRG) measures energy and machinery use purchased from non-farm sources as a proportion of total farm revenue. NRG ratios are higher with greater farm dependence on non-farm generated inputs (Levins, 1996). Integrated farms should have lower NRG indicators because they purchase fewer inputs such as fertilizer.

NRG is approximately equal to costs returned to the input sector divided by total farm revenues as used in the previous FVA_p calculation.

Support for Local Families (SLF) measures the amount of farm income retained by local farmers and farm workers. The more a farm supports the local families that are employed by the farm (including the farm family itself), the closer the SLF value is to 1 (Levins, 1996). Because of higher labor costs, SLF should be higher for integrated farms. However, depending on the size of net farm income, this indicator may be lower for integrated farms. SLF is roughly equal to direct costs returned to the farming sector divided by total farm revenues as described in previous sections on FVA measures.

Feed Balance (FB) between crops produced on-farm and purchased feed is equal to 1 if a farm only sells crops and has no livestock. A livestock farm that does not sell crops and buys all of its feed has a negative FB. The closer crop sales are to the value of feed purchases, the closer FB is to zero (Levins, 1996). The FB for an integrated farm should be closer to 0 than that of a non-integrated farm due to less purchased feed and/or increased crop sales. Potato farms have FB of +1 and are not compared. Freyenberger et al. (2001) used these sustainability indicators for comparing conventional and sustainable farms in Kansas during 1995 and 1996.

Coupled and Conventional Indicator Results

Economic and sustainability indicators for coupled and conventional potato and dairy farms were calculated. Conventional and coupled indicators were not tested for statistically significant differences since they were based on representative budgets constructed from a limited number of cooperating producers. Thus, results should be viewed with caution. NFI, ROVC, and FVA were calculated in dollars per acre of crops.

Conventional and coupled indicators in this section were based on the same coupling type (L-coupled and LF-coupled), duration (short-term and long-term), and size classifications (small and medium-large) as representative farm budgets. Similarly, medium and large cooperating farms were aggregated into the medium-large group due to low sample size.

Potato Farm Indicators

Indicators for conventional and coupled potato farms (Table 6.3) were compared for both short-term (Appendix F-1) and long-term (Appendix F-2) coupling. Crops included potato plus rotation crop or crops. Typical expected indicator values were obtained from the literature.

Economic Indicators measured both profitability and efficiency. Profitability indicators (NFI, ROVC, and POR) were greater for coupled potato farms for both coupled cases and both size classes in the short term because more potatoes were grown. For LF-coupled potato farms, per acre fixed costs were lower from equipment used for potatoes, grain corn, and forage. There was an increase in profitability from short-term to long-term coupled farms from manure-nutrient credits taken for potatoes and silage corn. POR for LF-coupled potato farms was higher than for L-coupled farms due to the addition of more profitable forage enterprises to complement potatoes. A typical value for POR was 0.10 with an expected range of -0.25 to 0.25. In this study, POR values for potato farms ranged between -0.054 and 0.184.

The asset turnover ratio (ATR), which measures the efficiency of asset use, was greater for coupled potato farms than for conventional primarily because the farm produced more potatoes on more acres without having to purchase more land assets. The ATR was lower for LF-coupled than L-coupled potato farms because the LF-coupled

Table 6.3. Central Maine economic and sustainability indicators for coupled and conventional potato and dairy farms.

				-------- ECONOMIC[c] --------					---- SUSTAINABILITY[d] ----				
Type	Coup.	Farm	Crop	-- Profitability --			Efficiency						
& Size	Hist.[a]	Type	Acres[b]	NFI[e]	ROVC[e]	POR	ATR	OER	FVA[e]	FVA_p	NRG	SLF	FB[f]
Potato S	None	Conv.	320	-$51	$200	-0.054	0.306	0.541	$126	0.132	0.633	0.086	-
	ST	L-Coup.	320	$12	$262	0.010	0.416	0.571	$225	0.193	0.576	0.150	-
		LF-Coup.	320	$57	$335	0.043	0.373	0.559	$304	0.228	0.549	0.187	-
	LT	L-Coup.	320	$76	$327	0.065	0.416	0.516	$289	0.248	0.521	0.205	-
		LF-Coup.	320	$124	$402	0.093	0.373	0.509	$370	0.278	0.501	0.237	-
ML	None	Conv.	640	$18	$225	0.019	0.348	0.559	$179	0.188	0.577	0.145	-
	ST	L-Coup.	640	$127	$334	0.098	0.507	0.595	$341	0.262	0.508	0.222	-
		LF-Coup.	640	$208	$443	0.134	0.451	0.572	$464	0.300	0.481	0.261	-
	LT	L-Coup.	640	$203	$409	0.156	0.507	0.536	$417	0.321	0.451	0.280	-
		LF-Coup.	640	$285	$520	0.184	0.451	0.522	$541	0.349	0.433	0.311	-
Dairy S	None	Conv.	171	-$245	$148	-0.245	0.210	0.235	-$131	-0.132	0.574	-0.182	-0.224
	ST	L-Coup.	171	-$245	$148	-0.245	0.210	0.235	-$131	-0.132	0.574	-0.182	-0.224
		LF-Coup.	171	-$295	$44	-0.296	0.235	0.398	-$240	-0.240	0.442	-0.286	-0.512
	LT	L-Coup.	171	-$243	$150	-0.244	0.210	0.234	-$130	-0.130	0.572	-0.180	-0.224
		LF-Coup.	171	-$295	$44	-0.296	0.235	0.398	-$240	-0.240	0.442	-0.286	-0.512
ML	None	Conv.	520	-$9	$319	-0.007	0.319	0.340	$92	0.073	0.405	0.041	-0.279
	ST	L-Coup.	520	-$9	$319	-0.007	0.319	0.340	$92	0.073	0.405	0.041	-0.279
		LF-Coup.	520	-$109	$187	-0.086	0.346	0.474	-$56	-0.045	0.316	-0.073	-0.523
	LT	L-Coup.	520	-$7	$321	-0.006	0.319	0.339	$94	0.075	0.404	0.043	-0.279
		LF-Coup.	520	-$109	$187	-0.086	0.346	0.474	-$56	-0.045	0.316	-0.073	-0.523

[a] Short-term (ST) and long-term (LT) coupled.

[b] Crop acres included potatoes and grain corn for potato farms and silage corn and hay/haylage for dairy farms. Dairy farm crop acreage did not include pasture.

[c] Economic indicators were net farm income (NFI), return over variable costs (ROVC), profit over revenues (POR), asset turnover ratio (ATR), and operating expense ratio (OER).

[d] Sustainability indicators were farming value added (FVA), FVA as a proportion of producer's share (FVA_p), energy and machinery use (NRG), support for local families (SLF), and feed balance (FB).

[e] NFI, ROVC, and FVA were in $/acre of cropland for both potato and dairy farms. Crop acreage for LF-coupled potato farms did not include forage grown for sale to the dairy farm. Per acre returns and FVA for LF-coupled dairy farms used the same crop acreage as conventional and L-coupled.

[f] FB comparison not applicable for potato farms since no feed was purchased and FB values were +1.

farm purchased more feed-crop producing equipment with a relatively modest boost in feed-crop revenues (Table 6.3). As seen in Table 6.3, ATR values for potato farms ranged from 0.306 for smaller conventional farms to 0.507 for larger L-coupled farms. Expected values for ATR ranged from 0.20 to 0.60.

The operating expense ratio (OER) measures the efficient use of production expenses. OER values were somewhat lower (preferred) for long-term coupled potato farms than conventional farms because of their more efficient use of purchased fertilizers. On the other hand, short-term coupled farms had slightly worse OER than conventional farms because potatoes comprised a larger proportion of the crop mix. Potatoes had a higher (less preferred) OER since a higher percentage of its costs constituted operating expenses relative to grain corn. OER values ranged from 0.516 for small, long-term LF-coupled potato farms to 0.595 for medium-large, short-term L-coupled farms. OER values were within an expected range of 0.20 to 0.80.

Sustainability Indicators such as FVA and FVA_p were more favorable for coupled farms than for conventional farms for both short- and long-term integration due to greater farm profits and paid labor from growing more potatoes. Coupled farms appeared to return more to the farming sector than conventional farms. There was also an increase in FVA_p from L-coupled to LF-coupled, due to higher labor costs per dollar of total revenue for more diversified crop enterprises and thus greater returns to the farming sector. The measures of FVA were also greater for long-term integration than for short-term integration due to reductions in purchased fertilizer. FVA_p was within an expected range of -0.20 to 0.50, ranging between 0.132 and 0.349.

Other sustainability indicators were more favorable for coupled than conventional farms. NRG was lower (preferred) for coupled than conventional for both size classes and both coupled types. Long-term integrators had lower NRG than short-term ones since they used less purchased fertilizer. L-coupled had lower NRG than conventional due to efficiencies in equipment use when growing more profitable potatoes. LF-coupled had lower NRG than L-coupled because the increase in energy and machinery costs was proportionally less than the increase in total revenues due to equipment inventory efficiencies. NRG values for potato farms were between 0.433 and 0.633. The expected NRG range was 0.30 to 0.70.

SLF was higher and thus more favorable for all coupled potato farms relative to conventional. SLF was higher for long-term than short-term integration because NFI was higher for long-term integrators. SLF was also greater for LF-coupled farms than for L-coupled farms due to higher NFI and labor expenses for growing dairy forage. SLF were between 0.086 and 0.311. The expected SLF range was -0.05 to 0.30. FB was not compared for potato farms since no feed was used and since values for total revenue and crop sales were the same.

Dairy Farm Indicators

All indicators in Table 6.3 for dairy farms were based on 2001 data, except for ATR, which also used 2000 Farm Credit data (Stafford et al., 2001). Since fluid milk prices were below break-even in 2001, several indicators were negative (Dalton and Bragg, 2003). Since no feed crops were grown and no manure-nutrient credits were taken, indicators for short- and long-term LF-coupled were identical. Dairy cropland used for calculating returns and FVA per acre included silage corn and hay/haylage but not pasture. Indicators are ranked in Appendices F-1 and F-2.

Economic Indicators were comparable or less favorable for coupled compared to conventional dairy farms. In general, profitability indicators (NFI, ROVC, and POR) were the same for short-term L-coupled dairy farms compared to conventional since their enterprise budgets were the same. For long-term L-coupled, profitability indicators were slightly better because of the small manure-nutrient credit taken for silage corn. LF-coupled dairy farms had lower values for NFI, ROVC, and POR because the production savings from not growing forage were less than the cost of purchasing forage from the coupled potato farm since stranded fixed costs from previously used feed crop equipment remained. At the feed prices used in this study, coupled dairy farms appeared to be better off if they grew their own forage. Values for POR were between -0.296 and -0.006, which were lower than a typical value of 0.10.

Financial efficiency measures were similar for L-coupled and conventional. Comparisons of LF-coupled with conventional were mixed. ATR values for L-coupled and conventional were the same since farm revenues and total assets were identical. LF-coupled farms had slightly higher ATR than conventional because fewer machinery assets were needed since forage crops were not grown. In this study, ATR values for dairy farms were between 0.210 and 0.346, while a typical ATR was 0.30.

OER for LF-coupled dairy farms was higher (less favorable) than for conventional farms due to higher operating expenses since new purchased feed costs exceeded savings in forage production. For L-coupled dairy farms, there was a slight decrease in OER going from short- to long-term coupling because of the small fertilizer reduction for silage corn. OER values ranged from 0.234 to 0.474. A typical value for OER was 0.66. OER for dairy farms was lower than typical values since family labor was not included explicitly.

<u>Sustainability Indicators</u> were also comparable or less favorable for coupled compared to conventional dairy farms. Short-term L-coupled dairy farms had FVA measures that were the same as conventional since crop production techniques were the

same and there was no change in cropped acres. Indicators for LF-coupled dairy farms were the same for both short- and long-term coupling. Long-term L-coupled farms had slightly higher FVA measures than conventional farms due to small reductions in purchased fertilizer from the manure-nutrient credit taken for silage corn. There was also a decrease in FVA and FVA_p from L-coupled to LF-coupled farms, which did not grow forage and required less labor than L-coupled dairy farms. FVA measures were lower even though a proportion of forage purchased from the coupled potato farm was returned to the farming sector. FVA_p ranged from -0.240 to 0.075.

Other comparisons of sustainability indicators were mixed for coupled and conventional dairy farms. NRG, SLF, and FB were identical for short-term L-coupled and conventional. Since forage was purchased from another farm rather than produced on-farm, LF-coupled had lower and thus more favorable NRG values because of lower machinery and energy costs. NRG improved slightly for L-coupled going from short-term to long-term due to less purchased fertilizer for silage corn. NRG values were between 0.316 and 0.574.

LF-coupled had lower SLF values due to lower labor expenditures and lower NFI. For all L-coupled dairy farms, SLF increased slightly from the short- to long-term because of higher NFI. SLF ranged from -0.286 to 0.043.

In both the short- and long-term, FB for L-coupled dairy farms was the same as for conventional farms since production and feeding regiments were the same. LF-coupled farms had more negative (less preferred) FB because forage was purchased and was not grown on-farm. FB values ranged between -0.523 and -0.224.

System Indicators

While individual farm indicators are of interest to the farmer, this analysis is ultimately interested in the workings of the agricultural system, a combination of crop and livestock enterprises. Indicators for conventional and integrated potato and dairy systems were also calculated (Table 6.4). Conventional systems were based on separate potato and dairy farms whose whole-farm budgets were combined. Like separate potato and dairy comparisons, indicators were calculated for small and medium-large, short- and long-term coupling, and for L-coupled and LF-coupled. For system budgets, acres of crops grown were aggregated from potato and dairy farm cropland.

Table 6.4. Central Maine economic indicators for coupled and conventional potato and dairy systems.

				ECONOMIC[c]					SUSTAINABILITY[d]			
				Profitability			Efficiency					
System Size	Coup. Hist.[a]	System Type	Crop Acres[b]	NFI[e]	ROVC[e]	POR	ATR	OER	FVA[e]	FVA_p	NRG	SLF
S	None	Conv.	491	-$119	$198	-0.123	0.263	0.495	$36	0.037	0.612	-0.010
	ST	L-Coup.	491	-$78	$239	-0.070	0.318	0.521	$101	0.091	0.575	0.046
		LF-Coup.	491	-$66	$250	-0.054	0.320	0.557	$137	0.112	0.519	0.051
	LT	L-Coup.	491	-$35	$282	-0.032	0.318	0.483	$143	0.130	0.537	0.084
		LF-Coup.	491	-$22	$294	-0.018	0.320	0.521	$180	0.148	0.484	0.087
ML	None	Conv.	1160	$6	$283	0.006	0.332	0.506	$140	0.129	0.488	0.091
	ST	L-Coup.	1160	$66	$343	0.052	0.402	0.534	$230	0.179	0.463	0.142
		LF-Coup.	1160	$66	$345	0.047	0.402	0.578	$254	0.179	0.416	0.128
	LT	L-Coup.	1160	$109	$386	0.085	0.402	0.501	$272	0.212	0.430	0.176
		LF-Coup.	1160	$109	$388	0.077	0.402	0.548	$297	0.209	0.387	0.158

[a] Short-term (ST) and long-term (LT) coupled.
[b] Crop acres included total potato plus dairy cropland.
[c] Economic indicators were net farm income (NFI), return over variable costs (ROVC), profit over revenues (POR), asset turnover ratio (ATR), and operating expense ratio (OER).
[d] Sustainability indicators were farming value added (FVA), FVA as a proportion of producer's share (FVA_p), energy and machinery use (NRG), and support for local families (SLF).
[e] NFI, ROVC, and FVA in $/acre.

Economic Indicators were generally preferable for coupled compared to conventional systems. Across each farm size, profitability indicators (NFI, ROVC, and POR) for coupled systems were greater than for conventional systems. L-coupled systems were more profitable than conventional due to increased profitability from growing more potatoes. LF-coupled systems showed equal or better profitability measures than L-coupled systems due to efficiencies in equipment use for crops. Profitability improved going from short- to long-term integration since greater manure-nutrient credits were taken for potatoes and silage corn after ten years of integration.

System comparisons were mixed for economic efficiency. Coupled systems had higher and thus more favorable values for ATR than conventional systems due to higher revenues from growing more potatoes. For LF-coupled systems, equipment savings also contributed to greater ATR than conventional. ATR was similar for L-coupled and LF-coupled since lower ATR for LF-coupled potato farms offset higher ATR for LF-coupled dairy farms.

OER was generally higher (less preferred) for coupled compared to conventional. L-coupled systems had higher OER than conventional since more potatoes were grown, a crop with a higher OER than grain corn. LF-coupled OER was slightly higher due to additional dairy forage expenses. However, higher OER for LF-coupled may be dependent on how forage transactions between LF-coupled potato and dairy farms were accounted for when calculating OER. Differences in OER between L-coupled and LF-coupled may also be due to slight differences in equipment inventories between potato and dairy farms. OER was lower (better) going from the short term to long term due to fertilizer costs that were lowered by manure-nutrient credits.

Sustainability Indicators were also preferable for coupled compared to conventional systems. Coupled systems had higher FVA measures than conventional because coupled systems grew more potatoes and less grain corn. Potatoes were more profitable and more labor intensive than grain corn. FVA also improved from short- to long-term coupling due to reduction in purchased fertilizer inputs. The NRG indicator was lower (more favorable) for coupled than for conventional systems since crop revenues were higher relative to NRG expenses for coupled farms due to equipment energy use efficiencies when increasing potato acreage relative to grain corn and when adding forage enterprises. NRG was more favorable for long-term than short-term integrators due to reduced purchased fertilizer use in the system from greater manure-nutrient credits taken after several years of coupling. SLF was greater for coupled systems, especially in the long-term, due to greater profitability of these systems. FB was not compared between agricultural systems since this indicator was not compared for potato farms.

Indicator Diagram Results

Radial diagrams are increasingly used to display outcomes containing differing metrics. By observing outcome values on rays extending from a vertex, the reader can visually grasp how well the displayed options compare across a number of objectives. Radial diagrams used here display the relative desirability of eight coupled farm systems compared to equivalent sized conventional systems.

Six economic (POR, ATR, and OER) and sustainability (FVA_p, NRG, and SLF) indicators were compared with ray diagrams for coupled and conventional potato and dairy systems (Figures 6.1 to 6.4). Indicators were graphed as rays on radial diagrams with possible ranges of -1 to +1. Minimum and maximum values for the expected range of each indicator were used as lower and upper bounds. Minimum indicator values correspond to the ray diagram origin, while maximum indicator values correspond to the

Figure 6.1. Central Maine comparison of conventional and short-term land-coupled indicators.

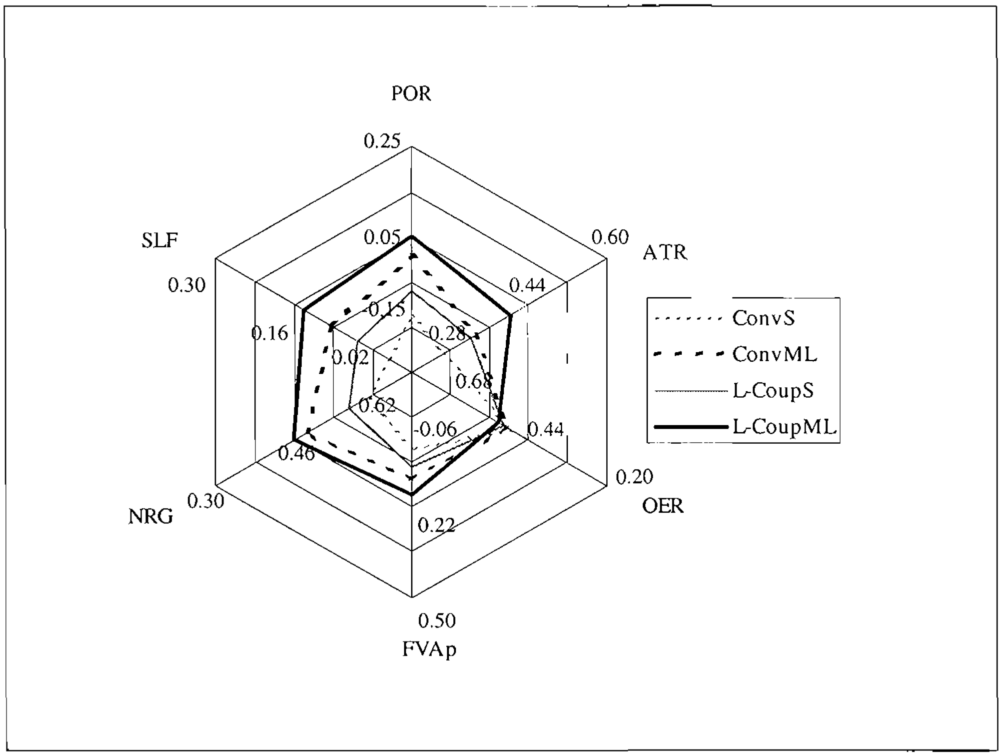


Figure 6.2. Central Maine comparison of conventional and long-term land-coupled indicators.

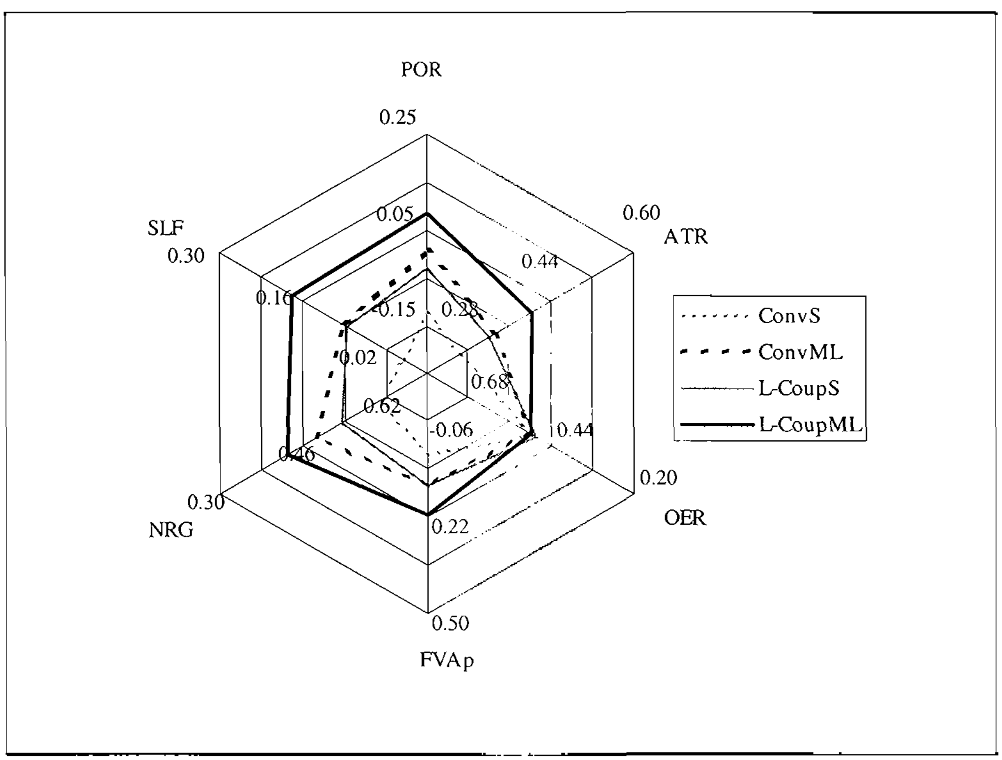


Figure 6.3. Central Maine comparison of conventional and short-term land/feed-coupled indicators.

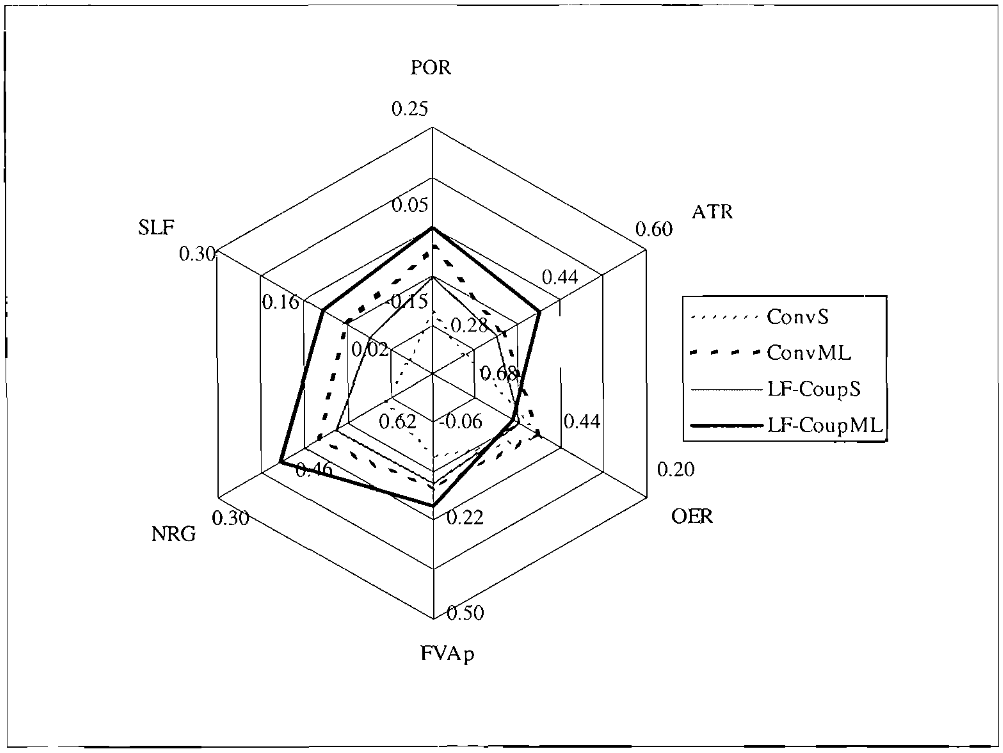
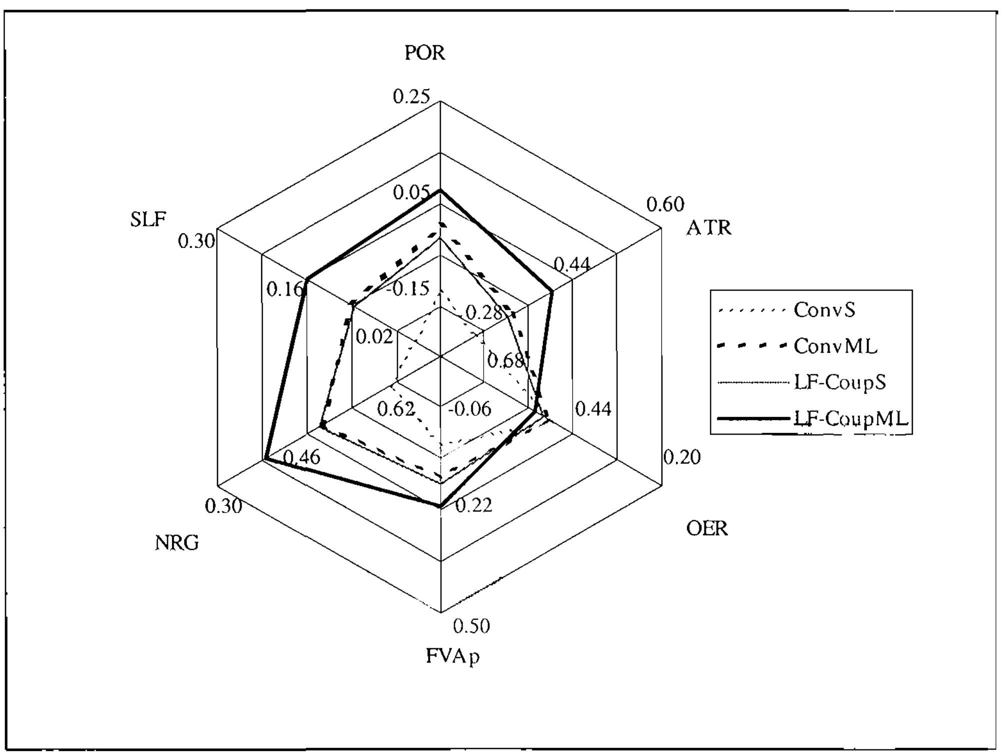


Figure 6.4. Central Maine comparison of conventional and long-term land/feed-coupled indicators.



outer bound of the diagram. Thus, more favorable indicator ratios are found further from the origin. Since lower OER and NRG indicator values are preferred, these two rays were reversed so the preferred lower ratios are further from the origin.

With the exception of OER, coupled systems were favored over conventional systems for all indicators. This was true for both size classes, small and medium-large, and for both coupled types, L-coupled (Figures 6.1 and 6.2) and LF-coupled (Figures 6.3 and 6.4). Medium-large-sized systems generally had higher indicator values than small ones regardless of farm type. Diagrams of small farm systems were contained within comparable diagrams of medium-large systems. Size generally dominated integration, where the best small farm systems were usually worse than the worst medium-large farm systems. Indicators were well within expected ranges.

Chapter 7

POTENTIAL COUPLED AND CONVENTIONAL COMPARISONS IN AROOSTOOK COUNTY

Coupled potato and dairy systems are currently limited to central Maine and southern Aroostook County. Increasing coupled potato and dairy integration in Aroostook County would involve expanding dairy farm numbers in this part of the state. In the past, dairy farms were more prevalent here. However in 2001, there were only twelve dairy farms in Aroostook with an average of 64 milk cows (Table 2.2). Aroostook County has great potential for integrating crops with livestock since this is currently where the majority of potato and potato rotation acreage in Maine are located (Table 2.1). However, few Aroostook dairy farmers have explored the possibility of coupling their operations with potato farmers. There has also been limited interest from dairy farmers in central and southern Maine in starting new facilities in Aroostook County. Farmers interested in such potential coupling have asked about the profitability of such systems. Thus, representative budgets and performance indicators for coupled and non-integrated potato and dairy production in Aroostook County were compared.

Integrated and Conventional Farm Characteristics

Typical rotations and crop management for conventional, land-coupled, and land/feed-coupled potato and dairy farms in Aroostook County are somewhat different from central Maine (Figures 7.1 to 7.4). Conventional potato farms in Aroostook County typically grow potatoes and barley in a two-year rotation. Even though some grain and silage corn cultivars may be able to be grown this far north, it was assumed that heat units and crop yields were low enough, especially in central and northern Aroostook County,

Figure 7.1. Potential Aroostook County conventional potato and dairy farm crop management before coupling.

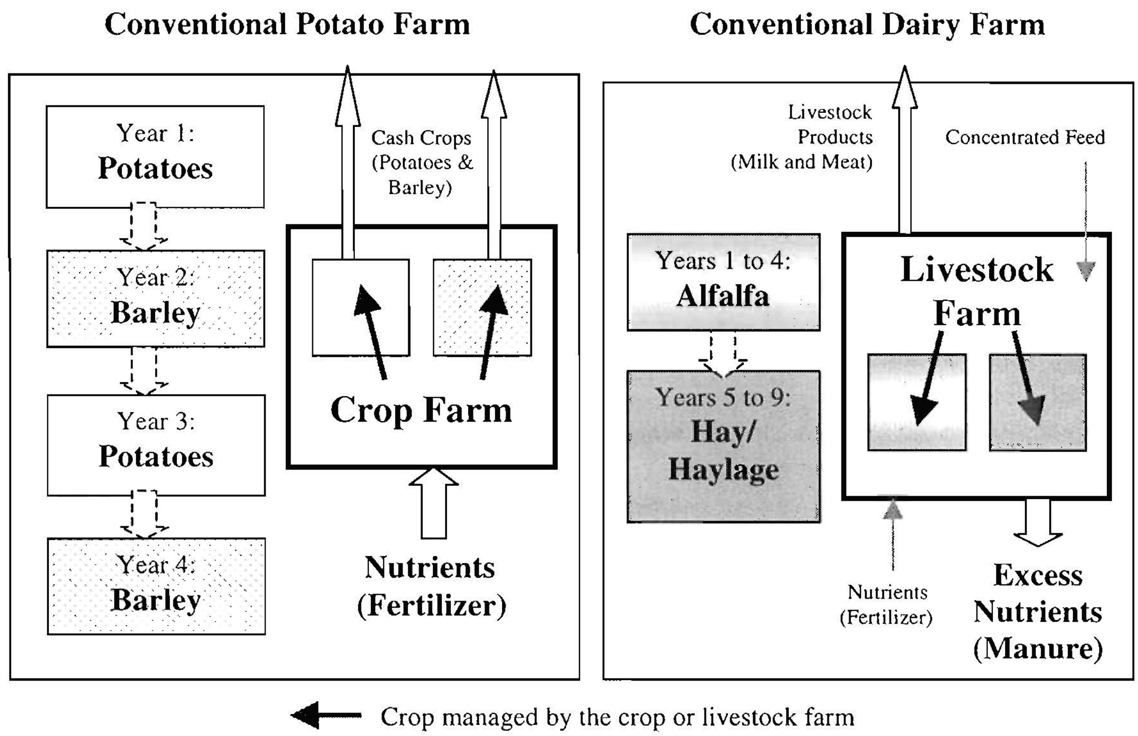


Figure 7.2. Aroostook County land-coupled crop management where potato farm expanded.

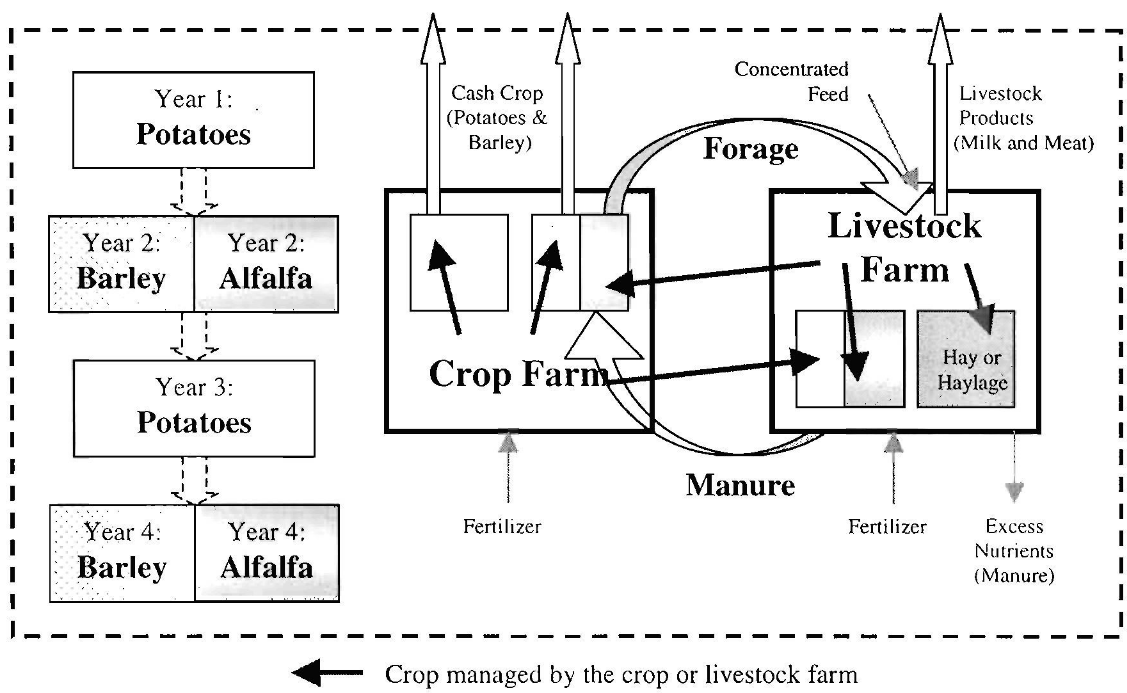


Figure 7.3. Aroostook County land-coupled crop management where dairy farm expanded.

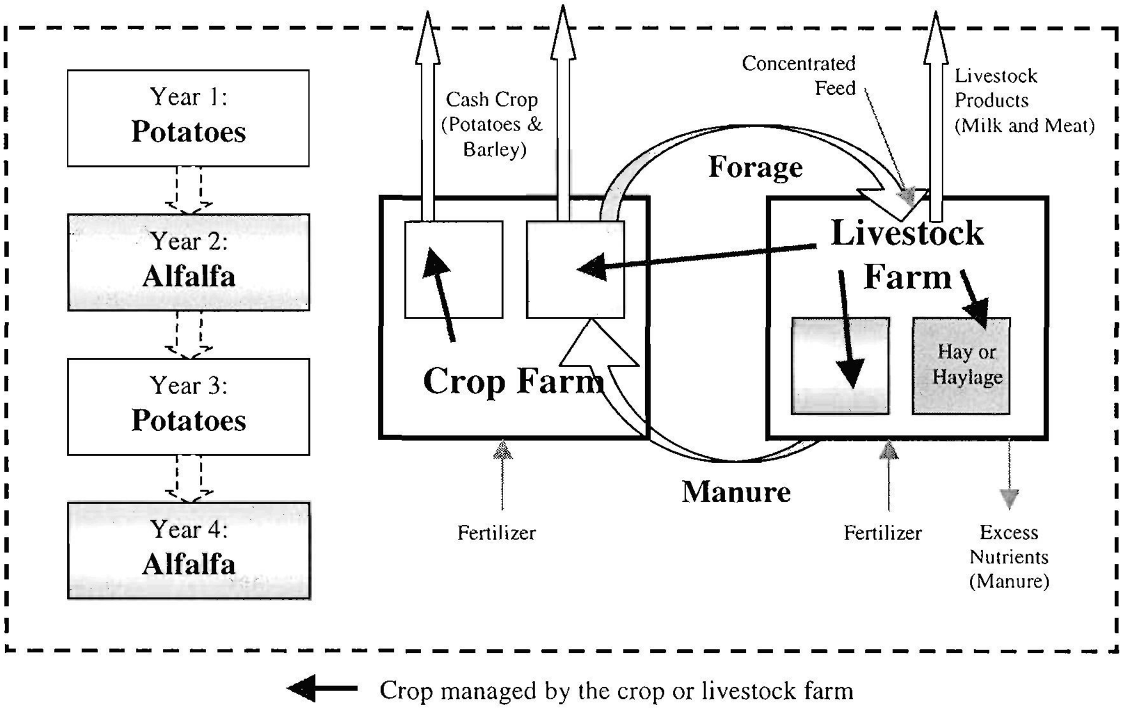
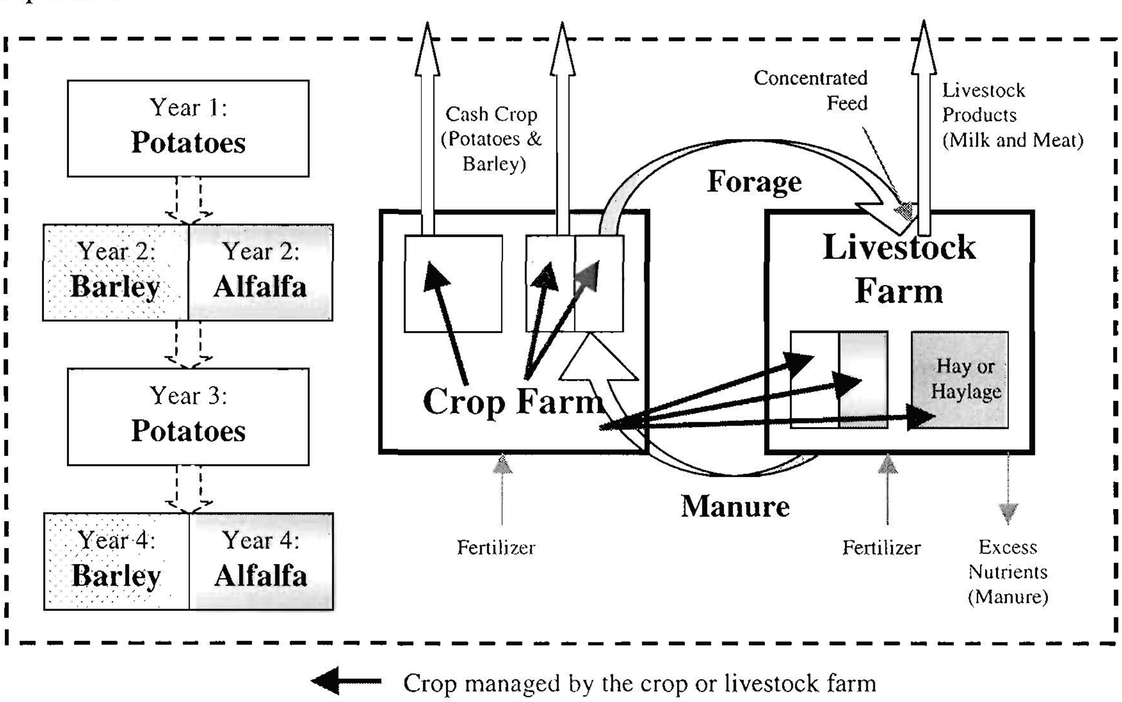


Figure 7.4. Aroostook County land/feed-coupled crop management where potato farm expanded.



to make growing corn impractical. Thus, it was assumed conventional dairy farms would manage alfalfa and hay or haylage, growing this forage in a long-term rotation such as four years of alfalfa followed by five years of hay/haylage. Although alfalfa stands may be susceptible to winter kill, especially in years with minimal snow cover, it was assumed that Aroostook alfalfa would last four years due to heavier snow pack there. Like much of the dairy industry, it was assumed Aroostook dairy farms grew forage and purchased all concentrates. Dairy manure was applied to forage used to feed livestock (Figure 7.1).

Similar to coupled farms in central Maine, L-coupled potato and dairy farms exchanged cropland. L-coupled potato farms raised just potatoes and barley. Dairy farms managed alfalfa grown on potato farmland. Potato farms managed any potatoes grown on dairy farmland but did not manage or pay for the production of dairy forage (Figures 7.2). Dairy farms covered the costs of forage storage and manure-spreading. Land coupling allowed either potato farm expansion (Figure 7.2) or expansion by the dairy farm (Figure 7.3).

This analysis assumed potatoes were rotated with establishment year alfalfa. Although it was not explored, more potato acres would be available by growing two years of back-to-back potatoes followed by four years of alfalfa. Here the rotational acreage available for coupling would be half of that for silage corn. Instead it was assumed only one year of potatoes was grown following four years of alfalfa. Thus the rotational acreage available for coupling with the potato farm was one-fourth the amount of an annual crop like silage corn.

For example, small dairy farms required 98 acres of alfalfa. In any given year, only 24.5 acres were available for rotation with the coupled potato farm's potatoes and

Table 7.1. Aroostook County enterprise budget crop yields and prices and farm acreages.

					-- Potato Farm Acres[b] --						-Dairy Farm Acres[b]-		
			Yield				L-		LF-		Conv.&		LF-
		Price	(cwt/	Price	Conv.		Coup.		Coup.		L-Coup.		Coup.
Crop	Yield/Acre[a]	($/unit)	acre)	($/cwt)	S	ML	S	ML	S	ML	S	ML	S & ML
Potato	283 cwt	$5.81	283	$5.81	160	320	172[c]	360	172[c]	360	-	-	-
Barley	71 bu	$1.50	34	$3.13	160	320	148[c]	280	148[c]	280	-	-	-
Alfalfa	6.25 tons	$50.00	125	$2.50	-	-	-	-	98	320	98	320	-
Dry Hay[d]	3.5 tons	$64.50	70	$3.23	-	-	-	-	73	-	73	-	-
Haylage[e]	6 tons	$32.55	120	$1.63	-	-	-	-	-	200	-	200	-

[a] Forage yields per acre shown as harvested tons and not tons of dry matter.
[b] Farm acres were operated crop acres, not owned and rented crop acres.
[c] Coupled potato acres were rounded down from 172.25, while barley acres were rounded up from 147.75.
[d] First cut harvested as round bales and second cut harvested as square bales.
[e] First cut haylage and 90% haylage and 10% square bales for second cut.

barley. If the small potato farm expanded, potato production increased to 172.25 acres, which was one-half the sum of acreages for alfalfa (24.5), potato (160), and barley (160). If the dairy farm expanded and the potato farm did not, then potato acreage remained the same, while forage production increased by the acreage previously devoted to barley.

Like central Maine, LF-coupled farms exchanged land. In addition to growing potatoes and barley, the potato farm grew alfalfa and hay/haylage for sale to the coupled dairy farm (Figure 7.4) at typical market prices (Table 7.1). Similar to central Maine, the dairy farm provided forage and manure storages plus manure-spreading equipment, while the potato farm paid for all other crop production costs. LF-coupled dairy farms focused entirely on milk production and did not grow any crops.

Although coupled integration was possible between existing potato and dairy farms in Aroostook County, it could have also happened if dairy farms from central and southern Maine started new operations in Aroostook County. Here the dairy farm purchased only enough land to accommodate livestock. The dairy farm bought forage from a nearby potato farm. This alternative coupled scenario was also analyzed and was classified as LF-coupled Start Up.

It was assumed that LF-coupled Start Up potato farms owned and rented the land needed to grow forage for the new dairy operation. In contrast, regular LF-coupled potato farms used the dairy farm's forage cropland as part of a land exchange. Compared to LF-coupled Start Up, regular LF-coupled potato farms had no production costs for owning or renting land used to grow the dairy farm's forage.

LF-coupled Start Up dairy farms purchased no forage cropland. These dairy farms had less total farm acreage for small (40) and ML (120) sizes than regular LF-coupled dairy farms for both central Maine and Aroostook County small (363) and ML (776). Start Up dairy farm acreages were based on a cooperating dairy farm exploring the possibility of starting a dairy operation in southern Aroostook County. Regular LF-coupled small farm acreages for pasture (29), woodland (157), and other (6) and ML acreages for pasture (43), woodland (200), and other (13) were assumed to be the same for central Maine and Aroostook County.

Crop yields, prices, and acreages and other data used for representative budgets were based on the 2001 calendar year and used similar sources as those for central Maine (Table 7.1). Crop prices were those generally received by cooperating farmers. Dry hay and haylage yields, prices, and production were assumed to be identical to central Maine. Like central Maine, it was assumed 25% of farmland was rented.

Crop production assumptions for Aroostook County were based on the most common practices of cooperating farms and were used to construct representative budgets (Table 7.2). Livestock assumptions for dairy farms were the same as central

Table 7.2. Aroostook County base crop production assumptions for potato and dairy farms.

Farm Crop	Manure Applied	Herbi -cides	--- Pesticide Applications --- Insecti- cides	Fungi- cides	Sprout Inhibit.[a]	Top Kill[b]	Times Harv- ested	Lime Applied (tons/acre)
Potato	No	2	2	13	1	2	1	0.50
Barley	No	1	-	-	-	-	1	0.61
Alfalfa	Yes	1[c]	-	-	-	-	2	0.50
Hay	Yes	-	-	-	-	-	2	0.50
Haylage	Yes	-	-	-	-	-	2	0.50

[a] Applied to 50% of potato acres for late storage varieties.
[b] Applied to 75% of potato acres for storage varieties since 25% of acres were harvested fresh out of field.
[c] Applied only for establishment year alfalfa. Non-establishment alfalfa received no herbicides.

Maine (Table 4.5). Like central Maine, family labor was not itemized and was captured in net farm income. Labor expense was only hired labor.

Aroostook County manure and fertilizer applications (NPK) for crops were similar to central Maine (Table 7.3). As in central Maine, manure and fertilizer assumptions were the same for L-coupled and LF-coupled farms. Like coupled farms in central Maine, no manure was applied during the potato or potato rotation (barley) year. Manure-nutrient credits were only taken in the long term.

Manure-nutrient credits were taken for barley under long-term coupling. Unlike silage corn in central Maine, it was assumed that there was no reduction in starter fertilizer for establishment-year alfalfa for long-term coupling. In the years following the establishment year, it was assumed that alfalfa did not receive manure or any fertilizer. More manure and less fertilizer was applied to dry hay and haylage compared to central Maine.

Table 7.3. Manure, fertilizer, and nutrient applications and fertilizer cost for conventional and coupled farms in Aroostook County.

				Manure	Fertilizer			Nutrients Applied as (lb/acre)								
				Applied	Type	Applied	Cost	Manure			Fertilizer			Total		
Farm Type	Industry	Size	Crop	(/acre)[a]	(Analysis)	(lb/acre)	($/ton)	N	P	K	N	P	K	N	P	K
Conventional	Potato	S & ML	Potato	-	Potato Blend (14-14-14)	1150	$205	-	-	-	161	161	161	161	161	161
& Coupled			Barley	-	At Plant Urea (34-0-0)	147	$230	-	-	-	50	0	0	66	0	0
(Short-Term)					Side Dress Urea (34-0-0)	46	$230	-	-	-	16	0	0			
Conventional	Dairy	S	Alfalfa (Est.)	12.5 ton	Alfalfa Pre-Plant (0-0-42)	271	$232	92	23	82	-	-	113	92	23	195
& Coupled			Alfalfa	-	None Applied	-	-	-	-	-	-	-	-	-	-	-
(Short-Term			Hay	25 ton	None Applied	-	-	183	45	164	-	-	-	183	45	164
& Long-Term)		ML	Alfalfa (Est.)	3000 gal	Alfalfa Pre-Plant (0-0-42)	271	$232	76	45	62	-	-	113	76	45	175
			Alfalfa	-	None Applied	-	-	-	-	-	-	-	-	-	-	-
			Haylage	6600 gal	Top Dress Urea (46-0-0)	110	$230	167	99	135	51	0	0	218	99	135
Coupled	Potato	S & ML	Potato	-	Potato Blend (14-14-14)	450	$205	-	-	-	63	63	63	63	63	63
(Long-Term)			Barley	-	At Plant Urea (34-0-0)	37	$230	-	-	-	12	0	0	14	0	0
					Side Dress Urea (34-0-0)	5	$230	-	-	-	2	0	0			

[a] Small farms used solid dairy manure (tons/acre) while medium-large (ML) farms used liquid dairy manure (gallons/acre).

Potato Farms

Potato farms assumed production of processing potatoes,[13] which comprised about 60% of the potato industry in Aroostook County and may not have represented tablestock (20%) and seed (20%) potato production (Corey, 2001). A two-year rotation of potatoes and barley was typical in Aroostook County. Coupled potato farms grew more potatoes and less barley than conventional farms with similar acreage since dairy farm alfalfa acreage increased land available for a one-to-one rotation with potatoes. Potato farms used an average contract price for processing potatoes of $5.81/cwt (Table 4.3). This processing potato price was a contract average for both french fries (McCain, 2000) and Frito Lay chips and was share-weighted by volume of processing potato shipments in 1999 (USDA, NASS-PS, 2000).

Potato farms assumed no irrigation since only 9.25% of harvested cropland acres in Aroostook County were irrigated according to the 1997 Census of Agriculture (MAWMAC, March 2003). Dry land potato farms were thought to best represent the industry. Non-irrigated marketable potato yields were assumed to be 282.5 cwt/acre, which was a share-weighted average yield[14] for potatoes used to produce french fries and chips. This was higher than the 30-year historical average of 260 cwt/acre for Maine (USDA, NASS, 2004a) and the 240 cwt/acre marketable yield for central Maine.

Crop management practices were similar to practices for central Maine (Table 7.2) with two herbicide and two insecticide applications for potatoes. Average fungicide applications were assumed to increase in Aroostook County (13) compared to central

[13] Processing potatoes were primarily marketed as McCains (45%) frozen french fries and Frito Lay (15%) potato chips (Corey, 2001).
[14] Typical Aroostook County potato yields for french fries and potato chips were 290 and 260 cwt/acre respectively (Corey, 2001).

Maine (8). Like central Maine, half of potato acreage was treated with sprout inhibitor and potatoes were top killed twice with herbicides. Crops required typical amounts of lime. A baseline level of 1150 lb/acre of 14-14-14 was applied at-plant (Table 7.3).

Manure was not applied to potatoes and barley. For both coupled potato and dairy farms, manure was only applied and incorporated prior to planting alfalfa during the establishment year. Manure was applied to hay/haylage during mid-summer. Like central Maine, no manure-nutrient credit for potatoes was assumed to be taken by short-term integrators. For long-term coupled potato farms, starter fertilizer on potatoes was reduced to 450 lb/acre (Table 7.3), to match the same nitrogen application used by cooperating coupled farmers in central Maine (Table 4.6). This was roughly a 61% reduction in nitrogen, phosphorus, and potassium compared to conventional.

Dairy Farms

Representative budgets were built off of central Maine dairy budgets with appropriate changes such as including alfalfa as a forage crop instead of silage corn. Alfalfa and forage grass acreages were the same as silage corn and forage grass in central Maine. It was assumed Aroostook County dairy farms met the same requirements for dry matter, total digestible nutrients, and crude protein as dairy farms in central Maine by using more corn meal in the ration. Like central Maine, a milk price of $15.16/cwt (Appendices C) was used for dairy budgets. The cost of milk hauling for Aroostook County was assumed to be $1.00/cwt based on data from a cooperating dairy producer in southern Aroostook. Hauling costs per cwt for central Maine dairy farms were $0.62 for small and $0.50 for ML. Like budgets for central Maine, returns to family labor were captured in net farm income and only the cost of hired labor was itemized. Dairy farms stored and spread manure and manure storage, type, bedding, and spreading equipment were assumed to be the same as central Maine.

Typical crop management for cooperating producers growing alfalfa involved one herbicide application during the establishment year. No herbicides were applied to alfalfa following establishment. Alfalfa required no fungicide applications and typically no insecticides. Prices for alfalfa haylage obtained from cooperating producers was variable, so a price of $50/ton from the Penn State Agronomy Guide was used (PSU, 2004). Hay and haylage received no pesticides and both were cut twice a season. Alfalfa, hay, and haylage acreages were limed. Crop management of dry hay and haylage was assumed identical to central Maine (Tables 4.4 and 7.2).

Manure was spread and incorporated prior to planting alfalfa. Alfalfa was fertilized prior to planting with potassium and did not receive any chemical fertilizer or manure in subsequent years. Small dairy farm budgets assumed alfalfa was baled as wet, plastic-wrapped bales, while ML budgets assumed both cuts were packed in horizontal silos as alfalfa haylage. Since alfalfa received less manure compared to silage corn in central Maine, more manure and less fertilizer was applied to hay and haylage (Tables 4.6 and 7.3).

Representative Budget Results

Coupled potato and barley enterprise budgets (Tables 7.7, 7.9, 7.11, and 7.13) and coupled potato and dairy whole-farm budgets in Appendices B-3, B-4, C-3, and C-4 represented integration lasting more than ten years (long term) where fertilizer use was reduced. Budgets for short-term and long-term integrated dairy farms were identical since alfalfa and hay/haylage fertilization did not change over time. Although budgets were not shown, short-term coupled potato farms took the same manure-nutrient credits for potatoes and barley as conventional. Profitability was compared for increased potato yields from integration. Coupled systems were also compared to conventional systems.

Potato Farms

Whole-farm (Appendices B-3 and B-4) and enterprise budgets for potatoes (Tables 7.6 to 7.9) and barley (Tables 7.10 to 7.13) were compared for Aroostook County small and medium-large conventional and coupled potato farms. Profitability measures were calculated per acre of total potato and barley cropland (both owned and rented). Profitability comparisons were summarized for whole-farm (Table 7.4) and enterprise (Table 7.5) budgets.

Profitability improved with coupling length and crop diversity. Rotation with established alfalfa expanded the land base available to the potato farm. Assuming a two-year potato-barley rotation and no potato yield increase and manure-nutrient credits from

Table 7.4. Relative profitability of conventional and coupled potato farms for Aroostook County.

Profit Measure	Size	Conventional[b]	Short-Term L-Coupled[c]	Short-Term LF-Coupled[d]	Short-Term LF-Coupled Start Up[e]	Long-Term L-Coupled[c]	Long-Term LF-Coupled[d]	Long-Term LF-Coupled Start Up[e]
ROVC[a]	S	$209	$229	$303	$294	$277	$351	$342
	ML	$232	$266	$395	$382	$315	$445	$431
NFI[a]	S	-$30	$33	$54	$31	$81	$102	$79
	ML	$33	$98	$187	$152	$147	$236	$201

[a] Return over variable costs (ROVC) and net farm income (NFI) in $/acre of potatoes and barley. For LF-coupled, acres used for calculating returns per acre did not include forage.
[b] Small (S) conventional farms grew 160 acres of potatoes and 160 acres of barley for a total of 320 owned and rented crop acres. Medium-large (ML) crop acreages were doubled.
[c] Small L-coupled raised 172 acres of potatoes and 148 acres of barley, while ML grew 360 acres of potatoes and 280 acres of barley. Total crop acreages were the same as conventional farms.
[d] LF-coupled crop acreages used to calculate returns per acre were the same as L-coupled. Additional crop acreages raised were alfalfa (98) and hay (73) for small and alfalfa (320) and haylage (200) for ML.
[e] LF-coupled Start Up used owned and rented land for dairy forage while LF-coupled used land exchanged with the LF-coupled dairy farm. Owned and rented forage acreage for S and ML increased by 171 and 520 acres, respectively.

Table 7.5. Aroostook County crop enterprise budget summary for conventional and coupled potato farms.

Potato Size	Coup. Hist.[a]	Farm Type	Potato[b] Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI	Rotation[bc] Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI
S	None	Conv.	160	$1,641	$1,193	$388	$448	$60	160	$106	$136	$90	-$30	-$120
	ST	L-Coup.	172	$1,641	$1,193	$367	$448	$81	148	$106	$136	$90	-$30	-$120
		LF-Coup.	172	$1,641	$1,193	$309	$448	$139	148	$106	$131	$65	-$25	-$90
									98	$313	$166	$111	$147	$36
									73	$226	$99	$83	$127	$44
		LF-Coup.	172	$1,641	$1,193	$309	$448	$139	148	$106	$131	$65	-$25	-$90
		Start Up							98	$313	$183	$138	$130	-$8
									73	$226	$116	$109	$110	$1
	LT	L-Coup.	172	$1,641	$1,120	$367	$521	$154	148	$106	$117	$90	-$11	-$101
		LF-Coup.	172	$1,641	$1,120	$309	$521	$212	148	$106	$113	$65	-$7	-$72
									98	$313	$166	$111	$147	$36
									73	$226	$99	$83	$127	$44
		LF-Coup.	172	$1,641	$1,120	$309	$521	$212	148	$106	$113	$65	-$7	-$72
		Start Up							98	$313	$183	$138	$130	-$8
									73	$226	$116	$109	$110	$1
ML	None	Conv.	320	$1,641	$1,153	$329	$488	$159	320	$106	$130	$69	-$24	-$93
	ST	L-Coup.	360	$1,641	$1,153	$300	$488	$188	280	$106	$130	$69	-$24	-$93
		LF-Coup.	360	$1,641	$1,153	$258	$488	$230	280	$106	$127	$52	-$21	-$73
									320	$313	$110	$48	$203	$155
									200	$195	$103	$54	$92	$38
		LF-Coup.	360	$1,641	$1,153	$258	$488	$230	280	$106	$127	$52	-$21	-$73
		Start Up							320	$313	$128	$74	$185	$111
									200	$195	$120	$80	$75	-$5
	LT	L-Coup.	360	$1,641	$1,079	$300	$562	$262	280	$106	$112	$69	-$6	-$75
		LF-Coup.	360	$1,641	$1,079	$258	$562	$304	280	$106	$109	$52	-$3	-$55
									320	$313	$110	$48	$203	$155
									200	$195	$103	$54	$92	$38
		LF-Coup.	360	$1,641	$1,079	$258	$562	$304	280	$106	$109	$52	-$3	-$55
		Start Up							320	$313	$128	$74	$185	$111
									200	$195	$120	$80	$75	-$5

[a] Short-term (ST) and long-term (LT) coupled.
[b] Revenue, costs, and returns in $/acre.
[c] Conventional and L-coupled potato rotation was barley. The order of budget summaries for LF-coupled potato rotation crops in this table is barley, alfalfa, and then dry hay (S) or haylage (ML).

coupling, net farm income increased by $63 to $65/acre in the short term (Table 7.4) from growing more potatoes and less barley with negative returns (Tables 7.10 to 7.13). LF-coupled Start Up farms were less profitable than regular LF-coupled due to additional land ownership and rental costs for forage production (Table 7.4).

Table 7.6. Aroostook County potato enterprise budget for a small conventional farm.[a]

	Total	Per Acre	Per Cwt
Number of Acres	160	-	-
Potato Yield (cwt)	45,200	283	-
Price ($/cwt)	$5.81	-	-
Annual Revenue	**$262,592**	**$1,641.20**	**$5.81**
Annual Operating Expenses			
Seed	$30,313	$189.46	$0.67
Fertilizer	$18,860	$117.88	$0.42
Lime	$1,600	$10.00	$0.04
Chemicals	$28,505	$178.16	$0.63
Labor	$36,688	$229.30	$0.81
Diesel Fuel and Oil	$12,058	$75.36	$0.27
Maintenance and Upkeep	$17,754	$110.96	$0.39
Supplies	$9,215	$57.59	$0.20
Insurance	$8,865	$55.40	$0.20
Miscellaneous			
Utilities	$6,101	$38.13	$0.13
Custom Hire	$0	$0	$0
Rent or Lease	$10,000	$62.50	$0.22
Freight and Trucking	$2,849	$17.81	$0.06
Storage and Warehousing	$1,879	$11.75	$0.04
Other Expenses	$1,130	$7.06	$0.03
Interest	$5,132	$32.07	$0.11
Total Operating Expenses	**$190,948**	**$1,193.43**	**$4.22**
Annual Ownership Expenses			
Depreciation and Interest	$58,378	$364.86	$1.29
Tax and Insurance	$3,630	$22.69	$0.08
Total Ownership Expenses	**$62,008**	**$387.55**	**$1.37**
Total Annual Cost	**$252,956**	**$1,580.98**	**$5.60**
Net Farm Income (NFI)	**$9,636**	**$60.22**	**$0.21**
Return over Variable Cost (ROVC)	**$71,643**	**$447.77**	**$1.59**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,580.98	$5.60
Short-run to Cover Operating Costs		$1,193.43	$4.22

[a] Numbers may not sum due to rounding.

Table 7.7. Aroostook County potato enterprise budget for a small long-term land-coupled farm.[a]

	Total	Per Acre	Per Cwt
Number of Acres	172	-	-
Potato Yield (cwt)	48,661	283	-
Price ($/cwt)	$5.81	-	-
Annual Revenue	**$282,697**	**$1,641.20**	**$5.81**
Annual Operating Expenses			
Seed	$32,634	$189.46	$0.67
Fertilizer	$7,945	$46.13	$0.16
Lime	$1,723	$10.00	$0.04
Chemicals	$30,688	$178.16	$0.63
Labor	$39,497	$229.30	$0.81
Diesel Fuel and Oil	$12,981	$75.36	$0.27
Maintenance and Upkeep	$19,113	$110.96	$0.39
Supplies	$9,920	$57.59	$0.20
Insurance	$9,543	$55.40	$0.20
Miscellaneous			
Utilities	$6,568	$38.13	$0.13
Custom Hire	$0	$0	$0
Rent or Lease	$10,766	$62.50	$0.22
Freight and Trucking	$3,067	$17.81	$0.06
Storage and Warehousing	$2,023	$11.75	$0.04
Other Expenses	$1,217	$7.06	$0.03
Interest	$5,183	$30.09	$0.11
Total Operating Expenses	**$192,868**	**$1,119.70**	**$3.96**
Annual Ownership Expenses			
Depreciation and Interest	$59,428	$345.01	$1.22
Tax and Insurance	$3,718	$21.58	$0.08
Total Ownership Expenses	**$63,146**	**$366.59**	**$1.30**
Total Annual Cost	**$256,014**	**$1,486.29**	**$5.26**
Net Farm Income (NFI)	**$26,683**	**$154.91**	**$0.55**
Return over Variable Cost (ROVC)	**$89,829**	**$521.50**	**$1.85**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,486.29	$5.26
Short-run to Cover Operating Costs		$1,119.70	$3.96

[a] Numbers may not sum due to rounding.

Table 7.8. Aroostook County potato enterprise budget for a medium-large conventional farm.[a]

	Total	Per Acre	Per Cwt
Number of Acres	320	-	-
Potato Yield (cwt)	90,400	283	-
Price ($/cwt)	$5.81	-	-
Annual Revenue	**$525,184**	**$1,641.20**	**$5.81**
Annual Operating Expenses			
Seed	$60,627	$189.46	$0.67
Fertilizer	$37,720	$117.88	$0.42
Lime	$3,200	$10.00	$0.04
Chemicals	$57,011	$178.16	$0.63
Labor	$64,925	$202.89	$0.72
Diesel Fuel and Oil	$21,878	$68.37	$0.24
Maintenance and Upkeep	$35,507	$110.96	$0.39
Supplies	$18,430	$57.59	$0.20
Insurance	$17,729	$55.40	$0.20
Miscellaneous			
Utilities	$12,202	$38.13	$0.13
Custom Hire	$0	$0	$0
Rent or Lease	$18,000	$56.25	$0.20
Freight and Trucking	$5,698	$17.81	$0.06
Storage and Warehousing	$3,759	$11.75	$0.04
Other Expenses	$2,260	$7.06	$0.03
Interest	$9,913	$30.98	$0.11
Total Operating Expenses	**$368,858**	**$1,152.68**	**$4.08**
Annual Ownership Expenses			
Depreciation and Interest	$99,174	$309.92	$1.10
Tax and Insurance	$6,214	$19.42	$0.07
Total Ownership Expenses	**$105,389**	**$329.34**	**$1.17**
Total Annual Cost	**$474,247**	**$1,482.02**	**$5.25**
Net Farm Income (NFI)	**$50,937**	**$159.18**	**$0.56**
Return over Variable Cost (ROVC)	**$156,326**	**$488.52**	**$1.73**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,482.02	$5.25
Short-run to Cover Operating Costs		$1,152.68	$4.08

[a] Numbers may not sum due to rounding.

Table 7.9. Aroostook County potato enterprise budget for a medium-large long-term land-coupled farm.[a]

	Total	Per Acre	Per Cwt
Number of Acres	360	-	-
Potato Yield (cwt)	101,700	283	-
Price ($/cwt)	$5.81	-	-
Annual Revenue	**$590,832**	**$1,641.20**	**$5.81**
Annual Operating Expenses			
Seed	$68,205	$189.46	$0.67
Fertilizer	$16,605	$46.13	$0.16
Lime	$3,600	$10.00	$0.04
Chemicals	$64,137	$178.16	$0.63
Labor	$73,040	$202.89	$0.72
Diesel Fuel and Oil	$24,613	$68.37	$0.24
Maintenance and Upkeep	$39,946	$110.96	$0.39
Supplies	$20,733	$57.59	$0.20
Insurance	$19,946	$55.40	$0.20
Miscellaneous			
Utilities	$13,727	$38.13	$0.13
Custom Hire	$0	$0	$0
Rent or Lease	$20,250	$56.25	$0.20
Freight and Trucking	$6,410	$17.81	$0.06
Storage and Warehousing	$4,229	$11.75	$0.04
Other Expenses	$2,543	$7.06	$0.03
Interest	$10,438	$29.00	$0.10
Total Operating Expenses	**$388,422**	**$1,078.95**	**$3.82**
Annual Ownership Expenses			
Depreciation and Interest	$101,675	$282.43	$1.00
Tax and Insurance	$6,435	$17.87	$0.06
Total Ownership Expenses	**$108,110**	**$300.30**	**$1.06**
Total Annual Cost	**$496,532**	**$1,379.25**	**$4.88**
Net Farm Income (NFI)	**$94,300**	**$261.94**	**$0.93**
Return over Variable Cost (ROVC)	**$202,410**	**$562.25**	**$1.99**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,379.25	$4.88
Short-run to Cover Operating Costs		$1,078.95	$3.82

[a] Numbers may not sum due to rounding.

Table 7.10. Aroostook County barley enterprise budget for a small conventional farm.[a]

	Total	Per Acre	Per Bu
Number of Acres	160	-	-
Barley Yield (bu)	11,330	71	-
Price ($/bu)	$1.50	-	-
Annual Revenue	**$16,995**	**$106.22**	**$1.50**
Annual Operating Expenses			
Seed	$3,057	$19.10	$0.27
Fertilizer	$3,545	$22.16	$0.31
Lime	$1,941	$12.13	$0.17
Chemicals	$800	$5.00	$0.07
Labor	$3,042	$19.01	$0.27
Diesel Fuel and Oil	$1,675	$10.47	$0.15
Maintenance and Upkeep	$2,129	$13.31	$0.19
Supplies	$1,600	$10.00	$0.14
Insurance	$53	$0.33	$0.01
Miscellaneous			
Utilities	$160	$1.00	$0.01
Rent or Lease	$2,000	$12.50	$0.18
Freight and Trucking	$354	$2.21	$0.03
Other Expenses	$800	$5.00	$0.07
Interest	$584	$3.65	$0.05
Total Operating Expenses	**$21,741**	**$135.88**	**$1.92**
Annual Ownership Expenses			
Depreciation and Interest	$13,344	$83.40	$1.18
Tax and Insurance	$1,073	$6.70	$0.09
Total Ownership Expenses	**$14,417**	**$90.10**	**$1.27**
Total Annual Cost	**$36,157**	**$225.98**	**$3.19**
Net Farm Income (NFI)	**-$19,162**	**-$119.76**	**-$1.69**
Return over Variable Cost (ROVC)	**-$4,745**	**-$29.66**	**-$0.42**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$225.98	$3.19
Short-run to Cover Operating Costs		$135.88	$1.92

[a] Numbers may not sum due to rounding.

Table 7.11. Aroostook County barley enterprise budget for a small long-term land-coupled farm.[a]

	Total	Per Acre	Per Bu
Number of Acres	148	-	-
Barley Yield (bu)	10,463	71	-
Price ($/bu)	$1.50	-	-
Annual Revenue	**$15,694**	**$106.22**	**$1.50**
Annual Operating Expenses			
Seed	$2,823	$19.10	$0.27
Fertilizer	$714	$4.83	$0.07
Lime	$1,792	$12.13	$0.17
Chemicals	$739	$5.00	$0.07
Labor	$2,764	$18.71	$0.26
Diesel Fuel and Oil	$1,539	$10.41	$0.15
Maintenance and Upkeep	$1,955	$13.23	$0.19
Supplies	$1,478	$10.00	$0.14
Insurance	$49	$0.33	$0.01
Miscellaneous			
Utilities	$148	$1.00	$0.01
Rent or Lease	$1,847	$12.50	$0.18
Freight and Trucking	$327	$2.21	$0.03
Other Expenses	$739	$5.00	$0.07
Interest	$467	$3.16	$0.04
Total Operating Expenses	**$17,378**	**$117.62**	**$1.66**
Annual Ownership Expenses			
Depreciation and Interest	$12,293	$83.20	$1.17
Tax and Insurance	$985	$6.67	$0.09
Total Ownership Expenses	**$13,278**	**$89.87**	**$1.27**
Total Annual Cost	**$30,657**	**$207.49**	**$2.93**
Net Farm Income (NFI)	**-$14,963**	**-$101.27**	**-$1.43**
Return over Variable Cost (ROVC)	**-$1,684**	**-$11.40**	**-$0.16**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$207.49	$2.93
Short-run to Cover Operating Costs		$117.62	$1.66

[a] Numbers may not sum due to rounding.

Table 7.12. Aroostook County barley enterprise budget for a medium-large conventional farm.[a]

	Total	Per Acre	Per Bu
Number of Acres	320	-	-
Barley Yield (bu)	22,660	71	-
Price ($/bu)	$1.50	-	-
Annual Revenue	**$33,991**	**$106.22**	**$1.50**
Annual Operating Expenses			
Seed	$6,113	$19.10	$0.27
Fertilizer	$7,090	$22.16	$0.31
Lime	$3,882	$12.13	$0.17
Chemicals	$1,600	$5.00	$0.07
Labor	$5,408	$16.90	$0.24
Diesel Fuel and Oil	$3,350	$10.47	$0.15
Maintenance and Upkeep	$3,186	$9.96	$0.14
Supplies	$3,200	$10.00	$0.14
Insurance	$107	$0.33	$0.01
Miscellaneous			
Utilities	$320	$1.00	$0.01
Rent or Lease	$4,000	$12.50	$0.18
Freight and Trucking	$707	$2.21	$0.03
Other Expenses	$1,600	$5.00	$0.07
Interest	$1,120	$3.50	$0.05
Total Operating Expenses	**$41,683**	**$130.26**	**$1.84**
Annual Ownership Expenses			
Depreciation and Interest	$20,254	$63.30	$0.89
Tax and Insurance	$1,715	$5.36	$0.08
Total Ownership Expenses	**$21,970**	**$68.65**	**$0.97**
Total Annual Cost	**$63,653**	**$198.92**	**$2.81**
Net Farm Income (NFI)	**-$29,662**	**-$92.69**	**-$1.31**
Return over Variable Cost (ROVC)	**-$7,693**	**-$24.04**	**-$0.34**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$198.92	$2.81
Short-run to Cover Operating Costs		$130.26	$1.84

[a] Numbers may not sum due to rounding.

Table 7.13. Aroostook County barley enterprise budget for a medium-large long-term land-coupled farm.[a]

	Total	Per Acre	Per Bu
Number of Acres	280	-	-
Barley Yield (bu)	19,828	71	-
Price ($/bu)	$1.50	-	-
Annual Revenue	**$29,742**	**$106.22**	**$1.50**
Annual Operating Expenses			
Seed	$5,349	$19.10	$0.27
Fertilizer	$1,352	$4.83	$0.07
Lime	$3,396	$12.13	$0.17
Chemicals	$1,400	$5.00	$0.07
Labor	$4,646	$16.59	$0.23
Diesel Fuel and Oil	$2,916	$10.41	$0.15
Maintenance and Upkeep	$2,774	$9.91	$0.14
Supplies	$2,800	$10.00	$0.14
Insurance	$93	$0.33	$0.01
Miscellaneous			
Utilities	$280	$1.00	$0.01
Rent or Lease	$3,500	$12.50	$0.18
Freight and Trucking	$619	$2.21	$0.03
Other Expenses	$1,400	$5.00	$0.07
Interest	$843	$3.01	$0.04
Total Operating Expenses	**$31,369**	**$112.03**	**$1.58**
Annual Ownership Expenses			
Depreciation and Interest	$17,754	$63.41	$0.90
Tax and Insurance	$1,495	$5.34	$0.08
Total Ownership Expenses	**$19,248**	**$68.74**	**$0.97**
Total Annual Cost	**$50,617**	**$180.78**	**$2.55**
Net Farm Income (NFI)	**-$20,876**	**-$74.56**	**-$1.05**
Return over Variable Cost (ROVC)	**-$1,627**	**-$5.81**	**-$0.08**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$180.78	$2.55
Short-run to Cover Operating Costs		$112.03	$1.58

[a] Numbers may not sum due to rounding.

Potato enterprises were identical for conventional and short-term coupling. Like grain corn in central Maine, barley was less profitable than dairy forage such as alfalfa, silage corn, and hay/haylage (Tables 5.2 and 7.5). Conventional barley was not integrated and received no manure applications. Coupled barley also did not receive manure but manure-nutrient credits were taken in the long term. Thus coupled barley was more profitable than conventional from lower fertilizer costs from these manure-nutrient credits (Tables 7.10 to 7.13).

Profitability also improved compared to conventional even if coupled potato acreage was not increased due to dairy rather than potato farm expansion. If L-coupled potato farms grew nothing but potatoes under a scenario where the dairy farm's establishment alfalfa acreage was large enough to displace all barley, NFI per acre was $8 for small and $65 for ML farms (data not presented) compared to conventional small (-$30) and ML ($33) farms (Table 7.4). Start Up LF-coupled potato farms were less profitable due to higher land ownership and rental costs for forage. Like grain corn, barley was not a profitable rotation crop. LF-coupled potato farms had higher profitability per acre (of potatoes and barley) than L-coupled farms (Table 7.4) due to the added revenue from growing dairy forage combined with equipment use efficiencies.

Long-term coupling improved NFI even further by $48 to $49/acre compared to short-term coupling (Table 7.4). As in the short term, potato enterprise budget NFI per acre was greater for long-term coupled farms because of reduced fixed costs per acre from more potatoes grown. Profitability was also higher for long-term coupled than for conventional due to increased manure-nutrient credits resulting in lower purchased fertilizer costs for potatoes (Tables 7.6 to 7.9) and barley (Tables 7.10 to 7.13).

Manure-nutrient credits for Aroostook County potatoes were assumed to be similar to those taken in central Maine. Short-term coupled farms took no manure-nutrient credit for potatoes and had the same enterprise fertilizer cost of $118/acre as conventional farms (Tables 7.6 and 7.8). Potato fertilizer costs were about 61% less for long-term coupled farms, at $46/acre (Tables 7.7 and 7.9). Similarly, fertilizer costs for barley were less on long-term coupled farms, $5/acre, than for barley grown on conventional farms, $22/acre (Tables 7.10 to 7.13).

Representative budget comparisons assumed conventional and coupled potato yields were the same for three reasons. First, cooperating integrated potato farms in Aroostook were limited. Second, the Maine Potato Ecosystem Project applied manure amendments during both the potato and rotation years. This analysis assumed manure application only during the alfalfa establishment year, which comprised only 25% of the rotational land base. Third, while potato yields may likely increase from integration because of increased soil quality, especially in dry years (Gallandt et al., 1998), there was some evidence that increased disease pressure could suppress yields (Porter, 2003).

Like central Maine, NFI was estimated for Aroostook County coupled potato farms at various yields ranging between -25% and +25% from the conventional base yield of about 283 cwt/acre (Table 7.14). This conventional base yield had NFI/acre of -$30 for small farms and $33 for ML farms. Yield differences were assumed to be caused by soil quality changes from integration and not from additional fertilizer. Harvest labor, truck fuel, and storage costs were adjusted in proportion to yield changes. The potato contract price has not changed recently so this was kept the same.

Table 7.14. Net farm income for Aroostook County whole-farm budgets of coupled potato farms with yield response for potatoes ranging from -25% to 25%.

Coupled[a] Marketable ----Yield ----		NFI ($/acre)[b]											
		Short-Term Integration						Long-Term Integration					
		S			ML			S			ML		
% Increase	cwt/ acre	L	LF	LFSU	L	LF	LFSU	L	LF	LF SU	L	LF	LFSU
-25%	212	-$185	-$164	-$187	-$130	-$41	-$76	-$137	-$116	-$140	-$81	$8	-$27
-20%	226	-$141	-$121	-$144	-$85	$4	-$31	-$94	-$73	-$96	-$35	**$54**	$18
-15%	240	-$98	-$77	-$100	-$39	**$50**	$15	-$50	**-$29**	-$52	$10	**$99**	**$64**
-10%	254	-$54	-$33	-$56	$7	**$96**	**$60**	**-$6**	**$15**	**-$9**	**$56**	**$145**	**$110**
-5%	268	**-$10**	**$10**	**-$13**	**$52**	**$141**	**$106**	**$38**	**$58**	**$35**	**$102**	**$191**	**$155**
0%	283	**$33**	**$54**	**$31**	**$98**	**$187**	**$152**	**$81**	**$102**	**$79**	**$147**	**$236**	**$201**
5%	297	**$77**	**$98**	**$75**	**$144**	**$233**	**$197**	**$125**	**$146**	**$122**	**$193**	**$282**	**$247**
10%	311	**$121**	**$141**	**$118**	**$189**	**$278**	**$243**	**$169**	**$189**	**$166**	**$238**	**$327**	**$292**
15%	325	**$164**	**$185**	**$162**	**$235**	**$324**	**$289**	**$212**	**$233**	**$210**	**$284**	**$373**	**$338**
20%	339	**$208**	**$229**	**$206**	**$280**	**$369**	**$334**	**$256**	**$277**	**$253**	**$330**	**$419**	**$383**
25%	353	**$252**	**$272**	**$249**	**$326**	**$415**	**$380**	**$300**	**$320**	**$297**	**$375**	**$464**	**$429**

[a] Coupled NFI per acre in bold face was greater than or equal to conventional NFI per acre of -$30 for small (S) and $33 for medium-large (ML).
[b] Acreage in denominator just potatoes and barley. For both LF-coupled, acreage used to calculate returns did not include forage.

NFI increased about $152 to $249 per acre over conventional for long-term integrators assuming potato yields increased by 5% (Table 7.14). Long-term integrators were no worse off than conventional with yield losses ranging from 5% to 20%. The bold face profits in Table 7.14 show where NFI for coupled potato farms was superior to conventional and demonstrated that long-term integrators can withstand yield losses of up to 20% and be as profitable as conventional farms.

Dairy Farms

Economic benefits were limited for L-coupled dairy farms without expansion. In both the short term and long term, L-coupled profitability was identical to conventional (Table 7.15; Appendices C-3 and C-4). LF-coupled dairy farms were less profitable than L-coupled and conventional due to stranded equipment costs. Start Up dairy farms had

Table 7.15. Relative profitability of Aroostook County conventional and coupled dairy farms.

Profit Measures	Size	Conventional[b]	-------- Short-Term & Long-Term -------- L-Coupled[c]	LF-Coupled[d]	LF-Coupled Start Up[e]
ROVC[a]	S	$228	$228	$113	$159
	ML	$463	$463	$323	$353
NFI[a]	S	-$167	-$167	-$238	-$150
	ML	$135	$135	$25	$84

[a] ROVC and NFI in $/acre of alfalfa and hay/haylage. Crop acreage did not include pasture.
[b] Small (S) conventional dairy farms grew 98 acres of alfalfa and 73 acres of hay for a total of 171 crop acres. Medium-large (ML) conventional dairy farms grew 320 acres of alfalfa and 200 acres of haylage for a total of 520 crop acres. The 29 and 43 acres of pasture for S and ML dairy farms, respectively, were not included as crop acres.
[c] L-coupled farms raised the same crop acreages as conventional farms.
[d] LF-coupled dairy farms did not raise forage since LF-coupled potato farms grew this. However, returns were calculated using the same crop acres as conventional and L-coupled farms.
[e] LF-coupled Start Up dairy farms also did not raise forage. Even though no crop acres were owned, returns were calculated using the same cropland as conventional and other coupled farms.

Table 7.16. Aroostook County crop enterprise budget summary for conventional and coupled dairy farms.

			Alfalfa[b]						Hay/Haylage[bc]					
Dairy Size	Coup. History[a]	Farm Type	Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI	Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI
S	None	Conv.	98	$312	$188	$169	$124	-$45	73	$226	$128	$210	$98	-$112
	ST	L-Coup.	98	$312	$188	$169	$124	-$45	73	$226	$128	$210	$98	-$112
		LF-Coup.	0	-	-	-	-	-	0	-	-	-	-	-
		LF-Cp.SU	0	-	-	-	-	-	0	-	-	-	-	-
	LT	L-Coup.	98	$312	$188	$169	$124	-$45	73	$226	$128	$210	$98	-$112
		LF-Coup.	0	-	-	-	-	-	0	-	-	-	-	-
		LF-Cp.SU	0	-	-	-	-	-	0	-	-	-	-	-
ML	None	Conv.	320	$312	$134	$136	$178	$42	200	$195	$124	$113	$71	-$42
	ST	L-Coup.	320	$312	$134	$136	$178	$42	200	$195	$124	$113	$71	-$42
		LF-Coup.	0	-	-	-	-	-	0	-	-	-	-	-
		LF-Cp.SU	0	-	-	-	-	-	0	-	-	-	-	-
	LT	L-Coup.	320	$312	$134	$136	$178	$42	200	$195	$124	$113	$71	-$42
		LF-Coup.	0	-	-	-	-	-	0	-	-	-	-	-
		LF-Cp.SU	0	-	-	-	-	-	0	-	-	-	-	-

[a] Short-term (ST) and long-term (LT) coupled.
[b] Revenue, costs, and returns in $/acre.
[c] The small (S) farm grew dry hay, while the medium-large (ML) farm raised primarily haylage.

Table 7.17. Aroostook County alfalfa enterprise budget for a small conventional and land-coupled dairy farm.[a]

	Total	Per Acre	Per Ton
Number of Acres	98	-	-
Alfalfa Yield (ton)	613	6.25	-
Price ($/ton)	$50	-	-
Annual Revenue	**$30,625**	**$312.50**	**$50.00**
Annual Operating Expenses			
Seed	$1,531	$15.63	$2.50
Fertilizer	$770	$7.86	$1.26
Lime	$980	$10.00	$1.60
Chemicals	$598	$6.10	$0.98
Labor	$3,530	$36.02	$5.76
Diesel Fuel and Oil	$988	$10.08	$1.61
Maintenance and Upkeep	$2,528	$25.80	$4.13
Supplies	$980	$10.00	$1.60
Insurance	$32	$0.33	$0.05
Miscellaneous			
Rent or Lease	$1,225	$12.50	$2.00
Storage and Warehousing	$4,288	$43.75	$7.00
Other Expenses	$490	$5.00	$0.80
Interest	$495	$5.06	$0.81
Total Operating Expenses	**$18,436**	**$188.12**	**$30.10**
Annual Ownership Expenses			
Depreciation and Interest	$15,510	$158.27	$25.32
Tax and Insurance	$1,089	$11.11	$1.78
Total Ownership Expenses	**$16,599**	**$169.38**	**$27.10**
Total Annual Cost	**$35,035**	**$357.50**	**$57.20**
Net Farm Income (NFI)	**-$4,410**	**-$45.00**	**-$7.20**
Return over Variable Cost (ROVC)	**$12,189**	**$124.38**	**$19.90**
Performance Measures			
Breakeven Revenue		$/acre	$/ton
Long-run to Cover All Costs		$357.50	$57.20
Short-run to Cover Operating Costs		$188.12	$30.10

[a] Numbers may not sum due to rounding. Alfalfa enterprise budget was a weighted average of one establishment year and three established years.

Table 7.18. Aroostook County alfalfa enterprise budget for a medium-large conventional and land-coupled dairy farm.[a]

	Total	Per Acre	Per Ton
Number of Acres	320	-	-
Alfalfa Yield (ton)	2,000	6.25	-
Price ($/ton)	$50	-	-
Annual Revenue	**$100,000**	**$312.50**	**$50.00**
Annual Operating Expenses			
Seed	$5,000	$15.63	$2.50
Fertilizer	$2,515	$7.86	$1.26
Lime	$3,200	$10.00	$1.60
Chemicals	$1,951	$6.10	$0.98
Labor	$9,399	$29.37	$4.70
Diesel Fuel and Oil	$4,504	$14.07	$2.25
Maintenance and Upkeep	$5,845	$18.27	$2.92
Supplies	$3,200	$10.00	$1.60
Insurance	$106	$0.33	$0.05
Miscellaneous			
Rent or Lease	$4,000	$12.50	$2.00
Storage and Warehousing	$640	$2.00	$0.32
Other Expenses	$1,600	$5.00	$0.80
Interest	$1,159	$3.62	$0.58
Total Operating Expenses	**$43,119**	**$134.75**	**$21.56**
Annual Ownership Expenses			
Depreciation and Interest	$40,634	$126.98	$20.32
Tax and Insurance	$2,854	$8.92	$1.43
Total Ownership Expenses	**$43,488**	**$135.90**	**$21.74**
Total Annual Cost	**$86,607**	**$270.65**	**$43.30**
Net Farm Income (NFI)	**$13,393**	**$41.85**	**$6.70**
Return over Variable Cost (ROVC)	**$56,881**	**$177.75**	**$28.44**
Performance Measures			
Breakeven Revenue		$/acre	$/ton
Long-run to Cover All Costs		$270.65	$43.30
Short-run to Cover Operating Costs		$134.75	$21.56

[a] Numbers may not sum due to rounding. Alfalfa enterprise budget was a weighted average of one establishment year and three established years.

more favorable profitability than regular LF-coupled since these newly established operations did not have to pay ownership and rental costs for forage cropland. Returns per acre for Start Up were calculated with the same cropland as other dairy farms.

Alfalfa and hay/haylage enterprise budgets were identical for conventional and L-coupled (Table 7.16). Potassium fertilizer costs for alfalfa was about $8/acre (Tables 7.17 to 7.18). No fertilizer was applied to hay for small farms since manure applications met crop nutrient requirements. Urea top dress for ML farms was about $13/acre (data not presented). No manure-nutrient credits were taken for forage in the long term. Thus fertilizer applications and costs for alfalfa and hay/haylage were the same.

Although this analysis did not show greater profitability for coupled dairy farms, profitability may improve if forage prices paid to the potato farm were lower. Initial representative budget analysis assumed that the potato farm expanded, while the dairy farm did not. Profitability may increase for the coupled dairy farm if it expanded alone or in conjunction with the potato farm. Dairy farm profitability may also improve when management can focus entirely on livestock and not crop production.

Increased profitability of a hypothetical dairy farm expansion was similarly demonstrated for Aroostook County as it was for central Maine by expansion of small conventional to ML LF-coupled. In this demonstration, alfalfa acreage grown by the small coupled potato farm increased from 98 to 258 acres to use all available rotational acreage. This assumed the expanding dairy farm bought 62 acres of alfalfa and 127 acres of haylage for increased feed needs in addition to the increased alfalfa and the same amount of forage grass managed by the potato farm. NFI for the expanding dairy farm increased by $192/acre compared to both conventional and L-coupled (Table 7.15).

The LF-coupled Start Up dairy farm demonstrated the potential for increased profitability of operations recently started in Aroostook County that did not need land base for forage production. NFI was $59 to $88/acre greater compared to regular LF-coupled due to savings from no ownership and rental costs paid for cropland (Table 7.15). There were no LF-coupled dairy farms in Aroostook County. Although LF-coupled Start Up may be more profitable than regular LF-coupled from reduced land requirements, Start Up dairies may have difficulties purchasing or renting cropland if they have to go back to growing their own forage.

Potato and Dairy Systems

Conventional and coupled budgets were compared as agricultural systems consisting of both potato and dairy farms. Similar to central Maine analysis, acreages, revenues, and costs from conventional and coupled representative potato and dairy

Table 7.19. Aroostook County whole-farm budget summary for conventional and coupled systems.

			Crop Acres					System Budget[a]				
System Size	Coup. History	Farm Type	Potato	Bar-ley	Alfalfa	Hay/ Haylage	Total	Rev.	Oper. Costs	Own. Costs	ROVC	NFI
S	None	Conv.	160	160	98	73	491	$909	$685	$309	$224	-$85
	ST	L-Coup.	172	148	98	73	491	$947	$702	$281	$245	-$36
		LF-Coup.	172	148	98	73	491	$1,043	$790	$300	$253	-$47
		LF-Cp.SU	172	148	98	73	491	$1,043	$784	$291	$259	-$32
	LT	L-Coup.	172	148	98	73	491	$947	$671	$281	$276	-$5
		LF-Coup.	172	148	98	73	491	$1,043	$759	$300	$284	-$16
		LF-Cp.SU	172	148	98	73	491	$1,043	$753	$291	$290	-$1
ML	None	Conv.	320	320	320	200	1160	$1,045	$693	$273	$352	$79
	ST	L-Coup.	360	280	320	200	1160	$1,098	$728	$256	$370	$114
		LF-Coup.	360	280	320	200	1160	$1,218	$839	$265	$379	$114
		LF-Cp.SU	360	280	320	200	1160	$1,218	$837	$260	$381	$121
	LT	L-Coup.	360	280	320	200	1160	$1,098	$701	$256	$397	$141
		LF-Coup.	360	280	320	200	1160	$1,218	$812	$265	$406	$141
		LF-Cp.SU	360	280	320	200	1160	$1,218	$810	$260	$408	$148

[a] Revenue, costs, and returns in $/acre of total potato and dairy farm cropland, not including pasture.

budgets were aggregated to the farm-level. To compare to integrated systems, conventional potato and dairy farms were artificially combined (Table 7.19).

In the short term, profitability measures were greater for coupled compared to conventional farm systems (Table 7.19). As in central Maine, this was mainly attributed to greater profitability of coupled potato farms from increased potato acreage and decreased barley acreage. In the long term, coupled profitability was also greater than conventional from less fertilizer used for potatoes and barley in coupled systems.

Differences in ownership and operating costs for L-coupled and LF-coupled cases were from different machinery, equipment storages, and maintenance costs for potato and dairy farms. Thus profitability for these coupled systems were similar, though not necessarily identical for farms with the same size and coupling history. Profitability for Start Up coupled systems was greater due to less land (pasture, woodland, and other) required compared to conventional and other coupled systems.

Like central Maine, profitability of Aroostook County coupled systems where the potato farm expanded and the dairy farm remained the same size were similarly itemized into four separate components. On average, NFI increased $42/acre from expansion of

Table 7.20. System profitability increases of component parts of coupling in Aroostook County (NFI in $/acre of potato and dairy farm cropland).

Coupling Components	--------- Farm Size --------- Small	Medium-Large	Average	--- Percent of Total --- w/o Yield Increase	w/ Yield Increase
Crop acreage changes	$49	$35	$42	48%	27%
Manure nutrient credits	$31	$27	$29	33%	19%
Coupling arrangement[a]	$11	$0	$6	6%	4%
Reduced land base for Start Up[b]	$15	$7	$11	13%	7%
Potato yield increase	$70	$61	$65		43%

[a] Shifting from land to land/feed coupled.
[b] Shifting to land/feed coupled Start Up.

potato acreage during short-term coupling. In the long term if manure nutrient credits were taken, average gains were $29/acre. System gains were minimal for shifts from land to land/feed coupled ($6/acre) and to land/feed coupled Start Up ($11/acre). If potato yields increased 5%, system NFI improved by $65/acre (Table 7.20).

Performance Indicator Results

Economic and sustainability indicators were calculated for Aroostook County conventional and coupled farms as they were for central Maine. NFI, ROVC, and FVA were calculated in dollars per acre of crops raised by conventional and L-coupled farms. Like farm budgets, indicators varied by coupling type (land, land/feed, and land/feed Start Up), duration (short-term and long-term), and size (small and medium-large).

Potato Farm Indicators

Indicators for coupled potato farms were generally favored over conventional (Table 7.21). Indicators were ranked for both short-term (Appendix F-3) and long-term (Appendix F-4) coupled farms. Performance indicators were compared to ranges of expected values that were the same as those used for central Maine.

Economic Indicators of profitability (NFI, ROVC, and POR) were greater for coupled potato farms for all coupled cases and both size classes in the short term since more potatoes were grown. For LF-coupled potato farms, per acre fixed costs were lower from equipment used for potatoes, barley, and forage. Profitability increased from the short term to the long term because of manure-nutrient credits taken for potatoes and barley. POR for LF-coupled was higher than for L-coupled from more profitable forage enterprises complementing potatoes. Potato farms selling forage to Start Up dairy farms had lower profitability indicators than regular LF-coupled due to increased land

Table 7.21. Aroostook County economic and sustainability indicators for coupled and conventional potato and dairy farms.

				--------- ECONOMIC[c] ---------					----- SUSTAINABILITY[d] -----				
Type	Coup.	Farm	Crop	--- Profitability ---			Efficiency						
& Size	Hist.[a]	Type	Acres[b]	NFI[e]	ROVC[e]	POR	ATR	OER	FVA[e]	FVA_p	NRG	SLF	FB[f]
Potato S	None	Conv.	320	-$30	$209	-0.034	0.296	0.517	$120	0.138	0.639	0.108	-
	ST	L-Coup.	320	$33	$229	0.036	0.381	0.557	$202	0.216	0.562	0.177	-
		LF-Coup.	320	$54	$303	0.050	0.355	0.503	$249	0.230	0.553	0.193	-
		LF-Cp.SU	491	$31	$294	0.029	0.331	0.500	$227	0.210	0.553	0.171	-
	LT	L-Coup.	320	$81	$277	0.087	0.381	0.505	$250	0.268	0.512	0.229	-
		LF-Coup.	320	$102	$351	0.094	0.355	0.458	$296	0.275	0.510	0.237	-
		LF-Cp.SU	491	$79	$342	0.073	0.331	0.455	$275	0.254	0.510	0.215	-
ML	None	Conv.	640	$33	$232	0.038	0.353	0.521	$178	0.204	0.573	0.164	-
	ST	L-Coup.	640	$98	$266	0.101	0.426	0.564	$255	0.263	0.517	0.226	-
		LF-Coup.	640	$187	$395	0.158	0.426	0.502	$375	0.316	0.486	0.282	-
		LF-Cp.SU	1160	$152	$382	0.128	0.380	0.498	$342	0.288	0.486	0.253	-
	LT	L-Coup.	640	$147	$315	0.152	0.426	0.513	$304	0.314	0.468	0.277	-
		LF-Coup.	640	$236	$445	0.199	0.426	0.461	$424	0.357	0.446	0.324	-
		LF-Cp.SU	1160	$201	$431	0.169	0.380	0.456	$391	0.330	0.446	0.294	-
Dairy S	None	Conv.	171	-$167	$228	-0.171	0.203	0.132	-$69	-0.071	0.566	-0.120	-0.149
	ST	L-Coup.	171	-$167	$228	-0.171	0.203	0.132	-$69	-0.071	0.566	-0.120	-0.149
	&LT	LF-Coup.	171	-$238	$113	-0.244	0.225	0.301	-$182	-0.187	0.464	-0.234	-0.432
		LF-Cp.SU	40	-$150	$159	-0.154	0.260	0.344	-$107	-0.110	0.464	-0.144	-0.432
ML	None	Conv.	520	$135	$463	0.107	0.319	0.225	$213	0.169	0.385	0.139	-0.182
	ST	L-Coup.	520	$135	$463	0.107	0.319	0.225	$213	0.169	0.385	0.139	-0.182
	&LT	LF-Coup.	520	$25	$323	0.020	0.344	0.364	$68	0.054	0.316	0.025	-0.395
		LF-Cp.SU	120	$84	$353	0.066	0.386	0.387	$118	0.094	0.316	0.072	-0.395

[a] Short-term (ST) and long-term (LT) coupled.
[b] Crop acres included potatoes and barley for potato farms and alfalfa and hay/haylage for dairy farms. Dairy farm crop acreage did not include pasture.
[c] Economic indicators were net farm income (NFI), return over variable costs (ROVC), profit over revenues (POR), asset turnover ratio (ATR), and operating expense ratio (OER).
[d] Sustainability indicators were farming value added (FVA), FVA as a proportion of producer's share (FVA_p), energy and machinery use (NRG), support for local families (SLF), and feed balance (FB).
[e] NFI, ROVC, and FVA were in $/acre of cropland for both potato and dairy farms. Crop acreage for LF-coupled potato farms did not include forage grown for sale to the dairy farm. Per acre returns and FVA for LF-coupled dairy farms used the same crop acreage as conventional and L-coupled.
[f] FB comparison not applicable for potato farms since no feed was purchased and FB values were +1.

ownership and rental costs. A typical POR was 0.10 with an expected range of -0.25 to 0.25. In this study, POR values for potato farms ranged between -0.034 and 0.199.

Asset turnover ratio (ATR) was greater for coupled than conventional since the potato farm produced more potatoes on more acres without having to purchase more land.

ATR was lower for LF-coupled than L-coupled due to the need for feed-crop equipment assets accompanied by a relatively modest increase in feed-crop revenues. Potato farms selling forage to Start Up dairy farms had lower ATR than regular LF-coupled due to decreased revenues from increased cropland ownership and rental costs. ATR ranged from 0.296 for smaller conventional farms to 0.426 for L-coupled and LF-coupled (Table 7.21). Expected ATR values ranged from 0.20 to 0.60.

The operating expense ratio (OER) was lower (preferred) for long-term coupled potato farms than for conventional due to less purchased fertilizers. However, short-term L-coupled had worse OER than conventional because potatoes made up a larger proportion of the crop mix. Potatoes had a higher (less preferred) OER since a higher percentage of this crop's costs constituted operating expenses relative to barley. LF-coupled farms had more favorable OER due to increased forage revenues, while OER for potato farms selling forage to Start Up dairy farms was even better due to higher forage cropland ownership costs. OER values ranged from 0.455 to 0.564, which was within an expected range of 0.20 to 0.80.

Sustainability Indicators such as FVA and FVA_p were more favorable for coupled than conventional for both short- and long-term integration because of greater farm profits and paid labor from growing more potatoes. FVA_p increased from L-coupled to LF-coupled due to higher labor costs per dollar of total revenue for more diversified crop enterprises. FVA_p decreased from LF-coupled farms to those coupled with Start Up dairy farms due to increased cropland ownership and rental costs. FVA measures were also greater for long-term than for short-term integration due to less purchased fertilizer. FVA_p was within an expected range of -0.20 to 0.50, ranging between 0.138 and 0.357.

NRG was lower (preferred) for coupled than for conventional. Long-term integrators had lower NRG than short-term ones since they used less purchased fertilizer. L-coupled had lower NRG than conventional from equipment efficiencies when raising more profitable potatoes. Both LF-coupled cases had lower NRG than L-coupled since the increase in NRG costs was proportionally less than the increase in total revenues due to equipment efficiencies. NRG values for potato farms ranged from 0.446 and 0.639, which was within the expected NRG range of 0.30 to 0.70.

SLF was higher for all coupled potato farms compared to conventional. SLF was greater in the long term since NFI was higher for long-term integrators. SLF was also greater for LF-coupled than L-coupled due to higher NFI and labor expenses for growing dairy forage. Potato farms raising forage for Start Up dairy farms had lower SLF compared to regular LF-coupled farms due to lower NFI. SLF was between 0.108 and 0.324, falling mostly within an expected range of -0.15 to 0.30. Livestock feed was not used so FB was not compared.

Dairy Farm Indicators

Like central Maine, dairy indicators were based on 2001 data (Table 7.21), except for ATR, which also used 2000 Farm Credit data (Stafford et al., 2001). Some indicators for small farms were negative from fluid milk prices below cost of production. Since no manure-nutrient credits were taken for forage, indicators for short- and long-term couplers were identical. Cropland used for calculating NFI, ROVC, and FVA per acre included conventional and L-coupled acreages for alfalfa and hay/haylage but not pasture. Indicators were ranked in Appendices F-3 and F-4.

Economic Indicators were the same or less favorable for coupled compared to conventional. In general, profitability indicators were the same for L-coupled compared to conventional since it was assumed that the potato farm expanded, not the dairy farm. LF-coupled had lower profitability indicators than L-coupled because production savings from not growing forage were less than the cost of purchasing forage from the coupled potato farm. This was due to stranded fixed costs from previously used forage crop equipment. Start Up dairy farms fared better from savings in cropland ownership and rental costs. POR values ranged from -0.244 and 0.107. POR was predominantly lower than typical (0.10) because fluid milk prices were below breakeven for small farms.

ATR values for L-coupled and conventional were the same since farm revenues and total assets were identical. LF-coupled had slightly higher ATR than conventional because less equipment was needed since forage was not grown. Start Up dairy farms had even higher ATR since less land was required for this type of operation. ATR for dairy farms were between 0.203 and 0.386, while a typical ATR value was 0.30.

OER for LF-coupled was higher (less favorable) than for conventional and L-coupled because of higher operating expenses from purchased feed costs exceeding forage production savings. Start Up dairy farms had even higher OER due to lower depreciation from less required land base. OER ranged from 0.132 to 0.387. OER was lower than typical (0.66) since family labor was not included as an operating expense.

Sustainability Indicators for farming value added (FVA and FVA_p) decreased from L-coupled to LF-coupled. LF-coupled dairy farms did not grow forage and required less labor. FVA measures were better for Start Up dairy farms compared to regular LF-coupled since costs returned to the input sector in the form of land ownership and rental costs were lower. FVA_p ranged from -0.187 to 0.169.

Both types of LF-coupled farms had lower (more favorable) NRG values because of lower machinery and energy costs required for growing forage. LF-coupled had lower SLF due to lower labor expenditures and lower NFI. Start Up dairy farms had higher SLF than regular LF-coupled due to greater NFI. NRG and SLF ranged from 0.316 to 0.566 and from -0.234 to 0.139, respectively.

FB for L-coupled and conventional was the same since crop sales and feeding assumptions were identical. Both types of LF-coupled farms had more negative (less preferred) FB because forage was purchased and was not raised on-farm. FB values ranged between -0.432 and -0.149.

System Indicators

Like the analysis for central Maine, indicators for conventional and integrated potato and dairy systems were calculated (Table 7.22). Conventional systems were based on separate potato and dairy whole-farm budgets that were combined. Like individual potato and dairy comparisons, indicators were calculated for small and ML, short- and long-term integration, and for three different coupled types. For the system analysis, crop acres grown were aggregated from potato and dairy cropland.

Economic Indicators were preferable for coupled compared to conventional systems and improved from short- to long-term integration with the exception of OER. L-coupled systems were more profitable than conventional because of greater farm profitability from growing more potatoes. LF-coupled profitability measures were slightly less than or equal to L-coupled due to additional equipment costs offsetting

Table 7.22. Aroostook County economic indicators for coupled and conventional potato and dairy systems.

				ECONOMIC[c]					SUSTAINABILITY[d]			
				Profitability			Efficiency					
System Size	Coup. Hist.[a]	Farm Type	Crop Acres[b]	NFI[e]	ROVC[e]	POR	ATR	OER	FVA[e]	FVA_p	NRG	SLF
S	None	Conv.	491	-\$85	\$224	-0.094	0.253	0.441	\$54	0.060	0.612	0.015
	ST	L-Coup.	491	-\$36	\$245	-0.039	0.290	0.470	\$107	0.113	0.564	0.071
		LF-Coup.	491	-\$47	\$253	-0.046	0.298	0.494	\$132	0.126	0.524	0.054
		LF-Cp.SU	491	-\$32	\$259	-0.031	0.304	0.495	\$144	0.138	0.524	0.068
	LT	L-Coup.	491	-\$5	\$276	-0.006	0.290	0.437	\$139	0.146	0.532	0.104
		LF-Coup.	491	-\$16	\$284	-0.016	0.298	0.464	\$163	0.156	0.495	0.084
		LF-Cp.SU	491	-\$1	\$290	-0.001	0.304	0.465	\$175	0.168	0.495	0.098
ML	None	Conv.	1160	\$79	\$352	0.075	0.333	0.424	\$194	0.185	0.471	0.150
	ST	L-Coup.	1160	\$114	\$370	0.104	0.363	0.450	\$236	0.215	0.449	0.181
		LF-Coup.	1160	\$114	\$379	0.094	0.384	0.491	\$282	0.232	0.407	0.163
		LF-Cp.SU	1160	\$121	\$381	0.099	0.383	0.490	\$286	0.235	0.407	0.169
	LT	L-Coup.	1160	\$141	\$397	0.129	0.363	0.425	\$263	0.240	0.425	0.206
		LF-Coup.	1160	\$141	\$406	0.116	0.384	0.468	\$309	0.254	0.386	0.186
		LF-Cp.SU	1160	\$148	\$408	0.122	0.383	0.468	\$313	0.257	0.386	0.191

[a] Short-term (ST) and long-term (LT) coupled.
[b] Crop acres included total potato plus dairy cropland.
[c] Economic indicators were net farm income (NFI), return over variable costs (ROVC), profit over revenues (POR), asset turnover ratio (ATR), and operating expense ratio (OER).
[d] Sustainability indicators were farming value added (FVA), FVA as a proportion of producer's share (FVA_p), energy and machinery use (NRG), and support for local families (SLF).
[e] NFI, ROVC, and FVA in \$/acre.

increased value from forage production. Start Up systems had slightly higher profitability measures due to lower costs from less land required for dairy farms. Profitability improved going from short- to long-term coupling due to lower fertilizer costs from manure-nutrient credits taken for potatoes and barley.

Coupled systems had higher (more favorable) ATR values than conventional systems because of higher revenues from growing more potatoes. For LF-coupled systems, equipment savings contributed to even greater ATR. OER was higher (less preferred) for coupled compared to conventional. L-coupled systems had higher OER than conventional since more potatoes were grown, which had an OER greater than barley. OER for both types of LF-coupled systems was higher due to additional dairy forage expenses and/or slight differences in equipment inventories between potato and dairy farms. OER was lower (better) going from the short- to long-term coupling because of lower fertilizer costs from manure-nutrient credits for potatoes and barley.

Sustainability Indicators were also better for coupled compared to conventional systems. Coupled systems had higher FVA measures than conventional since coupled systems grew more potatoes and less barley. Potatoes were more profitable and more labor intensive than barley. FVA measures also improved with greater coupling duration because of less purchased fertilizers. NRG was lower (more favorable) for coupled than for conventional systems since crop revenues were higher relative to NRG expenses when increasing potato acreage relative to barley and when adding forage enterprises. NRG was more favorable in the long term due to reduced purchased fertilizers from greater manure-nutrient credits. SLF was greater for coupled systems because of greater profitability. As was done for central Maine, FB was not compared since it was not used for potato farms.

Indicator Diagram Results

Similar to central Maine, economic (POR, ATR, and OER) and sustainability (FVA_p, NRG, and SLF) indicators were compared with ray diagrams for coupled and conventional potato and dairy systems (Figures 7.5 to 7.10). Indicators had possible ranges of -1 to +1 with minimum and maximum values for the expected range of each indicator used as lower and upper bounds corresponding to the ray diagram origin and outer bound, respectively. More favorable indicator ratios were found further from the origin. Lower OER and NRG were preferred. These two rays were reversed so preferred lower ratios were located further away from the origin of the diagram.

Figure 7.5. Aroostook County comparison of conventional and short-term land-coupled indicators.

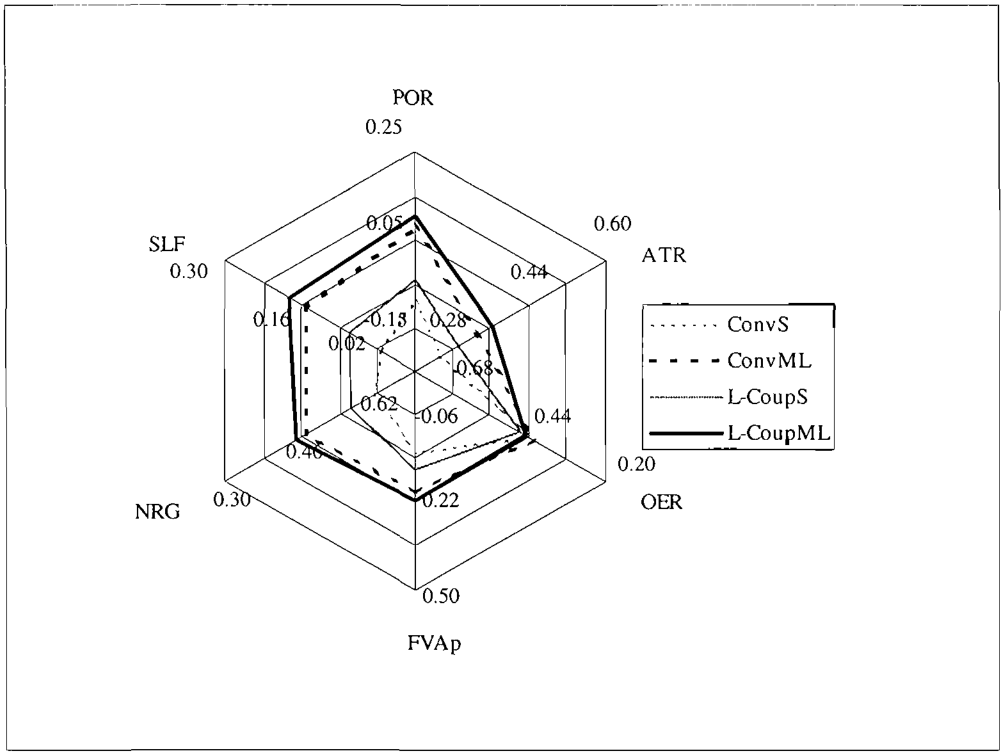


Figure 7.6. Aroostook County comparison of conventional and long-term land-coupled indicators.

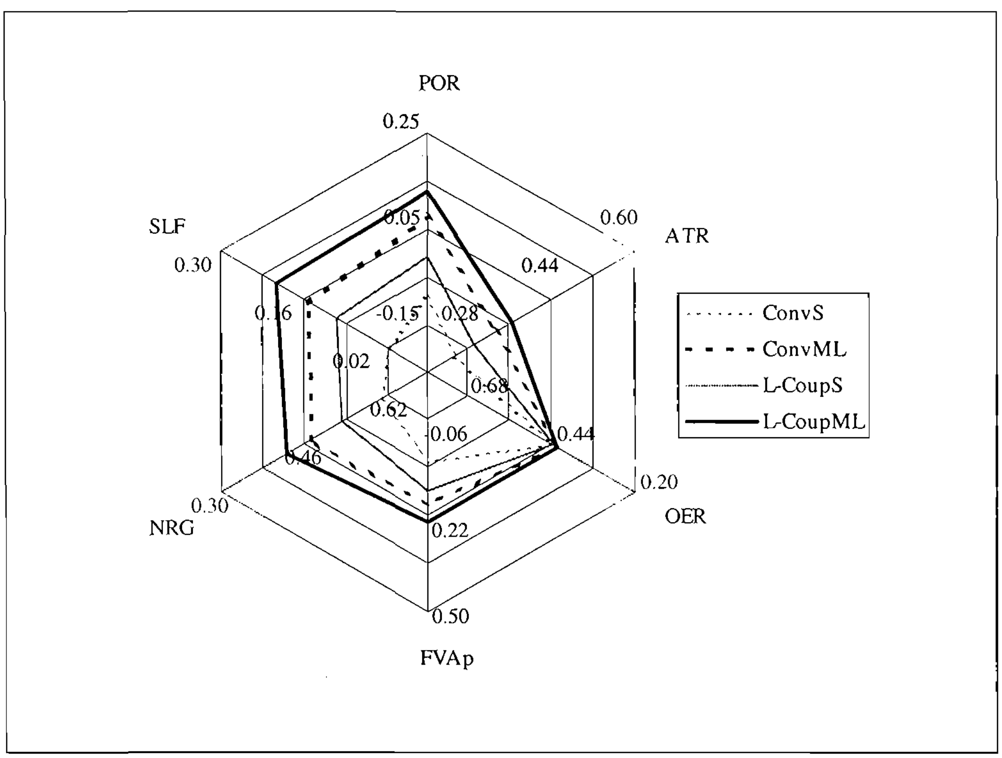


Figure 7.7. Aroostook County comparison of conventional and short-term land/feed-coupled indicators.

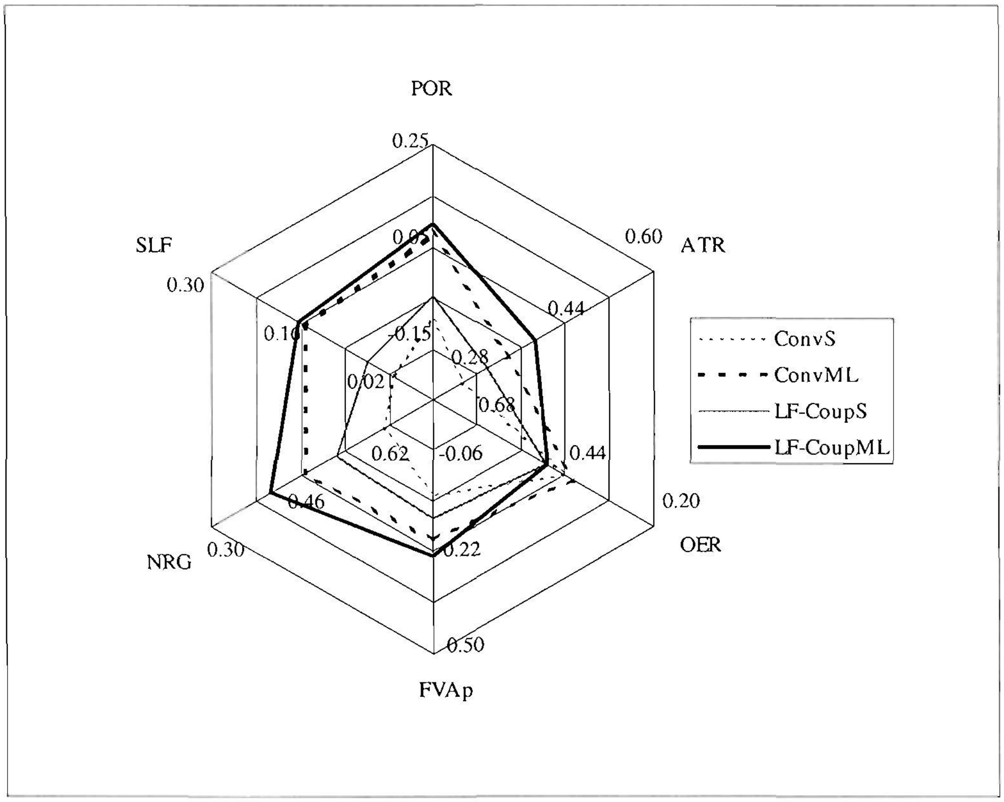


Figure 7.8. Aroostook County comparison of conventional and long-term land/feed-coupled indicators.

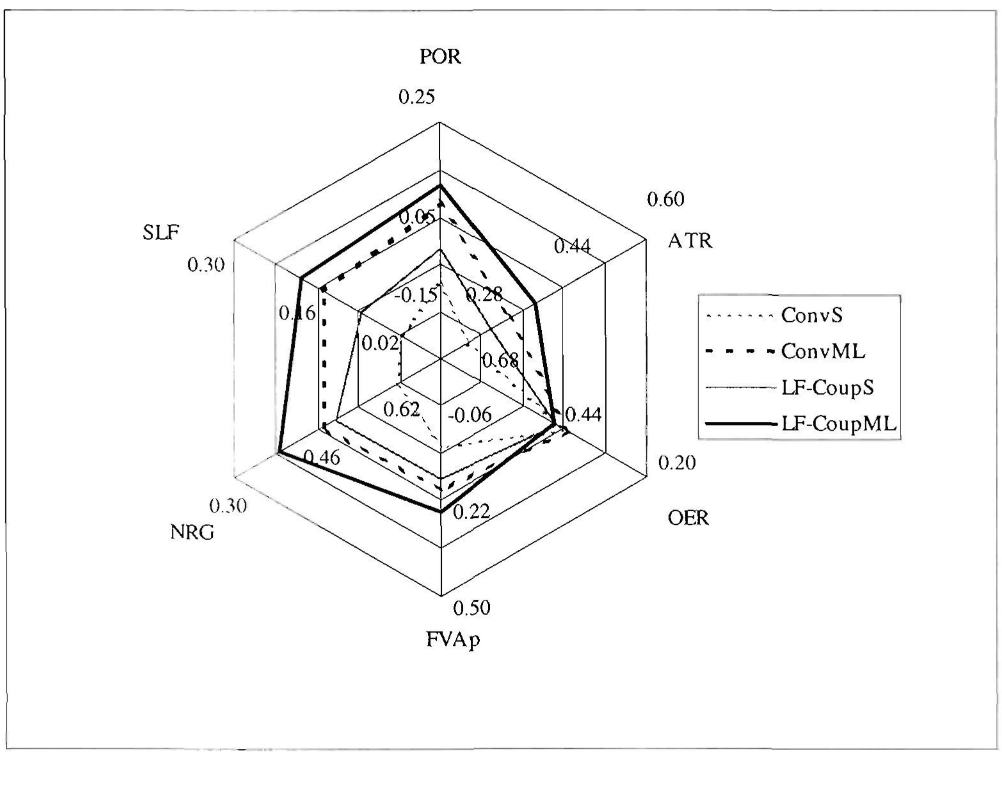


Figure 7.9. Aroostook County comparison of conventional and short-term land/feed-coupled Start Up indicators.

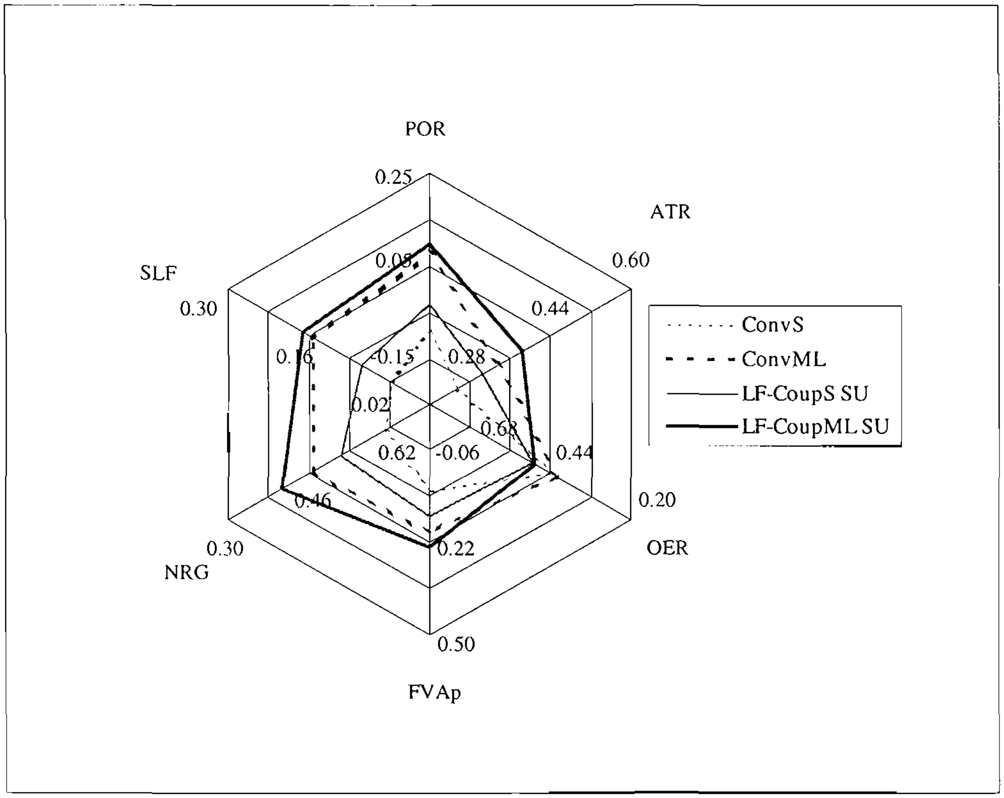
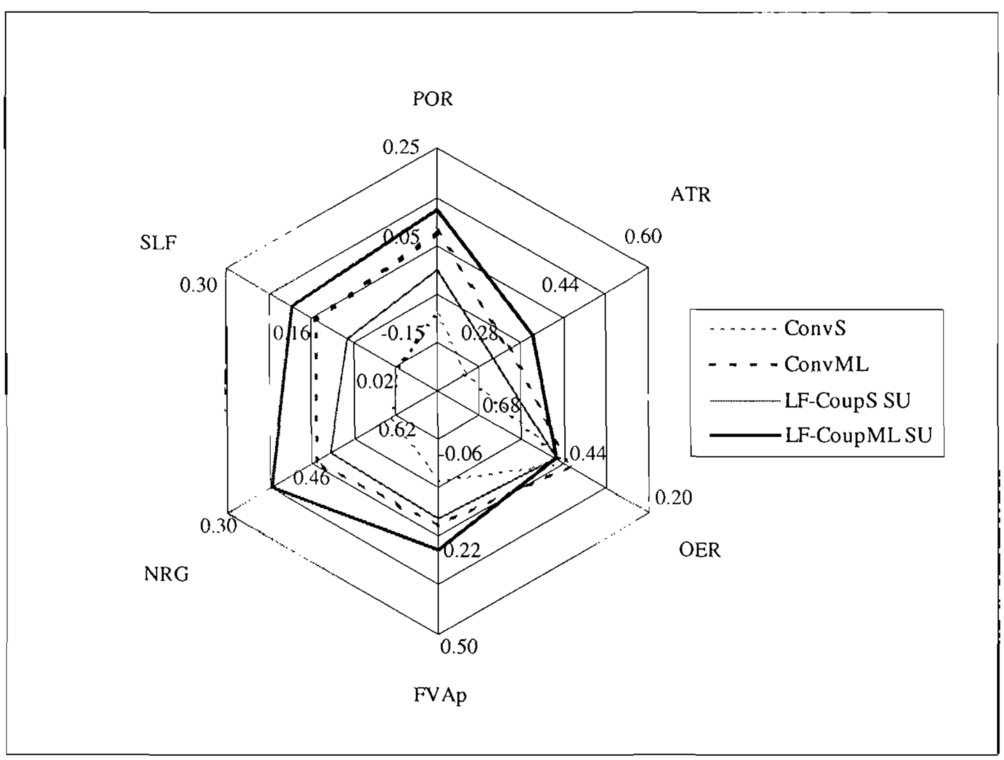


Figure 7.10. Aroostook County comparison of conventional and long-term land/feed-coupled Start Up indicators.



Indicator diagram results were similar to those for central Maine. With the exception of OER, coupled systems were favored over conventional for all indicators. This was true for both size classes, small and medium-large, and for all coupled types, L-coupled (Figures 7.5 and 7.6), LF-coupled (Figures 7.7 and 7.8), and Start Up (Figures 7.9 and 7.10). Like central Maine, size dominated integration, where the best small systems were usually worse than the worst ML systems. Indicators were within expected ranges, which were the same ranges as those used for central Maine.

Chapter 8

ON-FARM INTEGRATED AND CONVENTIONAL DAIRY COMPARISONS IN CENTRAL MAINE AND AROOSTOOK COUNTY

Previous chapters analyzed the profitability of and sustainability indicators for coupled integration in central Maine and Aroostook County. Although there was potential for coupling in Aroostook County, there has been limited interest in establishing new land/feed-coupled dairy operations there. Coupling between current potato and dairy farms in Aroostook has also been limited. Dairy farms in central and southern Maine, comprising the bulk of the industry, were typically located far away from larger potato farms (Figure 2.3; Tables 2.1 and 2.2). An exception was Penobscot County, where many of Maine's coupled potato and dairy farms were located.

Un-coupled Maine dairy farms may have difficulty integrating with distant potato farms. However, these dairy farms may alternatively become more on-farm integrated where more crops used for livestock feed and/or cash crops were grown on the farm. Maine dairy farms typically raised forage such as silage corn and hay/haylage but imported concentrated feed grown out of state. Some on-farm integrated dairy farms in Maine grew concentrated feed such as barley and soybeans in addition to forage.

Maine on-farm integrated dairy farms cited potential benefits to increasing the level of integration on their farms. Imported feed nutrients can become overly concentrated as manure on conventional dairy farms, resulting in non-point source pollution. Growing all feed required by livestock could reduce such nutrient build-up in soils and may decrease production costs. Two cooperating on-farm integrated dairy farms grew their own crops for processing into concentrated feed and provided the basis for comparing on-farm integration to conventional dairy in central Maine and Aroostook County.

On-Farm Integrated Farm Characteristics

Typical crop rotations and management were illustrated for on-farm integrated dairy farms in central Maine (Figure 8.1) and Aroostook County (Figure 8.2). Forage was the same as conventional and coupled dairy farms. Silage corn or alfalfa was assumed to be grown in a long rotation such as four years of forage followed by five years of hay/haylage. On-farm integrated dairy farms in Aroostook County assumed that growing corn was impractical due to lack of sufficient heat units. Instead, alfalfa was grown as a perennial crop for four years. On-farm integrated dairy farms raised concentrated feed crops (barley and/or soybeans) in addition to forage.

Like conventional and coupled dairy, 2001 production data was used from similar sources. Both small (S) and medium-large (ML) on-farm integrated dairy farms assumed 25% of farmland was rented. A milk price of $15.16/cwt was used for on-farm integrated dairy budgets. Forage yields, prices, and acreages were the same as coupled dairy (Table 8.1). Data for concentrated feed crops were based on cooperating on-farm integrated farmers and recommendations from Tim Griffin (2004) and Richard Kersbergen (2005).

Crop acreages selected balanced dry matter (DM), total digestible nutrients (TDN), and crude protein (CP) requirements for dairy cows given assumed crop yields. Dairy herd requirements for these ration parameters were calculated in SPARTAN (Kersbergen, 2005). Typical crop DM, TDN, and CP contents were used for corn silage, alfalfa, barley, and soybeans (Harris, 1992), while national averages were used for hay and haylage since New York and Pennsylvania values were similar (DOC, 2003).

Figure 8.1. Central Maine on-farm integrated dairy farm crop management.

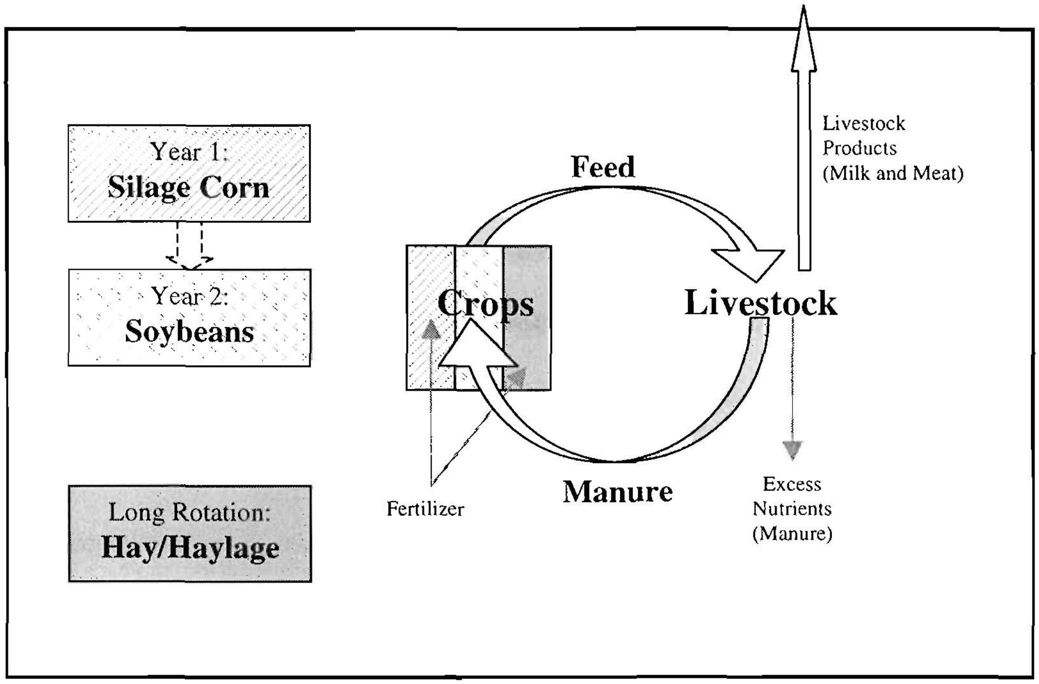


Figure 8.2. Aroostook County on-farm integrated dairy farm crop management.

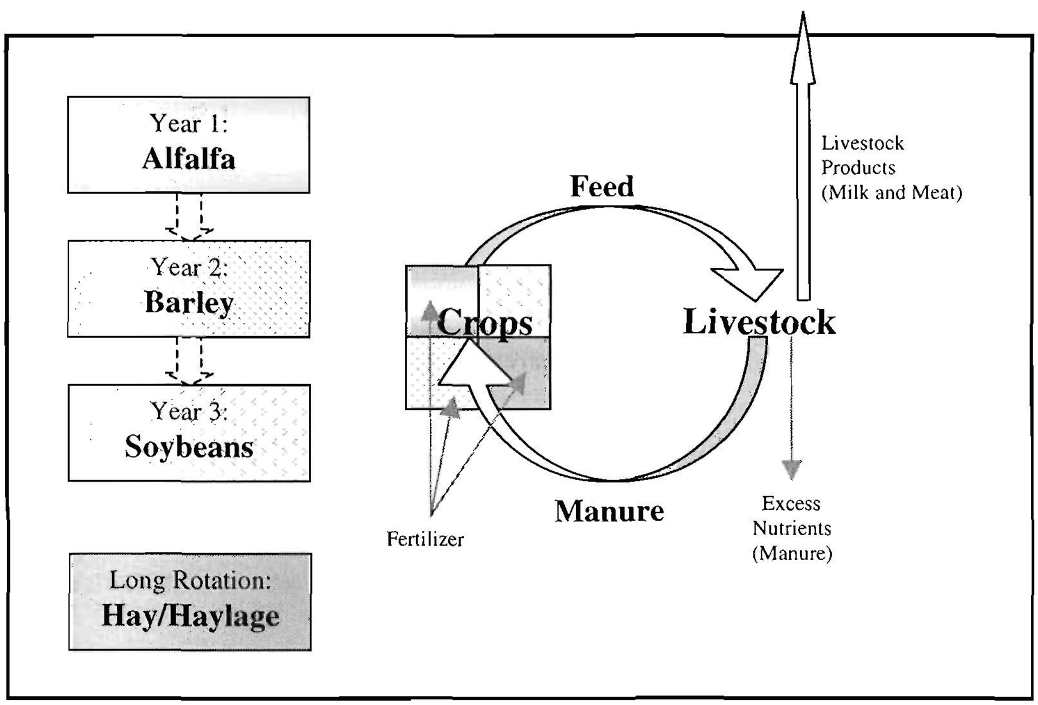


Table 8.1. On-farm integrated dairy crop yields, prices, and acreages for central Maine and Aroostook County.

			Yield		-------- Acreage --------			
					Central -- Maine[b] --		Aroostook -- County[b] --	
Crop	Yield/Acre[a]	Price ($/unit)	(cwt/ acre)	Price ($/cwt)	S	ML	S	ML
Silage Corn	15 tons	$25.00	300	$1.25	95	320	-	-
Alfalfa	6.25 tons	$50.00	125	$2.50	-	-	80	320
Dry Hay[c]	3.5 tons	$64.50	70	$3.23	70	-	120	-
Dry Hay[d]	6 tons	$46.95	120	$2.35	-	-	-	230
Haylage[e]	6 tons	$32.55	120	$1.63	-	200	-	-
Barley	71 bu	$1.50	34	$3.13	0	0	20	80
Soybeans[f]	45 bu	$5.60	27	$9.33	50	150	20	80

[a] Forage yields per acre shown as harvested tons and not tons of dry matter.
[b] Farm acres were operated crop acres, not owned and rented crop acres.
[c] First cut harvested as round bales and second cut harvested as square bales.
[d] First cut round-baled dry hay and second cut harvested as 90% round bales and 10% square bales.
[e] First cut haylage and 90% haylage and 10% square bales for second cut.
[f] A Maine average soybean yield of 45 bushels/acre from Griffin (2004), which may be more than typical Aroostook County soybean yields.

Production assumptions for representative budgets were based on the most common practices of cooperating on-farm integrated dairy farms. Crop production assumptions were the same as central Maine (Table 4.4) and Aroostook County (Table 7.2). Baseline livestock assumptions for dairy farms were also the same (Table 4.5). Family labor was not itemized as a cost and was instead captured in net farm income. Central Maine and Aroostook County had the same difference in milk hauling costs.

On-farm integrated dairy farms required additional acreage to grow crops for concentrated feed. For some dairy farms, land may not be available or land quality may not be suitable for growing barley and soybeans. On-farm integrators needed additional crop acres for central Maine small (44) and ML (150) and Aroostook County small (69) and ML (190) farms compared to conventional (Tables 4.3, 7.1, and 8.1). Whole-farm budget profitability measures per acre were calculated for on-farm integrated farms using these greater crop acreage requirements compared to conventional.

Silage corn and alfalfa management and yields were assumed the same as central Maine and Aroostook County, respectively. Barley production was similar to long-term coupled systems in Aroostook County. Barley was stored in bins, dried, and crushed prior to use as livestock feed. Soybeans assumed one herbicide application, no pesticides, no fertilizer, one harvest, and assumed 0.61 tons/acre of lime applied per year. Soybeans were also stored in bins, dried, and processed by roasting (central Maine) or extrusion (Aroostook County) prior to feeding to dairy cows.

Raw soybeans required processing prior to use as livestock feed to improve digestibility for dairy cows. Central Maine on-farm integrated dairy farms used a cooperative roaster and had a roasted soybean feeding limit of 6 lb/day for milk cows and 1.5 lb/day for heifers. Feeding more roasted soybeans per day to dairy cows and heifers typically caused upset stomachs. Thus, supplementation with purchased concentrated feed was needed for central Maine. Dry cows were not fed soybeans.

Aroostook on-farm integrated dairy farms did not roast soybeans, but rather fed soybean meal. Aroostook dairy farms trucked soybeans to Canadian processors. These processors extracted soybean oil through an extrusion process, leaving soybean meal that was transported back to the farm for feed. On-farm integrated farms paid an average of $55 to $66/ton to the processor for the soybean meal, which was the difference between the price of soybean meal and soybeans. Unlike central Maine, no daily limit was placed on feeding soybean meal to dairy cows and heifers.

Fertilizer applications (NPK) and manure-nutrient credits were the same as coupled farms for silage corn and alfalfa (Tables 4.6, 7.3, and 8.2) and were based on the

Table 8.2. Manure, fertilizer, and nutrient applications and fertilizer cost for central Maine and Aroostook County on-farm integrated farms.

	Integ-ration			Manure Applied	Fertilizer			Nutrients Applied as (lb/acre)								
					Type	Applied	Cost	Manure			Fertilizer			Total		
Farm Type	Length	Crop	Size	(/acre)[a]	(Analysis)	(lb/acre)	($/ton)	N	P	K	N	P	K	N	P	K
On-Farm Dairy	ST	Silage Corn	S	20 ton	Side Dress Urea (46-0-0)	125	$230	147	36	131	58	-	-	205	36	131
			ML	4000 gal	Side Dress Urea (46-0-0)	125	$230	117	70	95	58	-	-	175	70	95
		Barley	S	8 ton	At Plant Urea (34-0-0)	147	$230	59	14	52	50	-	-	125	14	52
					Side Dress Urea (34-0-0)	46	$230	-	-	-	16	-	-			
			ML	2750 gal	At Plant Urea (34-0-0)	147	$230	70	41	56	50	-	-	136	41	56
					Side Dress Urea (34-0-0)	46	$230	-	-	-	16	-	-			
	LT	Silage Corn	S	20 ton	Side Dress Urea (46-0-0)	100	$230	147	36	131	46	-	-	193	36	131
			ML	4000 gal	Side Dress Urea (46-0-0)	100	$230	117	70	95	46	-	-	163	70	95
		Barley	S	8 ton	At Plant Urea (34-0-0)	37	$230	59	14	52	13	-	-	74	14	52
					Side Dress Urea (34-0-0)	5	$230	-	-	-	2	-	-			
			ML	2750 gal	At Plant Urea (34-0-0)	37	$230	70	41	56	13	-	-	85	41	56
					Side Dress Urea (34-0-0)	5	$230	-	-	-	2	-	-			
	ST & LT	Alfalfa (Est.)	S	10.5 ton	Alfalfa Pre-Plant (0-0-42)	271	$232	77	19	69	-	-	113	77	19	182
		Alfalfa		-	None Applied	-	-	-	-	-	-	-	-	-	-	-
		Alfalfa (Est.)	ML	3000 gal	Alfalfa Pre-Plant (0-0-42)	271	$232	76	45	62	-	-	113	76	45	175
		Alfalfa		-	None Applied	-	-	-	-	-	-	-	-	-	-	-
		Soybeans	S	-	None Applied	-	-	-	-	-	-	-	-	-	-	-
			ML	-	None Applied	-	-	-	-	-	-	-	-	-	-	-
		Hay (C)[b]	S	12.5 ton	Top Dress Urea (46-0-0)	100	$230	92	23	82	46	-	-	138	23	82
		Hay (C)[b]	ML	4000 gal	Haylage Topdr. (10-20-10)	200	$220	101	60	82	20	40	20	158	100	102
					Top Dress Urea (46-0-0)	80	$230	-	-	-	37	-	-			
		Hay (A)[b]	S	10 ton	Top Dress Urea (46-0-0)	100	$230	73	18	66	46	-	-	119	18	66
		Haylage (A)[b]	ML	4800 gal	Haylage Topdr. (10-20-10)	200	$220	121	72	98	20	40	20	178	112	118
					Top Dress Urea (46-0-0)	80	$230	-	-	-	37	-	-			

[a] Small farms used solid dairy manure (tons/acre) while medium-large (ML) farms used liquid dairy manure (gallons/acre).
[b] Hay grown in Central Maine (C) and hay/haylage grown in Aroostook County (A).

Maine Potato Ecosystem Project for barley (Gallandt et al., 1998; Porter and McBurnie, 1996). Less manure was applied to forage compared to coupled farms since manure also had to be spread on barley. Manure storage, type, bedding, and spreading were the same as conventional and coupled dairy.

Cropland used by on-farm integrated farms was assumed to either have an extensive history of manure application (integrated) or no past manure (non-integrated). Additional crops grown by on-farm integrators for concentrated feed were either integrated or non-integrated. Non-integrated crops did not take manure nutrient credits (short-term), while integrated crops did (long-term).

Representative Budget Results

Profitability (Table 8.3) and selected costs (Table 8.4) were summarized for whole-farm budgets. Enterprise budgets were also summarized for forage (Table 8.5) and crops grown for concentrated feed (Table 8.6). On-farm integrated whole-farm budgets (Appendices C-1 to C-4) and soybean enterprise budgets (Tables 8.7 to 8.10) represented long-term integration. Although budgets were not shown, short-term on-farm integrated dairy farms took less manure-nutrient credits for silage corn (central Maine) and barley (Aroostook).

NFI was \$130 to \$203/acre greater for central Maine on-farm integrated dairy farms compared to central Maine conventional. Aroostook County on-farm integrated NFI was \$50 to \$51/acre greater than Aroostook conventional (Table 8.3). Total ROVC and NFI for on-farm integrated whole-farm budgets in Aroostook were always greater than conventional (Appendices C-3 and C-4). Total NFI for on-farm integrators in

Table 8.3. Relative profitability of Central Maine and Aroostook County conventional and on-farm integrated dairy farms.

Profit Measures	Size	-- Conventional[b] -- Central ME[c]	Aroo-stook[d]	-- Short-Term -- Central ME[c]	Aroo-stook[d]	-- Long-Term -- Central ME[c]	Aroo-stook[d]
ROVC[a]	S	$148	$228	$254	$210	$256	$211
	ML	$319	$463	$473	$452	$474	$454
NFI[a]	S	-$245	-$167	-$115	-$117	-$113	-$115
	ML	-$9	$135	$194	$186	$195	$188

[a] ROVC and NFI in $/acre of forage and concentrates. Crop acreage did not include pasture.
[b] Central Maine conventional small (S) dairy farms grew 98 acres of silage corn and 73 acres of hay for total crop acreage of 171 acres, while medium-large (ML) grew 320 acres of silage corn and 200 acres of haylage for a total of 520 crop acres. Aroostook County alfalfa acres were the same as silage corn in central Maine. Aroostook hay/haylage acres were also the same as central Maine. The 29 and 43 acres of pasture for S and ML dairy farms, respectively, were not included as crop acres.
[c] Total crop acreages were greater for central Maine small (215) and ML (670) on-farm integrated farms compared to conventional small (171) and ML (520).
[d] Total crop acreages were greater for Aroostook County small (240) and ML (710) on-farm integrated farms compared to conventional small (171) and ML (520).

Aroostook was greater than those in central Maine (Appendices C-1 to C-4) even though per acre profitability was lower in Aroostook (Table 8.3).

Profitability for on-farm integrated dairy farms were greater than conventional since the cost of purchased concentrated feed for conventional exceeded the cost of growing and processing soybeans and/or barley for concentrates (Table 8.4). For example, on-farm integrators in central Maine purchased a small amount of concentrates due to limitations of feeding roasted soybeans. However, the variable and fixed costs of growing and processing soybeans to meet the remainder of required concentrated feed was less than the cost of purchasing soybean meal. Results were the same for Aroostook County on-farm integrators growing and processing barley and soybeans compared to purchasing corn meal for use as concentrated feed (Table 8.4).

Aroostook on-farm integrated dairy farms did not purchase any concentrated feed and these farms had lower labor costs compared to central Maine (Table 8.4). Silage

Table 8.4. Selected concentrated feed purchase and production expenses for conventional and on-farm integrated dairy farms.

Conc. Feed Purchase and Production Expenses	Central Maine				Aroostook County			
	Small		Medium/Large		Small		Medium/Large	
	Conv-entional	On-Farm	Conv-entional	On-Farm	Conv-entional	On-Farm	Conv-entional	On-Farm
Variable Costs:								
Conc. Feed	$42,344	$639	$182,400	$10,560	$24,837	$0	$118,750	$0
Labor	$10,824	$11,943	$31,616	$35,467	$8,580	$11,426	$20,724	$25,393
Crop Expenses	$14,819	$17,247	$50,398	$59,056	$13,728	$19,231	$32,508	$55,513
Fuel and Oil	$5,902	$7,048	22,823	$26,497	$5,320	$6,186	$21,216	$23,866
Machinery Repairs	$11,986	$14,015	$32,000	$34,818	$12,086	$13,789	$32,040	$35,480
Property Taxes	$7,869	$8,162	$18,751	$19,747	$7,869	$8,328	$18,751	$20,013
Farm Insurance	$7,883	$9,263	$18,022	$20,138	$7,943	$9,235	$18,046	$20,420
Land Rent	$4,535	$5,085	$9,694	$11,569	$4,535	$5,397	$9,694	$12,069
Fixed Costs:								
Deprec. & Interest								
Land	$8,081	$9,061	$17,274	$20,616	$8,081	$9,618	$17,274	$21,507
Mach. & Equip.	$16,750	$27,930	$36,306	$49,564	$17,124	$26,316	$36,531	$50,442
Total Selected:								
Variable Costs	$106,164	$73,400	$365,704	$217,853	$84,899	$73,593	$271,729	$192,753
Fixed Costs	$24,831	$36,991	$53,580	$70,180	$25,205	$35,934	$53,805	$71,949
Expenses	$130,995	$110,391	$419,284	$288,033	$110,103	$109,527	$325,534	$264,702

corn (Tables 5.10 to 5.13) only grown in central Maine had higher labor costs per acre than other crops grown for forage and concentrated feed such as alfalfa (Tables 7.17 and 7.18), hay and haylage (Appendix D-2), barley (data not presented), and soybeans (Tables 8.7 to 8.10).

Machinery and equipment costs were also lower for Aroostook County on-farm integrators compared to central Maine (Table 8.4) due to extra processing equipment costs to roast and grind soybeans (Tables 8.7 to 8.10). For smaller farms, equipment maintenance, propane, and fixed costs per acre for a $30,000 soybean roaster and a $20,000 soybean grinder ($156/acre) exceeded transport and extrusion costs ($85/acre).

Table 8.5. Central Maine and Aroostook County enterprise budget summary for forage grown by on-farm integrated dairy farms.

Dairy Loc. & Size	Integ. Hist.[a]	Farm Type	-- Silage Corn (C) or Alfalfa (A)[b] -- Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI	------------- Hay/Haylage[bc] ------------ Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI
Central	None	Conv.	98	$375	$220	$181	$155	-$26	73	$226	$139	$165	$87	-$78
Maine	ST	On-Farm	95	$375	$218	$172	$157	-$15	70	$226	$137	$159	$89	-$70
S	LT	On-Farm	95	$375	$215	$172	$160	-$12	70	$226	$137	$159	$89	-$70
Aroo-	None	Conv.	98	$313	$188	$169	$125	-$44	73	$226	$128	$210	$98	-$112
stook	ST	On-Farm	80	$313	$185	$150	$128	-$22	120	$226	$135	$156	$91	-$65
S	LT	On-Farm	80	$313	$185	$150	$128	-$22	120	$226	$135	$156	$91	-$65
Central	None	Conv.	320	$375	$202	$137	$173	$36	200	$195	$141	$95	$54	-$41
Maine	ST	On-Farm	320	$375	$200	$125	$175	$50	200	$195	$139	$89	$56	-$33
ML	LT	On-Farm	320	$375	$197	$125	$178	$53	200	$195	$139	$89	$56	-$33
Aroo-	None	Conv.	320	$313	$135	$136	$178	$42	200	$195	$124	$113	$71	-$42
stook	ST	On-Farm	320	$313	$133	$119	$180	$61	230	$282	$135	$95	$147	$52
ML	LT	On-Farm	320	$313	$133	$119	$180	$61	230	$282	$135	$95	$147	$52

[a] Fields used for crops were short-term (ST) or long-term (LT) integrated.
[b] Revenue, costs, and returns in $/acre. Silage corn was grown in central Maine (C), while alfalfa was raised in Aroostook County (A).
[c] The small farm grew dry hay, while the medium-large (ML) farm raised hay in central Maine and primarily haylage in Aroostook County.

Table 8.6. Central Maine and Aroostook County enterprise budget summary for concentrated feed crops grown by on-farm integrated dairy farms.

Dairy Loc. & Size	Integ. Hist.[a]	---------------- Barley[b] ---------------- Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI	--------------- Soybeans[b] --------------- Acres	Rev.	Oper. Costs	Own. Costs	ROVC	NFI
Central	ST	0	-	-	-	-	-	50	$252	$171	$324	$81	-$243
ME S	LT	0	-	-	-	-	-	50	$252	$171	$324	$81	-$243
Aroo-	ST	20	$106	$172	$295	-$66	-$361	20	$252	$246	$343	$6	-$337
stook S	LT	20	$106	$155	$295	-$49	-$344	20	$252	$246	$343	$6	-$337
Central	ST	0	-	-	-	-	-	150	$252	$142	$162	$110	-$52
ME ML	LT	0	-	-	-	-	-	150	$252	$142	$162	$110	-$52
Aroo-	ST	80	$106	$144	$147	-$38	-$185	80	$252	$224	$258	$28	-$230
stook ML	LT	80	$106	$126	$147	-$20	-$167	80	$252	$224	$258	$28	-$230

[a] Fields used for crops were short-term (ST) or long-term (LT) integrated.
[b] Revenue, costs, and returns in $/acre.

Table 8.7. Central Maine soybean enterprise budget for a small on-farm integrated dairy farm.[a]

	Total	Per Acre	Per Bu
Number of Acres	50	-	-
Soybean Yield (bu)	2,250	45	-
Price ($/bu)	$5.60	-	-
Annual Revenue	**$12,600**	**$252.00**	**$5.60**
Annual Operating Expenses			
Seed	$1,041	$20.82	$0.46
Fertilizer	$0	$0	$0
Lime	$607	$12.13	$0.27
Chemicals	$328	$6.57	$0.15
Labor	$1,437	$28.75	$0.64
Diesel Fuel and Oil	$1,225	$24.50	$0.54
Maintenance and Upkeep	$2,480	$49.61	$1.10
Supplies	$500	$10.00	$0.22
Insurance	$17	$0.33	$0.01
Miscellaneous			
Utilities	$75	$1.50	$0.03
Rent or Lease	$625	$12.50	$0.28
Other Expenses	$0	$0	$0
Interest	$230	$4.60	$0.10
Total Operating Expenses	**$8,566**	**$171.31**	**$3.81**
Annual Ownership Expenses			
Depreciation and Interest	$15,241	$304.81	$6.77
Tax and Insurance	$962	$19.24	$0.43
Total Ownership Expenses	**$16,202**	**$324.05**	**$7.20**
Total Annual Cost	**$24,768**	**$495.36**	**$11.01**
Net Farm Income (NFI)	**-$12,168**	**-$243.36**	**-$5.41**
Return over Variable Cost (ROVC)	**$4,034**	**$80.69**	**$1.79**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$495.36	$11.01
Short-run to Cover Operating Costs		$171.31	$3.81

[a] Numbers may not sum due to rounding.

Table 8.8. Central Maine soybean enterprise budget for a medium-large on-farm integrated dairy farm.[a]

	Total	Per Acre	Per Bu
Number of Acres	150	-	-
Soybean Yield (bu)	6,750	45	-
Price ($/bu)	$5.60	-	-
Annual Revenue	**$37,800**	**$252.00**	**$5.60**
Annual Operating Expenses			
Seed	$3,124	$20.82	$0.46
Fertilizer	$0	$0	$0
Lime	$1,820	$12.13	$0.27
Chemicals	$985	$6.57	$0.15
Labor	$3,851	$25.68	$0.57
Diesel Fuel and Oil	$3,675	$24.50	$0.54
Maintenance and Upkeep	$3,693	$24.62	$0.55
Supplies	$1,500	$10.00	$0.22
Insurance	$50	$0.33	$0.01
Miscellaneous			
Utilities	$225	$1.50	$0.03
Rent or Lease	$1,875	$12.50	$0.28
Other Expenses	$0	$0	$0
Interest	$574	$3.83	$0.09
Total Operating Expenses	**$21,371**	**$142.48**	**$3.17**
Annual Ownership Expenses			
Depreciation and Interest	$22,790	$151.94	$3.38
Tax and Insurance	$1,539	$10.26	$0.23
Total Ownership Expenses	**$24,329**	**$162.19**	**$3.60**
Total Annual Cost	**$45,701**	**$304.67**	**$6.77**
Net Farm Income (NFI)	**-$7,901**	**-$52.67**	**-$1.17**
Return over Variable Cost (ROVC)	**$16,429**	**$109.52**	**$2.43**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$304.67	$6.77
Short-run to Cover Operating Costs		$142.48	$3.17

[a] Numbers may not sum due to rounding.

Table 8.9. Aroostook County soybean enterprise budget for a small on-farm integrated dairy farm.[a]

	Total	Per Acre	Per Bu
Number of Acres	20	-	-
Soybean Yield (bu)	900	45	-
Price ($/bu)	$5.60	-	-
Annual Revenue	**$5,040**	**$252.00**	**$5.60**
Annual Operating Expenses			
Seed	$416	$20.82	$0.46
Fertilizer	$0	$0	$0
Lime	$243	$12.13	$0.27
Chemicals	$131	$6.57	$0.15
Labor	$597	$29.87	$0.66
Diesel Fuel and Oil	$315	$15.74	$0.35
Maintenance and Upkeep	$984	$49.22	$1.09
Supplies	$200	$10.00	$0.22
Insurance	$7	$0.33	$0.01
Miscellaneous			
Utilities	$20	$1.00	$0.02
Rent or Lease	$250	$12.50	$0.28
Other Expenses	$1,634	$81.68	$1.82
Interest	$132	$6.62	$0.15
Total Operating Expenses	**$4,930**	**$246.49**	**$5.48**
Annual Ownership Expenses			
Depreciation and Interest	$6,457	$322.86	$7.17
Tax and Insurance	$401	$20.05	$0.45
Total Ownership Expenses	**$6,858**	**$342.90**	**$7.62**
Total Annual Cost	**$11,788**	**$589.39**	**$13.10**
Net Farm Income (NFI)	**-$6,748**	**-$337.39**	**-$7.50**
Return over Variable Cost (ROVC)	**$110**	**$5.51**	**$0.12**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$589.39	$13.10
Short-run to Cover Operating Costs		$246.49	$5.48

[a] Numbers may not sum due to rounding.

Table 8.10. Aroostook County soybean enterprise budget for a medium-large on-farm integrated dairy farm.[a]

	Total	Per Acre	Per Bu
Number of Acres	80	-	-
Soybean Yield (bu)	3,600	45	-
Price ($/bu)	$5.60	-	-
Annual Revenue	**$20,160**	**$252.00**	**$5.60**
Annual Operating Expenses			
Seed	$1,666	$20.82	$0.46
Fertilizer	$0	$0	$0
Lime	$970	$12.13	$0.27
Chemicals	$525	$6.57	$0.15
Labor	$1,972	$24.65	$0.55
Diesel Fuel and Oil	$1,280	$16.00	$0.36
Maintenance and Upkeep	$2,563	$32.03	$0.71
Supplies	$800	$10.00	$0.22
Insurance	$27	$0.33	$0.01
Miscellaneous			
Utilities	$80	$1.00	$0.02
Rent or Lease	$1,000	$12.50	$0.28
Other Expenses	$6,534	$81.68	$1.82
Interest	$481	$6.01	$0.13
Total Operating Expenses	**$17,898**	**$223.72**	**$4.97**
Annual Ownership Expenses			
Depreciation and Interest	$19,435	$242.94	$5.40
Tax and Insurance	$1,249	$15.61	$0.35
Total Ownership Expenses	**$20,684**	**$258.55**	**$5.75**
Total Annual Cost	**$38,581**	**$482.27**	**$10.72**
Net Farm Income (NFI)	**-$18,421**	**-$230.27**	**-$5.12**
Return over Variable Cost (ROVC)	**$2,262**	**$28.28**	**$0.63**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$482.27	$10.72
Short-run to Cover Operating Costs		$223.72	$4.97

[a] Numbers may not sum due to rounding.

For larger farms, roasting costs ($61/acre) were 28% less than those for extrusion and transport.

Cooperating on-farm integrated dairy farms in central Maine shared a soybean roaster with other producers, while each individual farm owned their own soybean grinder. Central Maine soybean enterprise budgets (Tables 8.7 and 8.8) assumed that only one farm owned and used the roaster. If two farms shared roasting costs, central Maine soybean processing costs were comparable to those in Aroostook County.

On-farm integrated forage had more favorable profitability than conventional since fixed costs were distributed over additional concentrated feed crop acreage (Table 8.5). Silage corn (Table 8.5) and barley (Table 8.6) enterprises had slightly better profitability in the long term due to small manure nutrient credits taken for these crops. Short- and long-term budgets of alfalfa, hay/haylage (Table 8.5) and soybean (Table 8.6) were identical. Soybeans were more profitable per acre in central Maine (Tables 8.6 to 8.10) due to greater acreages grown compared to Aroostook County.

Performance Indicator Results

Economic and sustainability indicators were calculated for on-farm integrated farms as they were for coupled farms. NFI, ROVC, and FVA were calculated in dollars per acre of crops. Like representative farm budgets, coupled indicators varied by duration (short-term and long-term) and size classifications (small and medium-large). Like coupled farms, dairy farm indicators in Table 8.11 were based on 2001 data, except for ATR, which was based on 2000 Farm Credit data (Stafford et al., 2001). Some indicators were negative since fluid milk prices were below cost of production. Cropland used for calculating NFI, ROVC, and FVA per acre for on-farm integrated farms

Table 8.11. Central Maine and Aroostook County economic and sustainability indicators for on-farm integrated and conventional dairy farms.

Dairy Type & Size	Farm Type	Integ. Hist.[a]	Crop Acreage[b]	ECONOMIC[c] Profitability NFI[e]	ROVC[e]	POR	Efficiency ATR	OER	SUSTAINABILITY[d] FVA[e]	FVA_p	NRG	SLF	FB
Central ME S	Conv.	None	171	-$245	$148	-0.245	0.210	0.235	-$131	-0.132	0.574	-0.182	-0.224
	On-Farm	ST	215	-$115	$254	-0.148	0.178	-0.046	-$17	-0.022	0.684	-0.076	-0.004
		LT	215	-$113	$256	-0.146	0.178	-0.048	-$16	-0.020	0.683	-0.075	-0.004
Aroostook S	Conv.	None	171	-$167	$228	-0.171	0.203	0.132	-$69	-0.071	0.566	-0.120	-0.149
	On-Farm	ST	240	-$117	$210	-0.168	0.180	-0.016	-$32	-0.047	0.662	-0.099	0.000
		LT	240	-$115	$211	-0.166	0.180	-0.018	-$31	-0.044	0.660	-0.097	0.000
Central ME ML	Conv.	None	520	-$9	$319	-0.007	0.319	0.340	$92	0.073	0.405	0.041	-0.279
	On-Farm	ST	670	$194	$473	0.198	0.291	0.076	$280	0.288	0.445	0.253	-0.016
		LT	670	$195	$474	0.200	0.291	0.075	$282	0.289	0.444	0.254	-0.016
Aroostook ML	Conv.	None	520	$135	$463	0.107	0.319	0.225	$213	0.169	0.385	0.139	-0.182
	On-Farm	ST	710	$186	$452	0.202	0.289	0.066	$252	0.274	0.436	0.240	0.000
		LT	710	$188	$454	0.204	0.289	0.064	$254	0.276	0.434	0.243	0.000

[a] Fields used for crops were short-term (ST) or long-term (LT) integrated.
[b] Crop acreage included forage for conventional and forage plus crops grown for concentrated feed for on-farm integrated. Dairy farm crop acreage did not include pasture.
[c] Economic indicators were net farm income (NFI), return over variable costs (ROVC), profit over revenues (POR), asset turnover ratio (ATR), and operating expense ratio (OER).
[d] Sustainability indicators were farming value added (FVA), FVA as a proportion of producer's share (FVA_p), energy and machinery use (NRG), support for local families (SLF), and feed balance (FB).
[e] NFI, ROVC, and FVA in $/acre of crops grown.

included both forage and crops grown for concentrated feed. Short-term (Appendix F-5) and long-term (Appendix F-6) indicators were ranked against conventional.

Economic Indicators were generally more favorable for on-farm integrated dairy farms compared to conventional. As previously mentioned, the improved profitability of on-farm integrated farms was due to barley and/or soybeans being less costly to grow and process than purchasing concentrated feed (Table 8.4). POR values ranged from -0.245 to 0.204 with a typical indicator value of 0.10. The expected range was expanded (-0.30 to 0.30) for indicator diagrams. All profitability indicators improved slightly going from short- to long-term integration due to manure nutrient credits taken for silage corn (central Maine) and barley (Aroostook County).

ATR values for on-farm integrators were less favorable than conventional since farm revenues were unchanged while farm assets increased from additional equipment needed to grow and process crops grown for concentrated feed. ATR was between 0.178 and 0.319, compared to a typical ATR value of 0.30. The expected range was expanded (0.10 to 0.60) for indicator diagrams.

OER for on-farm integrators was lower (more favorable) compared to conventional due to lower costs from growing concentrated feed crops. OER values ranged from -0.048 to 0.340. OER was lower than typical (0.66) since family labor was not included as an operating expense. The expected OER range (0.20 to 1.20) was expanded for diagrams. OER improved slightly in the long term from a reduction in operating expenses from manure nutrient credits.

Sustainability Indicators were also more favorable for on-farm integrated dairy farms compared to conventional with the exception of NRG. FVA and FVA_p were greater for on-farm integrators since costs returned to the farming sector such as labor from concentrated feed crop production and property taxes from greater land ownership were higher. Since farm revenues were the same as conventional, greater returns to the farming sector increased these FVA measures. FVA and FVA_p improved slightly in the long term from reductions in purchased fertilizers for silage corn and barley. FVA_p ranged from -0.132 to 0.289, falling within an expected range of -0.200 to 0.500.

On-farm integrated farms had higher (less favorable) NRG values because of greater machinery and energy costs required for growing crops for concentrated feed. NRG improved (decreased) slightly in the long term from reduced fertilizer use. SLF was greater for on-farm integrators due to increased labor expenditures and increased profitability from raising barley and/or soybeans. NRG and SLF ranged from 0.385 to 0.684 and from -0.182 to 0.254, respectively. The expected range for NRG was 0.30 to 0.70, while the expected range for SLF was increased (-0.15 to 0.30) for diagrams.

FB for on-farm integrated dairy farms was closer to zero (more favorable) compared to conventional since purchased feed was reduced. It was assumed that farm revenues were the same as conventional and that no crops were sold. Central Maine on-farm integrators had slightly negative feed balances since these farms required some purchased concentrates due to limitations of feeding roasted soybeans. FB values ranged between -0.279 and 0.000, with an expected range of -1 to 0 for diagrams.

Indicator Diagram Results

Like coupled farms, economic (POR, ATR, and OER) and sustainability (FVA_p, NRG, and SLF) indicators were compared with ray diagrams for long-term on-farm integrated and conventional dairy farms (Figures 8.3 and 8.4). Indicators' ranges were -1 to +1 with minimum and maximum values for the indicators' expected ranges used as lower and upper bounds corresponding to the ray diagram origin and outer bound, respectively. More favorable indicator ratios were further from the origin. Lower OER and NRG were preferred so these two rays were reversed so preferred lower ratios were located further away from the origin of the diagram. Dairy farm FB was graphed from -1 to a preferred value of 0.

Indicators were more favorable for on-farm integrated dairy farms compared to conventional with the exception of ATR, OER, and NRG. This was true for both size classes in central Maine (Figure 8.3) and Aroostook County (Figure 8.4). Short-term on-farm integrated diagrams were not presented since they were visually similar to long-term

Figure 8.3. Central Maine comparison of conventional and long-term on-farm integrated dairy indicators.

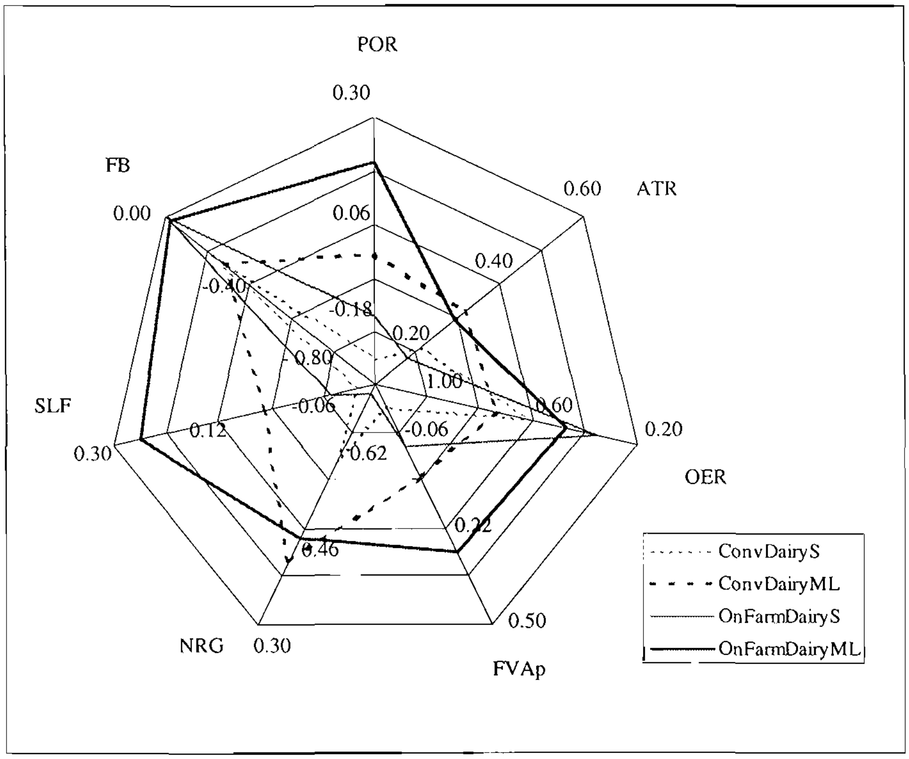
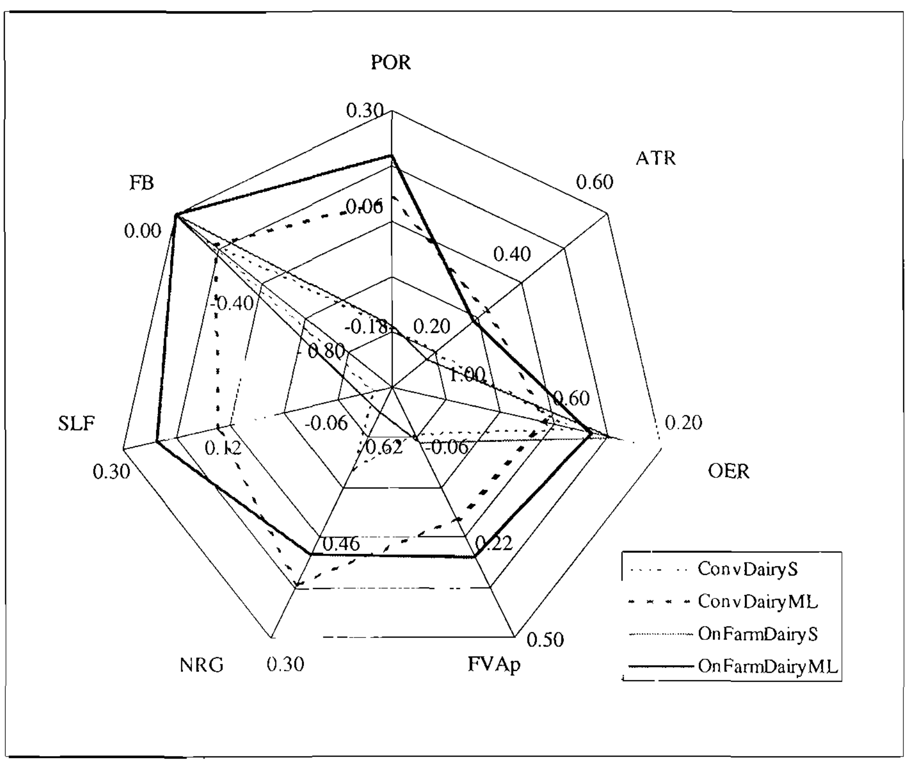


Figure 8.4. Aroostook County comparison of conventional and long-term on-farm integrated dairy indicators.



ones due to small manure nutrient credits. As in the long term, short-term on-farm integrated indicators were better than conventional except for ATR, OER, and NRG.

Size generally dominated integration where the best small farms were usually worse than the worst medium-large ones. One exception was OER since depreciation exceeded operating expenses for small dairy farms. Another was FB for central Maine since small on-farm integrated dairy farms purchased less concentrated livestock feed relative to farm income. Indicators were within expected ranges. Expected ranges were expanded for POR, ATR, OER, and SLF to include all data.

Chapter 9

SUMMARY AND CONCLUSIONS

Integrating crops and livestock can introduce technical and economic efficiencies that may increase productivity and profitability and that may reduce soil-nutrient loading and non-point source pollution. Benefits from coupling potato and dairy farms were less direct than originally expected because farmers did not capture all of the potential gains during early transition years. For example, short-term couplers did not take manure-nutrient credits for potatoes and silage corn, while long-term couplers took these credits. Surveyed farmers were hesitant to expose themselves to the risk of taking manure-nutrient credits for uncertain yield increases in high-value crops, such as potatoes, especially when chemical fertilizer was relatively inexpensive. These risks were greater in the short term when organic matter levels were low from less manure applications.

Analyses of budgets and economic indicators in central Maine suggested that potato and dairy farms and systems coupled for only two years (short term) had greater profitability and performance indicator values than conventional non-coupled systems. Profitability increased in the short term since land base for higher value crops expanded from coupling. Potato farms were able to grow more potatoes, a more profitable cash crop, and less grain corn, a less profitable rotation crop while keeping the same rotation sequence. This was possible because silage corn was added as a rotation crop during coupling with the dairy farm. Coupled potato farms were about $62 to $190/acre more profitable than conventional, even with equal potato yields and no reductions in chemical fertilizer.

arrangements between farmers, 4) reduced land requirements for Start Up dairy farms, and 5) a 5% assumed increase in potato yields. Average NFI for coupled agricultural systems in central Maine and Aroostook improved the most ($75/acre) of all coupling components if potato yields increased 5% in the long term. However, if potato yields did not increase, gains were on average slightly greater for potato acreage expansion in the short term ($46/acre) compared to manure nutrient credits taken in the long term ($36/acre). This assumed potato farm and not dairy farm expansion.

On-farm integrated dairy farms had higher profitability compared to conventional. Instead of expanding herd size, dairy farms grew barley and soybeans to reduce purchased concentrated feed and to tighten nutrient cycling. On-farm integrated dairy farms had net farm income $130 to $203/acre greater than central Maine conventional and $50 to $51/acre greater than Aroostook County conventional. It was cheaper to grow and process crops for concentrated feed than it was to buy concentrates at typical market prices. Soybean transport and extrusion costs in Aroostook County were less than processing costs in central Maine, which required expensive roasters and grinders. Caution should be taken comparing central Maine to Aroostook on-farm dairy since these integrators had different crops, concentrated feed rations, and processing assumptions.

Like separate coupled potato and dairy farms, net farm income for coupled and on-farm integrated agricultural systems were greater than conventional and increased after many years of integration (Table 9.1). In budget analyses of coupled potato and dairy farms in central Maine and Aroostook County, potato yields were assumed to increase by 5% in the long term. The average annual increase in total potato yields from the Maine Potato Ecosystem Project from 1991 to 2003 was about 11%, while marketable

Table 9.1. Summary of agricultural system net farm income for central Maine and Aroostook County ($/acre of owned and rented cropland).

		----- Central Maine -----			--------- Aroostook ---------		
Integ. History[a]	System Type[b]	Small	Medium-Large	Average	Small	Medium-Large	Average
None	Conv.	-$119	$6	-$57	-$85	$79	-$3
ST	L-Coup.	-$78	$66	-$6	-$38	$113	$38
	LF-Coup.	-$66	$66	$0	-$49	$113	$32
	LF-Cp.SU	-	-	-	-$34	$120	$43
	On-Farm D	-$115	$194	$40	-$117	$186	$35
LT	L-Coup.	-$35	$109	$37	-$7	$140	$67
	LF-Coup.	-$22	$109	$44	-$17	$140	$62
	LF-Cp.SU	-	-	-	-$3	$147	$72
	On-Farm D	-$113	$195	$41	-$115	$188	$37

[a] History of integration from none to short-term (ST) and long-term (LT).
[b] Type of agricultural systems were conventional (Conv.), land-coupled (L-Coup.), land/feed-coupled (LF-Coup.), land/feed-coupled Start Up (LF-Cp.SU), and on-farm integrated dairy (On-Farm D). Start Up systems were in Aroostook County and not central Maine. Conventional was an artificial combination of potato and dairy farms, while on-farm integrated dairy was just a dairy farm.

(US #1) potato yields increased on average of about 6%. The EPIC simulation model's modest potato yield response from amendment of about 0.22% was not consistent with research farm data. Although cooperating farmers and University of Maine researchers reported increased potato yields from long-term manure applications, these increases were not detected using EPIC.

Coupled and on-farm integrated agricultural systems in both central Maine and Aroostook County had profitability and sustainability indicator values that were more favorable than conventional systems in both the short term and the long term. Economic efficiency indicators were less successful at distinguishing between integrated and non-integrated systems. Farming value added measures were consistently more favorable for integrated systems compared to other sustainability indicators. For example, on-farm integrated dairy farms had higher (less favorable) energy and machinery costs compared to conventional from growing crops for concentrated feed in addition to forage.

This thesis has demonstrated both short- and long-term economic benefits and more favorable sustainability indicator values for both coupled and on-farm integration in central Maine and Aroostook County. However, both types of integration are not extensively practiced by potato and dairy farms in this state. Only about 1.4% of potato farms, 2.5% of dairy farms, and 5.3% of potato and dairy farm cropland are integrated. Several challenges to adopting integrated crop and livestock systems include 1) distance between potential couplers, 2) establishing and maintaining successful coupled relationships, 3) management of inter-farm coupling and other crops, 4) land access and availability, 5) the terms of processing potato contracts, and 6) structural factors such as farm specialization and consolidation in addition to infrastructure and markets.

Even if coupling is more profitable in both the short term and long term than non-integrated systems, unless farmers are willing to relocate, it still requires farms to be in close proximity. Coupling between cooperating farms usually occurs within ten miles of the dairy farm. The current potential for integration may be limited given the spatial separation of the two industries. Even though about 75% of potato farms in Aroostook County were located within fifteen miles of a dairy farm[15], the potential for integration was limited by the small size and limited number of dairy farms. Current dairy farm cropland in Aroostook is trivial compared to potato farm acres (Tables 2.1 and 2.2).

In 2001, there were only about 12 dairy farms in Aroostook County milking about 762 cows and using slightly less than 2000 crop acres. This was substantially less than the roughly 47,000 acres of crops grown in rotation with a potato cash crop in Aroostook in 1997. Assuming all current dairy cropland was integrated, potential integrated acreage

[15] This was calculated using Geographic Information System (GIS) buffer analysis. Geo-coded potato and dairy farms in GIS used mailing addresses and may not represent actual farm centers. Also, GIS buffer analysis used straight-line distances. Actual road travel distances between farms may be different.

in Aroostook was only 4% of available potato rotation cropland. Crop acreage was not available for all Maine potato farms so approximate potato rotation acreage available for integration within ten to fifteen miles of Maine dairy farms could not be determined using Geographic Information Systems.

In addition to a proximity requirement, coupled sets of farms need to be of similar scale to reduce the transaction costs of the relationship. For example, a 500-cow dairy farm would have more transaction costs associated with integrating with fifty ten-acre potato farms rather than one 500-acre potato farm. Likewise, a potato farm would have more transaction costs from integrating with multiple dairy farms. Transaction costs would be less if both farms were of similar scale.

Farmers engaged in inter-farm coupling need to have adequate working relationships. Most coupling arrangements were verbal and not formally written down on paper. Current potato and dairy couplers in central Maine and southern Aroostook County stressed that worrying about which producer was making out better in the short term was not the basis of a successful relationship. Instead, cooperating producers emphasized faith and trust that the relationship would benefit both crop and livestock farms in the long term. Many farmers may not be able to do this.

Despite the prevalence of inter-farm coupling in central Maine, many potato and dairy farmers in this part of Maine were not integrated. These farmers may not be willing to trust and deal with another farmer in such a relationship even if there are short- and long-term economic benefits. Recent low milk prices forced many dairy farmers to leave the industry. Considering this uncertainty, potato farmers may hesitate to couple with dairy farmers that are not guaranteed to still be in business in the long term.

The added management time needed to coordinate coupling with others may not be appealing to certain farmers. Land coupling management is the most simple where potato and dairy farmers decide where potatoes and forage rotations are grown. Land/feed coupling is more complex since the potato farmer needs to adequately manage forage in addition to potatoes. Cooperating dairy farmers that were considering coupling in this manner stressed that the dairy farmer needed to closely work with the potato farmer during early transition years to ensure adequate forage quality.

Similarly, management under on-farm dairy integration is more complex from growing crops for concentrated feed in addition to forage. In both central Maine and Aroostook County, capital and labor also have to be devoted to processing barley and soybeans into concentrated feed. The added complexity of managing these new crops may not be desirable to many dairy farmers. On-farm integration may be more appealing to organic dairy farmers that face concentrated feed costs that are about double those for conventional dairy farmers.

Another challenge to integrating crop and livestock systems is constraint on access to land. Limited land base can actually encourage integration. For example in central Maine, limited land base availability has actually encouraged at least one coupled dairy farmer to integrate with a nearby potato farmer in order to expand this farmer's herd. On the other hand, access to land for dairy farmers considering Start Up operations in Aroostook County may be limiting since dairy farmers are dependent on the potato farmer or farmers they are coupled with. If for some reason the coupled relationship does not work out, the Start Up dairy farmer may find it challenging to purchase or rent enough nearby cropland to raise forage.

In this analysis, it was assumed that on-farm integrated dairy farms had access to enough land to raise crops for concentrated feed in addition to existing forage. In central Maine, this may not be a realistic assumption. In this area of the state, high quality land may not be available to on-farm integrated dairy farms to grow crops for concentrated feed in addition to forage. If this is the case, then on-farm integrated dairy farms may be less profitable than conventional since they would have to downsize their forage acreages and subsequently their herds in order to grow crops for concentrated feed. In Aroostook County there would be less of a land constraint, making profitable on-farm integration more realistic here compared to central Maine.

The terms of processing potato contracts may limit integration. Potato farms under contract may not be able to expand acreage and realize short-term benefits of coupling. Also, diseases such as powdery scab that are associated with greater soil moisture from applied manure may reduce potato quality resulting in contract penalties or even rejection of shipments by processors. For processing growers raising proprietary varieties, it may be easier to grow and sell potatoes with reasonable scab resistance. For seed potato farmers selling a wide range of cultivars, this may not be the case.

Structural factors such as specialization and spatial consolidation of crop and livestock industries in addition to infrastructure and markets may further challenge inter-farm coupling and on-farm integration. For example, Aroostook County has long specialized in potato production and has seen a decline in its dairy industry. The number of dairy farms and service firms such as fluid milk processors, agricultural supply companies, and breeders have decreased. Widespread future integration in Aroostook would require not only an increase in livestock farms, but accompanying infrastructure.

This is especially true for dairy, although livestock increases from beef would also require appropriate infrastructure and markets. In addition, relocation of dairy farms to Aroostook County may be further challenged by lack of financing for start-up costs.

In addition to the economic benefits found in this study, advantages of integrated systems such as improved soil quality may be more difficult to quantify. This thesis did not quantify soil quality benefits perceived by many cooperating producers after long-term integration. Integrated farmers in Maine also mentioned that coupling provided more land base to expanding dairy farms and greater opportunities for disposal of livestock waste. Stringent changes in nutrient management plan requirements may make integration more appealing in areas with more limited land base for spreading manure. Land exchange may also reduce land rental costs for farms.

There were other benefits from integrating crops and livestock that were not included in representative budgets. Some coupled farms stated that their managerial skills improved from interaction with another specialized producer. Shared equipment and labor beyond what was specified in coupled budgets were also not included. Also, potential benefits of increased productivity for LF-coupled dairy farms from being able to focus solely on managing livestock were not accounted for in representative budgets.

There are several areas for future research. Coupling in Aroostook County likely may involve barley and soybeans and should be modeled. Sensitivity analyses should be conducted by changing milk prices, which have fluctuated substantially in recent years. The profitability of integrated versus non-integrated systems was not analyzed for potato and beef farms. Since there was only one pair of coupled beef and potato farms using forage grass as a potato rotation crop, the profitability of beef and potato integration and growing concentrated livestock feed crops for on-farm finishing was not studied.

Also, the profitability of on-farm integration for organic dairy farmers needs to be determined. Organic dairy farmers may benefit from on-farm integration since the prices for purchased concentrated feed are about double those for non-organic. Improving nutrient imbalances caused by importing chicken feed for large egg facilities in Maine was also not explored. Finally, the EPIC model needs to be better validated for potato rotations both unamended and amended with manure and compost.

New strategies in research, education, and policy may be needed to overcome some of the challenges to integrating crops and livestock. For example, manure and feed transportation between inter-farm couplers for distances beyond a spreading radius of ten miles could be subsidized. Processing costs for soybeans and barley could also be subsidized for on-farm integrated dairy farms. Tax incentives for re-establishing dairy operations in Aroostook County and subsidizing fluid milk transportation costs for northern Maine dairy producers are additional examples.

Coupled and on-farm integration encourage exchanges and transactions between producers that maintain economic activity in local communities and should be encouraged by policy makers. Researchers could develop predictive models of where integration is likely to be successful. Model results could help focus where limited funding could be directed to encourage crop and livestock integration. Agricultural extension could assist Maine potato and dairy farmers in taking nutrient credits during early phases of integration and in transitioning to more diversified enterprises such as crops grown for concentrated livestock feed and mixed vegetables.

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APPENDICES

Appendix A

CHARACTERISTICS OF COOPERATING PRODUCERS

Coupled Potato Farms

Small representative coupled potato farms grew potatoes in rotation with either barley or silage corn. Silage corn was grown under a coupling arrangement with a nearby dairy farm. One farm raised forage for sale to a coupled dairy farm. Total farm acreage was about 925 acres, of which 30% were owned. Crops took up about 763 acres, while average cultivated ground was about 499 acres. About 160 acres of potatoes were grown. Other crops included forage such as haylage and alfalfa.

Non-irrigated potato yields for cultivars ranged from 158 to 262 cwt/acre. Irrigated yields ranged from 250 to 320 cwt/acre. Average barley and silage corn yields were about 50 bu/acre and 15 tons/acre respectively. Haylage yields were normally about 9 tons/acre off of two cuts. Alfalfa yields were about 4 tons/acre for one cut off a newly established stand and about 9 tons/acre for three cuts off a mature crop.

The typical small, coupled farm was integrated in either a potato-corn rotation with a dairy farm or a potato-barley-clover rotation with a feeder beef farm. Manure was not applied during the potato year. Typical liquid manure applications were about 5000 gal/acre on corn and about 4000 gal/acre on grass using spreader trucks. Manure on corn was spring or fall applied, while manure on forage grass was applied during the fall. Beef manure was applied early during the clover year.

Integration with the dairy or beef farm had happened for a couple of years and involved land exchange. About 321 acres, or 64% of the representative farm's cultivated cropland was integrated. More acres were devoted to integration for the small representative potato farm compared to larger coupled potato farms since more forage was grown that was integrated with potatoes. Forage acres were classified as integrated in addition to potatoes for one of the farms used to derive this representative farm.

Medium coupled potato farm acreage was about 931 acres, of which 61% was owned. Crops took up 590 acres and cultivated cropland was 501 acres. About 316 acres of potatoes were grown. Smaller amounts of sweet corn, winter squash, and pumpkins were also grown. Non-irrigated potato yields for cultivars ranged from 215 to 230 cwt/acre. Irrigated yields ranged from 250 to 275 cwt/acre.

The potato farm had been integrated with a dairy farm from two to more than ten years. About 141 acres, or 28% of the farm's cultivated land was integrated. The medium-sized potato farm's integrated rotation was potato-corn or potato-corn-barley. Manure was not applied during the potato year. Typical liquid manure applications were 4000 to 7000 gal/acre on silage corn and 4500 gal/acre on green chop barley. Manure on silage corn was spring or fall applied, while manure on barley was applied during mid-summer.

Large coupled farms grew processing potato cultivars and both grain and silage corn. Rotation was two-year potato-corn. Irrigation was used for most potatoes. Typical non-irrigated potato yields ranged from 215 to 250 cwt/acre, while irrigated yields varied between 250 to 320 cwt/acre. Typical grain corn yields were about 90 bu/acre. Recently, the farm started to grow silage corn for a large dairy farm's expanding herd.

The coupled relationship with the large dairy farm involved exchanges of land and silage corn production for cash and manure. The potato farm had also been coupled with three small dairy farms for a few years. These relationships involved land exchange and explicit trades of operations for manure. Liquid dairy manure was spring applied at rates of 7000 gal/acre during the corn year. Solid dairy and hen manure were both applied between 5 to 11 tons/acre. About 19% of the farm's acreage was integrated.

Coupled Dairy Farms

Small representative coupled dairy farms milked about 67 Holsteins in either a tie stall or a small herringbone parlor. Farm herd average was about 206 cwt/year. There were about 64 heifers and calves. All forage was grown on-farm and concentrated feed was imported as a pellet grain mix. Total farm acreage was about 318 acres, with about 71% of those acres owned. Average crop acreage was about 184 acres, while average cultivated acreage was about 86 acres. Crops included forage such as silage corn, haylage, and dry hay. Average silage corn yields in 2001 were about 18 tons/acre. Grass yields for 2001 were about 8 tons of haylage harvested as first cut round bales and a second crop of 100 square bales/acre weighing 40 lb/bale.

Solid manure was bedded with sawdust. Manure storage included either a pit or stacking pad. Solid dairy manure was spread with solid spreaders at a rate of about 5 to 10 tons/acre on silage corn and 5 to 7 tons/acre on forage grass. The small, coupled dairy farm also used hen manure from large egg facilities applied at rates of about 5 to 11 tons/acre for silage corn and up to 5 tons/acre for grass. Hen manure was delivered without charge to field stacking sites. Conventional fertilizer use was limited on crops.

The representative farm was integrated in a potato-corn rotation with a nearby potato farm. Manure was either spring or fall applied to silage corn and was not applied during the potato year. Land exchange was involved. Integration with the potato farm had occurred for a few years and prior to the current arrangement, the representative farm was integrated with a former potato farm that sold its land to the current potato grower. About 57 acres, or 66% of the representative farm's cultivated ground was integrated.

Medium coupled dairy farms milked about 145 Holsteins in a medium sized herringbone parlor. Farm herd average was about 208 cwt/ year. There were about 107 young-stock. All forage was grown on-farm. Livestock concentrated feed was imported as grain or was grown on-farm (barley and soybeans). Barley was crushed at the farm. Soybeans were trucked to a processor where they were crushed for oil with the meal returned to the farm for feed.

Total farm acreage was about 714 acres, of which about 62% were owned. Average crop acreage was about 532 acres, while average cultivated land was about 322 acres. Major crops included forage such as silage corn, haylage, and alfalfa, in addition to the concentrated feed crops mentioned above. Average silage corn yields were about 16 tons/acre. Forage grass yields were about 6 tons/acre for two cuts of haylage. Alfalfa yields were about 13 tons/acre for three cuts and both barley and soybeans yielded about 76 bu/acre. Typical soybean yields in central Maine were 45 bu/acre.

Manure was bedded with either sand or sawdust depending on the season. Liquid manure was primarily stored in pits, while solid manure was stored on a stacking pad. Typical liquid manure applications ranged from 4000 to 7000 gal/acre on silage corn and were applied at about 4000 gal/acre on forage grass using spreader trucks. Manure was fall or spring applied on silage corn and applied during the mid-summer on grass. Solid dairy manure was spread on silage corn and grass with solid spreaders at rates ranging from 4 to 25 tons/acre. Application rates depended on soil tests. Conventional fertilizer applications were reduced for manured crops and if manure was spring applied.

The typical medium, coupled farm was integrated in a potato-corn rotation with a potato farm. Manure was spread on silage corn and not during the potato year. Integration involved land exchange or land rental from a common owner and had occurred for a couple of years. About 45 acres, or 14% of cultivated land was integrated. Less acreage was devoted to integration for medium compared to other sizes of coupled dairy farms. One reason for this was that the rest of the potato farmer's fields were beyond a feasible spreading and harvesting distance. Another reason was a lack of available potato acreage for integration due to the potato farmer being integrated with a second dairy farmer.

Large coupled dairy farms milked about 434 Holsteins in a large herringbone or parallel parlor. Farm herd average was about 229 cwt/year. There were 270 young-stock. All forage was grown on-farm and concentrated feed was imported as grain mixes. Total farm acreage was about 961 acres, of which about 76% was owned. Crops took up about 584 acres, while average cultivated cropland was about 434 acres. Crops included forage such as silage corn, haylage, green chop barley, and alfalfa. Silage corn and haylage yields were about 15 and 9 tons/acre respectively. Green chop barley yielded about 6 tons/acre. Alfalfa yields were about 4 tons/acre for one cut off a newly established crop and about 9 tons/acre for three cuts off a mature stand.

Manure was primarily bedded with sand but sawdust was used for young-stock. Most manure was stored in liquid pits. Typical liquid manure applications ranged from 5000 to 7000 gal/acre on silage corn and were applied at about 4000 to 6000 gal/acre on forage grass using spreader trucks. Manure on silage corn was spring or fall applied, while manure on forage grass was either applied during the fall or in two summer applications. Liquid manure was spread on green chop barley in mid-summer at about 4500 gal/acre. About 3000 to 4000 gal/acre of liquid dairy manure was spring applied on alfalfa. Conventional fertilizer applications were reduced on crops receiving manure. Inorganic fertilizer applications were reduced for spring compared to fall manure.

The large, coupled farm was integrated in either a potato-corn or a potato-corn-barley rotation with a potato farm. Manure was not applied during the potato year. Integration involved land exchange and had occurred for a couple of years to over a decade. About 180 acres, or 42% of the farm's cultivated land was integrated. Less acreage was devoted to integration for large compared to small, coupled dairy farms since one of the cooperating farms had a longer rotation involving more forage.

Coupled Beef Farm

The representative coupled beef farm was integrated with a nearby potato farm. The farm raised feeder cows for local finishing operations and sold feeder calves at auction. The farm's herd was split fairly evenly between Angus and Hereford/Charolais. The beef farm grew its own hay and haylage with some haylage sold to a local deer farm. Hay was baled as 800 lb round bales or 40 lb square bales. Haylage was baled as 1100 lb wet round wrapped bales. Cows were pastured during the growing season.

Solid beef manure was bedded with cedar shavings. Manure storage was a stacking pile. Solid manure was spread on most grass using a solid spreader at an average rate of about 10 tons/acre. Recently, the beef farm had been involved in a three-year rotation of potatoes-barley-clover with the potato farm. Manure was spread during the spring of the mammoth red clover year. The coupling arrangement involved land exchange. The coupled beef farm was integrated on only about 9% of its acreage.

On-Farm Integrated Farms

Dairy/Mixed Vegetable on-farm integrated dairy farms milked about 110 cows in either a medium-sized herringbone parlor or with a pipeline system in a tie stall barn. Farm herd average was about 188 cwt/year. There were about 88 heifers and calves. All forage was grown, while concentrated feed was both purchased and raised on-farm such as soybeans roasted cooperatively with other local farmers.

Total farm acreage was about 1142 acres, 71% of which was owned. Average crop and cultivated acreage were about 650 and 317 acres respectively. Major crops included forage such as silage corn, haylage, alfalfa, as well as the soybeans previously mentioned. Silage corn yields were 16 tons/acre. First cut haylage yielded about 5 to 8 tons/acre. Second cut per acre yields were either 15 wet wrapped bales or 50 square bales. Alfalfa yielded about 16 tons/acre for three cuts, while soybeans yielded about 70 bu/acre. Typical soybean yields in central Maine were 45 bu/acre.

Grain corn and oats were grown, yielding about 144 and 60 bu/acre respectively. The on-farm integrated dairy farm also raised sweet corn, winter squash, pumpkins, tomatoes, and various mixed vegetables. Mixed vegetables included potatoes, peas, green beans, cucumbers, summer squash, zucchini, onions, lettuce, beet greens, broccoli, cauliflower, and peppers. Vegetables were sold on-farm, at farmer's markets, and at local stores. Diversification included enterprise as well as crop diversification.

About 262 acres, or 83% of the representative farm's cultivated ground was integrated. Manure was bedded with either sand or sawdust. Liquid manure was primarily stored in pits, while solid manure was stored on a stacking pad. Hen manure from large egg facilities were also used on silage corn. Manure was either spring or fall-applied. Conventional fertilizer applications were reduced for manured crops.

If liquid dairy manure was used, it was applied at 5000 gal/acre on silage corn and forage grass using a spreader truck. Solid dairy manure applications on grain and silage corn were 5 tons/acre with an additional 3 tons/acre of hen manure. Solid manure was applied with solid spreaders on forage grass and mixed vegetables at 10 tons/acre. Sweet corn received either of the two previous types and amounts of manure. Manure was applied on alfalfa at rates of 8 tons/acre. Soybeans and oats were not manured.

Potato/Dairy on-farm integrated potato farms raised dairy replacements. Several processing potato cultivars were raised and forage was grown for livestock. Grain corn and small grains were sold as commodities to local distributors. Some potatoes were irrigated. Non-irrigated yields ranged from 230 to 250 cwt/acre. Other crops included silage and grain corn, forage grass, rye, and barley. Typical silage and grain corn yields were 18 tons/acre and 95 bu/acre respectively. Haylage was harvested in one cut of about 3 tons/acre. Rye and barley yielded about 60 bu/acre.

This representative farm was on-farm integrated on about 28% of its acreage. Solid manure was bedded with sawdust and was stored on a stacking pad. Manure was usually spread on silage corn at a rate of about 20 tons/acre during the spring using a solid spreader. Silage corn that got manure had spring-applied urea cut back from 100 to 50 lb/acre, while corn starter applications remained unchanged. The livestock component of the farm was managed as a separate operation from the cash and feed crops.

Appendix B-1

CENTRAL MAINE SMALL POTATO WHOLE-FARM BUDGETS

Central Maine Conventional Small[a]

	Acres	Yield/Acre	Unit Price
Potato	160	240 cwt	$6.88
Grain Corn	160	100 bu	$2.50
	Total	Per Acre	Per Cwt
Annual Revenue	**$304,107**	**$950.33**	**$6.42**
Annual Operating Expenses			
Seed	$41,658	$130.18	$0.88
Fertilizer	$33,010	$103.16	$0.70
Lime	$3,541	$11.07	$0.07
Chemicals	$30,238	$94.49	$0.64
Labor	$42,575	$133.05	$0.90
Diesel Fuel and Oil	$14,126	$44.14	$0.30
Maintenance and Upkeep	$21,538	$67.31	$0.45
Supplies	$10,815	$33.80	$0.23
Insurance	$8,917	$27.87	$0.19
Miscellaneous			
Utilities	$6,421	$20.07	$0.14
Custom Hire	$0	$0	$0
Rent or Lease	$12,000	$37.50	$0.25
Freight and Trucking	$2,849	$8.90	$0.06
Storage and Warehousing	$4,971	$15.53	$0.10
Other Expenses	$960	$3.00	$0.02
Interest	$6,452	$20.16	$0.14
Total Operating Expenses	**$240,070**	**$750.22**	**$5.07**
Annual Ownership Expenses			
Depreciation and Interest	$75,586	$236.21	$1.60
Tax and Insurance	$4,906	$15.33	$0.10
Total Ownership Expenses	**$80,492**	**$251.54**	**$1.70**
Total Annual Cost	**$320,562**	**$1,001.76**	**$6.77**
Net Farm Income (NFI)	**-$16,455**	**-$51.42**	**-$0.35**
Return over Variable Cost (ROVC)	**$64,036**	**$200.11**	**$1.35**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,001.76	$6.77
Short-run to Cover Operating Costs		$750.22	$5.07

[a] Numbers may not sum due to rounding.

Central Maine Long-Term Coupled Small
Land-Coupled[a]

	Acres	Yield/Acre	Unit Price
Potato	209	240 cwt	$6.88
Grain Corn	111	100 bu	$2.50

	Total	Per Acre	Per Cwt
Annual Revenue	**$372,740**	**$1,164.81**	**$6.61**
Annual Operating Expenses			
Seed	$51,788	$161.84	$0.92
Fertilizer	$16,205	$50.64	$0.29
Lime	$3,436	$10.74	$0.06
Chemicals	$37,109	$115.96	$0.66
Labor	$52,008	$162.53	$0.92
Diesel Fuel and Oil	$17,185	$53.70	$0.30
Maintenance and Upkeep	$26,046	$81.39	$0.46
Supplies	$13,147	$41.08	$0.23
Insurance	$11,616	$36.30	$0.21
Miscellaneous			
Utilities	$8,191	$25.60	$0.15
Custom Hire	$0	$0	$0
Rent or Lease	$14,450	$45.16	$0.26
Freight and Trucking	$3,721	$11.63	$0.07
Storage and Warehousing	$4,600	$14.37	$0.08
Other Expenses	$1,254	$3.92	$0.02
Interest	$7,201	$22.50	$0.13
Total Operating Expenses	**$267,957**	**$837.37**	**$4.75**
Annual Ownership Expenses			
Depreciation and Interest	$75,586	$236.21	$1.34
Tax and Insurance	$4,906	$15.33	$0.09
Total Ownership Expenses	**$80,492**	**$251.54**	**$1.43**
Total Annual Cost	**$348,449**	**$1,088.90**	**$6.18**
Net Farm Income (NFI)	**$24,291**	**$75.91**	**$0.43**
Return over Variable Cost (ROVC)	**$104,782**	**$327.44**	**$1.86**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,088.90	$6.18
Short-run to Cover Operating Costs		$837.37	$4.75

[a] Numbers may not sum due to rounding.

Central Maine Long-Term Coupled Small
Land/Feed-Coupled[a]

	Acres	Yield/Acre	Unit Price
Potato	209	240 cwt	$6.88
Grain Corn	111	100 bu	$2.50
Silage Corn	98	15 tons	$25.00
Hay	73	3.5 tons	$64.50

	Total	Per Acre[b]	Per Cwt
Annual Revenue	**$425,969**	**$867.55**	**$4.69**
Annual Operating Expenses			
Seed	$55,022	$112.06	$0.61
Fertilizer	$18,171	$37.01	$0.20
Lime	$5,355	$10.91	$0.06
Chemicals	$39,499	$80.45	$0.43
Labor	$61,210	$124.66	$0.67
Diesel Fuel and Oil	$19,507	$39.73	$0.21
Maintenance and Upkeep	$28,582	$58.21	$0.31
Supplies	$14,857	$30.26	$0.16
Insurance	$11,673	$23.77	$0.13
Miscellaneous			
Utilities	$8,191	$16.68	$0.09
Custom Hire	$0	$0	$0
Rent or Lease	$16,588	$33.78	$0.18
Freight and Trucking	$3,721	$7.58	$0.04
Storage and Warehousing	$4,869	$9.92	$0.05
Other Expenses	$2,109	$4.30	$0.02
Interest	$7,947	$16.19	$0.09
Total Operating Expenses	**$297,302**	**$605.50**	**$3.27**
Annual Ownership Expenses			
Depreciation and Interest	$83,459	$169.98	$0.92
Tax and Insurance	$5,585	$11.37	$0.06
Total Ownership Expenses	**$89,043**	**$181.35**	**$0.98**
Total Annual Cost	**$386,345**	**$786.85**	**$4.25**
Net Farm Income (NFI)	**$39,624**	**$80.70**	**$0.44**
Return over Variable Cost (ROVC)	**$128,667**	**$262.05**	**$1.42**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$786.85	$4.25
Short-run to Cover Operating Costs		$605.50	$3.27

[a] Numbers may not sum due to rounding.
[b] Acreage in denominator included all operated crop acres.

Appendix B-2

CENTRAL MAINE MEDIUM-LARGE POTATO WHOLE-FARM BUDGETS

Central Maine Conventional Medium-Large[a]

	Acres	Yield/Acre	Unit Price
Potato	320	240 cwt	$6.88
Grain Corn	320	100 bu	$2.50

	Total	Per Acre	Per Cwt
Annual Revenue	**$608,214**	**$950.33**	**$6.42**
Annual Operating Expenses			
Seed	$83,316	$130.18	$0.88
Fertilizer	$66,019	$103.16	$0.70
Lime	$7,082	$11.07	$0.07
Chemicals	$60,477	$94.49	$0.64
Labor	$76,243	$119.13	$0.80
Diesel Fuel and Oil	$26,014	$40.65	$0.27
Maintenance and Upkeep	$40,677	$63.56	$0.43
Supplies	$21,630	$33.80	$0.23
Insurance	$17,835	$27.87	$0.19
Miscellaneous			
Utilities	$12,842	$20.07	$0.14
Custom Hire	$0	$0	$0
Rent or Lease	$22,000	$34.38	$0.23
Freight and Trucking	$5,698	$8.90	$0.06
Storage and Warehousing	$9,941	$15.53	$0.10
Other Expenses	$1,920	$3.00	$0.02
Interest	$12,474	$19.49	$0.13
Total Operating Expenses	**$464,167**	**$725.26**	**$4.90**
Annual Ownership Expenses			
Depreciation and Interest	$124,128	$193.95	$1.31
Tax and Insurance	$8,178	$12.78	$0.09
Total Ownership Expenses	**$132,305**	**$206.73**	**$1.40**
Total Annual Cost	**$596,472**	**$931.99**	**$6.30**
Net Farm Income (NFI)	**$11,741**	**$18.35**	**$0.12**
Return over Variable Cost (ROVC)	**$144,047**	**$225.07**	**$1.52**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$931.99	$6.30
Short-run to Cover Operating Costs		$725.26	$4.90

[a] Numbers may not sum due to rounding.

Central Maine Long-Term Coupled Medium-Large
Land-Coupled[a]

	Acres	Yield/Acre	Unit Price
Potato	480	240 cwt	$6.88
Grain Corn	160	100 bu	$2.50
	Total	Per Acre	Per Cwt
Annual Revenue	**$832,320**	**$1,300.50**	**$6.70**
Annual Operating Expenses			
Seed	$116,394	$181.87	$0.94
Fertilizer	$31,008	$48.45	$0.25
Lime	$6,741	$10.53	$0.05
Chemicals	$82,910	$129.55	$0.67
Labor	$103,046	$161.01	$0.83
Diesel Fuel and Oil	$34,886	$54.51	$0.28
Maintenance and Upkeep	$56,324	$88.01	$0.45
Supplies	$29,245	$45.69	$0.24
Insurance	$26,647	$41.64	$0.21
Miscellaneous			
Utilities	$18,623	$29.10	$0.15
Custom Hire	$0	$0	$0
Rent or Lease	$29,000	$45.31	$0.23
Freight and Trucking	$8,546	$13.35	$0.07
Storage and Warehousing	$8,730	$13.64	$0.07
Other Expenses	$2,880	$4.50	$0.02
Interest	$15,326	$23.95	$0.12
Total Operating Expenses	**$570,306**	**$891.10**	**$4.59**
Annual Ownership Expenses			
Depreciation and Interest	$123,872	$193.55	$1.00
Tax and Insurance	$8,178	$12.78	$0.07
Total Ownership Expenses	**$132,049**	**$206.33**	**$1.06**
Total Annual Cost	**$702,355**	**$1,097.43**	**$5.66**
Net Farm Income (NFI)	**$129,965**	**$203.07**	**$1.05**
Return over Variable Cost (ROVC)	**$262,015**	**$409.40**	**$2.11**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$1,097.43	$5.66
Short-run to Cover Operating Costs		$891.10	$4.59

[a] Numbers may not sum due to rounding.

Central Maine Long-Term Coupled Medium-Large
Land/Feed-Coupled[a]

	Acres	Yield/Acre	Unit Price
Potato	480	240 cwt	$6.88
Grain Corn	160	100 bu	$2.50
Silage Corn	320	15 tons	$25.00
Haylage	200	6 tons	$32.55

	Total	Per Acre[b]	Per Cwt
Annual Revenue	**$991,380**	**$854.64**	**$4.06**
Annual Operating Expenses			
Seed	$126,954	$109.44	$0.52
Fertilizer	$40,928	$35.28	$0.17
Lime	$12,622	$10.88	$0.05
Chemicals	$90,715	$78.20	$0.37
Labor	$126,137	$108.74	$0.52
Diesel Fuel and Oil	$42,883	$36.97	$0.18
Maintenance and Upkeep	$61,741	$53.22	$0.25
Supplies	$34,445	$29.69	$0.14
Insurance	$26,820	$23.12	$0.11
Miscellaneous			
Utilities	$18,623	$16.05	$0.08
Custom Hire	$0	$0	$0
Rent or Lease	$35,500	$30.60	$0.15
Freight and Trucking	$8,546	$7.37	$0.04
Storage and Warehousing	$9,570	$8.25	$0.04
Other Expenses	$5,480	$4.72	$0.02
Interest	$17,473	$15.06	$0.07
Total Operating Expenses	**$658,437**	**$567.62**	**$2.70**
Annual Ownership Expenses			
Depreciation and Interest	$140,720	$121.31	$0.58
Tax and Insurance	$9,898	$8.53	$0.04
Total Ownership Expenses	**$150,618**	**$129.84**	**$0.62**
Total Annual Cost	**$809,055**	**$697.46**	**$3.31**
Net Farm Income (NFI)	**$182,325**	**$157.18**	**$0.75**
Return over Variable Cost (ROVC)	**$332,943**	**$287.02**	**$1.36**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$697.46	$3.31
Short-run to Cover Operating Costs		$567.62	$2.70

[a] Numbers may not sum due to rounding.
[b] Acreage in denominator included all operated crop acres.

Appendix B-3

AROOSTOOK SMALL POTATO WHOLE-FARM BUDGETS

Aroostook County Conventional Small[a]

		Acres	Yield/Acre	Unit Price
	Potato	160	283 cwt	$5.81
	Barley	160	71 bu	$1.50
		Total	Per Acre	Per Cwt
Annual Revenue		**$279,587**	**$873.71**	**$5.52**
Annual Operating Expenses				
Seed		$33,370	$104.28	$0.66
Fertilizer		$22,405	$70.02	$0.44
Lime		$3,541	$11.07	$0.07
Chemicals		$29,305	$91.58	$0.58
Labor		$39,730	$124.16	$0.78
Diesel Fuel and Oil		$13,733	$42.92	$0.27
Maintenance and Upkeep		$19,883	$62.13	$0.39
Supplies		$10,815	$33.80	$0.21
Insurance		$8,918	$27.87	$0.18
Miscellaneous				
Utilities		$6,261	$19.57	$0.12
Custom Hire		$0	$0	$0
Rent or Lease		$12,000	$37.50	$0.24
Freight and Trucking		$3,202	$10.01	$0.06
Storage and Warehousing		$1,879	$5.87	$0.04
Other Expenses		$1,930	$6.03	$0.04
Interest		$5,716	$17.86	$0.11
Total Operating Expenses		**$212,689**	**$664.65**	**$4.20**
Annual Ownership Expenses				
Depreciation and Interest		$71,722	$224.13	$1.42
Tax and Insurance		$4,703	$14.70	$0.09
Total Ownership Expenses		**$76,424**	**$238.83**	**$1.51**
Total Annual Cost		**$289,113**	**$903.48**	**$5.71**
Net Farm Income (NFI)		**-$9,526**	**-$29.77**	**-$0.19**
Return over Variable Cost (ROVC)		**$66,898**	**$209.06**	**$1.32**
Performance Measures				
Breakeven Revenue			$/acre	$/cwt
Long-run to Cover All Costs			$903.48	$5.71
Short-run to Cover Operating Costs			$664.65	$4.20

[a] Numbers may not sum due to rounding.

Aroostook County Long-Term Coupled Small
Land-Coupled[a]

		Acres	Yield/Acre	Unit Price
	Potato	172.25	283 cwt	$5.81
	Barley	147.75	71 bu	$1.50

	Total	Per Acre	Per Cwt
Annual Revenue	**$298,391**	**$932.47**	**$5.56**
Annual Operating Expenses			
Seed	$35,457	$110.80	$0.66
Fertilizer	$8,659	$27.06	$0.16
Lime	$3,515	$10.98	$0.07
Chemicals	$31,427	$98.21	$0.59
Labor	$42,261	$132.07	$0.79
Diesel Fuel and Oil	$14,520	$45.37	$0.27
Maintenance and Upkeep	$20,503	$64.07	$0.38
Supplies	$11,398	$35.62	$0.21
Insurance	$9,593	$29.98	$0.18
Miscellaneous			
Utilities	$6,716	$20.99	$0.13
Custom Hire	$0	$0	$0
Rent or Lease	$12,613	$39.41	$0.23
Freight and Trucking	$3,393	$10.60	$0.06
Storage and Warehousing	$2,023	$6.32	$0.04
Other Expenses	$1,955	$6.11	$0.04
Interest	$5,650	$17.66	$0.11
Total Operating Expenses	**$209,682**	**$655.26**	**$3.91**
Annual Ownership Expenses			
Depreciation and Interest	$58,918	$184.12	$1.10
Tax and Insurance	$3,815	$11.92	$0.07
Total Ownership Expenses	**$62,733**	**$196.04**	**$1.17**
Total Annual Cost	**$272,415**	**$851.30**	**$5.07**
Net Farm Income (NFI)	**$25,976**	**$81.17**	**$0.48**
Return over Variable Cost (ROVC)	**$88,709**	**$277.22**	**$1.65**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$851.30	$5.07
Short-run to Cover Operating Costs		$655.26	$3.91

[a] Numbers may not sum due to rounding.

Aroostook County Long-Term Coupled Small
Land/Feed-Coupled[a]

		Acres	Yield/Acre	Unit Price
	Potato	172.25	283 cwt	$5.81
	Barley	147.75	71 bu	$1.50
	Alfalfa	98	6.25 tons	$50.00
	Hay	73	3.5 tons	$64.50

	Total	Per Acre[b]	Per Cwt
Annual Revenue	**$345,495**	**$703.66**	**$4.86**
Annual Operating Expenses			
Seed	$36,988	$75.33	$0.52
Fertilizer	$9,429	$19.20	$0.13
Lime	$5,225	$10.64	$0.07
Chemicals	$32,024	$65.22	$0.45
Labor	$49,219	$100.24	$0.69
Diesel Fuel and Oil	$16,259	$33.11	$0.23
Maintenance and Upkeep	$23,107	$47.06	$0.33
Supplies	$13,108	$26.70	$0.18
Insurance	$9,649	$19.65	$0.14
Miscellaneous			
Utilities	$6,716	$13.68	$0.09
Custom Hire	$0	$0	$0
Rent or Lease	$12,613	$25.69	$0.18
Freight and Trucking	$3,393	$6.91	$0.05
Storage and Warehousing	$6,384	$13.00	$0.09
Other Expenses	$2,810	$5.72	$0.04
Interest	$6,247	$12.72	$0.09
Total Operating Expenses	**$233,171**	**$474.89**	**$3.28**
Annual Ownership Expenses			
Depreciation and Interest	$74,823	$152.39	$1.05
Tax and Insurance	$4,865	$9.91	$0.07
Total Ownership Expenses	**$79,688**	**$162.30**	**$1.12**
Total Annual Cost	**$312,858**	**$637.19**	**$4.40**
Net Farm Income (NFI)	**$32,637**	**$66.47**	**$0.46**
Return over Variable Cost (ROVC)	**$112,325**	**$228.77**	**$1.58**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$637.19	$4.40
Short-run to Cover Operating Costs		$474.89	$3.28

[a] Numbers may not sum due to rounding.
[b] Acreage in denominator included all operated crop acres.

Aroostook County Long-Term Coupled Small
Land/Feed-Coupled Start Up[a]

		Acres	Yield/Acre	Unit Price
	Potato	172.25	283 cwt	$5.81
	Barley	147.75	71 bu	$1.50
	Alfalfa	98	6.25 tons	$50.00
	Hay	73	3.5 tons	$64.50

	Total	Per Acre[b]	Per Cwt
Annual Revenue	**$345,495**	**$703.66**	**$4.86**
Annual Operating Expenses			
Seed	$36,988	$75.33	$0.52
Fertilizer	$9,429	$19.20	$0.13
Lime	$5,225	$10.64	$0.07
Chemicals	$32,024	$65.22	$0.45
Labor	$49,219	$100.24	$0.69
Diesel Fuel and Oil	$16,259	$33.11	$0.23
Maintenance and Upkeep	$23,812	$48.50	$0.34
Supplies	$13,108	$26.70	$0.18
Insurance	$9,649	$19.65	$0.14
Miscellaneous			
Utilities	$6,716	$13.68	$0.09
Custom Hire	$0	$0	$0
Rent or Lease	$14,750	$30.04	$0.21
Freight and Trucking	$3,393	$6.91	$0.05
Storage and Warehousing	$6,384	$13.00	$0.09
Other Expenses	$2,810	$5.72	$0.04
Interest	$6,325	$12.88	$0.09
Total Operating Expenses	**$236,092**	**$480.84**	**$3.32**
Annual Ownership Expenses			
Depreciation and Interest	$78,846	$160.58	$1.11
Tax and Insurance	$5,344	$10.88	$0.08
Total Ownership Expenses	**$84,191**	**$171.47**	**$1.19**
Total Annual Cost	**$320,283**	**$652.31**	**$4.51**
Net Farm Income (NFI)	**$25,213**	**$51.35**	**$0.35**
Return over Variable Cost (ROVC)	**$109,403**	**$222.82**	**$1.54**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$652.31	$4.51
Short-run to Cover Operating Costs		$480.84	$3.32

[a] Numbers may not sum due to rounding.
[b] Acreage in denominator included all operated crop acres.

Appendix B-4

AROOSTOOK MEDIUM-LARGE POTATO WHOLE-FARM BUDGETS

Aroostook County Conventional Medium-Large[a]

		Acres	Yield/Acre	Unit Price
	Potato	320	283 cwt	$5.81
	Barley	320	71 bu	$1.50
		Total	Per Acre	Per Cwt
Annual Revenue		**$559,174**	**$873.71**	**$5.52**
Annual Operating Expenses				
Seed		$66,740	$104.28	$0.66
Fertilizer		$44,810	$70.02	$0.44
Lime		$7,082	$11.07	$0.07
Chemicals		$58,611	$91.58	$0.58
Labor		$70,332	$109.89	$0.69
Diesel Fuel and Oil		$25,229	$39.42	$0.25
Maintenance and Upkeep		$38,693	$60.46	$0.38
Supplies		$21,630	$33.80	$0.21
Insurance		$17,836	$27.87	$0.18
Miscellaneous				
Utilities		$12,522	$19.57	$0.12
Custom Hire		$0	$0	$0
Rent or Lease		$22,000	$34.38	$0.22
Freight and Trucking		$6,405	$10.01	$0.06
Storage and Warehousing		$3,759	$5.87	$0.04
Other Expenses		$3,860	$6.03	$0.04
Interest		$11,033	$17.24	$0.11
Total Operating Expenses		**$410,541**	**$641.47**	**$4.05**
Annual Ownership Expenses				
Depreciation and Interest		$119,429	$186.61	$1.18
Tax and Insurance		$7,929	$12.39	$0.08
Total Ownership Expenses		**$127,358**	**$199.00**	**$1.26**
Total Annual Cost		**$537,900**	**$840.47**	**$5.31**
Net Farm Income (NFI)		**$21,275**	**$33.24**	**$0.21**
Return over Variable Cost (ROVC)		**$148,633**	**$232.24**	**$1.47**
Performance Measures				
Breakeven Revenue			$/acre	$/cwt
Long-run to Cover All Costs			$840.47	$5.31
Short-run to Cover Operating Costs			$641.47	$4.05

[a] Numbers may not sum due to rounding.

Aroostook County Long-Term Coupled Medium-Large
Land-Coupled[a]

		Acres	Yield/Acre	Unit Price
	Potato	360	283 cwt	$5.81
	Barley	280	71 bu	$1.50
		Total	Per Acre	Per Cwt
Annual Revenue		**$620,573**	**$969.65**	**$5.58**
Annual Operating Expenses				
Seed		$73,554	$114.93	$0.66
Fertilizer		$17,957	$28.06	$0.16
Lime		$6,996	$10.93	$0.06
Chemicals		$65,537	$102.40	$0.59
Labor		$77,686	$121.38	$0.70
Diesel Fuel and Oil		$27,529	$43.01	$0.25
Maintenance and Upkeep		$42,017	$65.65	$0.38
Supplies		$23,533	$36.77	$0.21
Insurance		$20,039	$31.31	$0.18
Miscellaneous				
Utilities		$14,007	$21.89	$0.13
Custom Hire		$0	$0	$0
Rent or Lease		$23,750	$37.11	$0.21
Freight and Trucking		$7,029	$10.98	$0.06
Storage and Warehousing		$4,229	$6.61	$0.04
Other Expenses		$3,943	$6.16	$0.04
Interest		$11,281	$17.63	$0.10
Total Operating Expenses		**$419,089**	**$654.83**	**$3.77**
Annual Ownership Expenses				
Depreciation and Interest		$100,644	$157.26	$0.90
Tax and Insurance		$6,668	$10.42	$0.06
Total Ownership Expenses		**$107,311**	**$167.67**	**$0.96**
Total Annual Cost		**$526,400**	**$822.50**	**$4.73**
Net Farm Income (NFI)		**$94,174**	**$147.15**	**$0.85**
Return over Variable Cost (ROVC)		**$201,485**	**$314.82**	**$1.81**
Performance Measures				
Breakeven Revenue			$/acre	$/cwt
Long-run to Cover All Costs			$822.50	$4.73
Short-run to Cover Operating Costs			$654.83	$3.77

[a] Numbers may not sum due to rounding.

Aroostook County Long-Term Coupled Medium-Large
Land/Feed-Coupled[a]

		Acres	Yield/Acre	Unit Price
	Potato	360	283 cwt	$5.81
	Barley	280	71 bu	$1.50
	Alfalfa	320	6.25 tons	$50.00
	Haylage	200	6 tons	$32.55

	Total	Per Acre[b]	Per Cwt
Annual Revenue	**$759,633**	**$654.86**	**$4.34**
Annual Operating Expenses			
Seed	$78,554	$67.72	$0.45
Fertilizer	$23,002	$19.83	$0.13
Lime	$12,196	$10.51	$0.07
Chemicals	$67,488	$58.18	$0.39
Labor	$94,811	$81.73	$0.54
Diesel Fuel and Oil	$34,943	$30.12	$0.20
Maintenance and Upkeep	$46,025	$39.68	$0.26
Supplies	$28,733	$24.77	$0.16
Insurance	$20,211	$17.42	$0.12
Miscellaneous			
Utilities	$14,007	$12.08	$0.08
Custom Hire	$0	$0	$0
Rent or Lease	$23,750	$20.47	$0.14
Freight and Trucking	$7,029	$6.06	$0.04
Storage and Warehousing	$5,069	$4.37	$0.03
Other Expenses	$6,543	$5.64	$0.04
Interest	$12,643	$10.90	$0.07
Total Operating Expenses	**$475,005**	**$409.49**	**$2.71**
Annual Ownership Expenses			
Depreciation and Interest	$125,193	$107.92	$0.71
Tax and Insurance	$8,253	$7.11	$0.05
Total Ownership Expenses	**$133,446**	**$115.04**	**$0.76**
Total Annual Cost	**$608,450**	**$524.53**	**$3.47**
Net Farm Income (NFI)	**$151,183**	**$130.33**	**$0.86**
Return over Variable Cost (ROVC)	**$284,629**	**$245.37**	**$1.62**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$524.53	$3.47
Short-run to Cover Operating Costs		$409.49	$2.71

[a] Numbers may not sum due to rounding.
[b] Acreage in denominator included all operated crop acres.

Aroostook County Long-Term Coupled Medium-Large
Land/Feed-Coupled Start Up[a]

		Acres	Yield/Acre	Unit Price
	Potato	360	283 cwt	$5.81
	Barley	280	71 bu	$1.50
	Alfalfa	320	6.25 tons	$50.00
	Haylage	200	6 tons	$32.55

	Total	Per Acre[b]	Per Cwt
Annual Revenue	**$759,633**	**$654.86**	**$4.34**
Annual Operating Expenses			
Seed	$78,554	$67.72	$0.45
Fertilizer	$23,002	$19.83	$0.13
Lime	$12,196	$10.51	$0.07
Chemicals	$67,488	$58.18	$0.39
Labor	$94,811	$81.73	$0.54
Diesel Fuel and Oil	$34,943	$30.12	$0.20
Maintenance and Upkeep	$48,170	$41.53	$0.27
Supplies	$28,733	$24.77	$0.16
Insurance	$20,211	$17.42	$0.12
Miscellaneous			
Utilities	$14,007	$12.08	$0.08
Custom Hire	$0	$0	$0
Rent or Lease	$30,250	$26.08	$0.17
Freight and Trucking	$7,029	$6.06	$0.04
Storage and Warehousing	$5,069	$4.37	$0.03
Other Expenses	$6,543	$5.64	$0.04
Interest	$12,882	$11.11	$0.07
Total Operating Expenses	**$483,888**	**$417.15**	**$2.76**
Annual Ownership Expenses			
Depreciation and Interest	$137,428	$118.47	$0.78
Tax and Insurance	$9,712	$8.37	$0.06
Total Ownership Expenses	**$147,139**	**$126.84**	**$0.84**
Total Annual Cost	**$631,028**	**$543.99**	**$3.60**
Net Farm Income (NFI)	**$128,606**	**$110.87**	**$0.73**
Return over Variable Cost (ROVC)	**$275,745**	**$237.71**	**$1.57**
Performance Measures			
Breakeven Revenue		$/acre	$/cwt
Long-run to Cover All Costs		$543.99	$3.60
Short-run to Cover Operating Costs		$417.15	$2.76

[a] Numbers may not sum due to rounding.
[b] Acreage in denominator included all operated crop acres.

Appendix C-1

CENTRAL MAINE SMALL DAIRY WHOLE-FARM BUDGETS

Central Maine Conventional Small[a]

	Total	Per Cow	Per Cwt
Number of Cows	66	-	-
Annual Milk Shipment (cwt)	10,413	159	-
Annual Revenue			
Milk Receipts	$157,878	$2,407.52	$15.16
Crop and Hay Revenue	$4,059	$61.90	$0.39
Livestock Revenue	$8,730	$133.13	$0.84
"Other" Revenue	$0	$0	$0
Total Revenue	**$170,668**	**$2,602.56**	**$16.39**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$10,824	$165.07	$1.04
Subtotal	*$10,824*	*$165.07*	*$1.04*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$42,344	$645.72	$4.07
Subtotal	*$42,344*	*$645.72*	*$4.07*
Livestock Expenses			
Breeding Fees	$1,971	$30.06	$0.19
Veterinary and Medicine	$4,201	$64.06	$0.40
Bedding	$2,362	$36.02	$0.23
DHIA Expenses	$729	$11.12	$0.07
Livestock Insurance	$1,486	$22.66	$0.14
Subtotal	*$10,749*	*$163.91*	*$1.03*
Crop and Pasture Expenses			
Seeds	$3,234	$49.32	$0.31
Chemicals	$2,390	$36.45	$0.23
Fertilizer	$2,248	$34.28	$0.22
Lime	$1,919	$29.26	$0.18
Other	$5,028	$76.67	$0.48
Subtotal	*$14,819*	*$225.98*	*$1.42*
Maintenance and Equipment Expenses			
Fuel and Oil	$5,902	$90.00	$0.57
Machinery Repairs	$11,986	$182.78	$1.15
Subtotal	*$17,888*	*$272.78*	*$1.72*

Central Maine Conventional Small Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$1,446	$22.05	$0.14
Hauling and Trucking	$6,404	$97.66	$0.62
Subtotal	*$7,850*	*$119.70*	*$0.75*
Interest (5.4% on 1/2 of total operating expense)	$2,821	$43.02	$0.27
Total Operating Expenses	**$107,296**	**$1,636.18**	**$10.30**
Annual Overhead Expenses			
Property Tax	$7,869	$120.00	$0.76
Farm Insurance	$7,883	$120.21	$0.76
Dues and Professional Fees	$1,018	$15.52	$0.10
Utilities	$6,362	$97.01	$0.61
Miscellaneous	$14,946	$227.91	$1.44
Total Overhead Expenses	**$38,078**	**$580.66**	**$3.66**
Annual Depreciation and Interest Expenses			
Land	$8,081	$123.23	$0.78
Buildings	$25,738	$392.48	$2.47
Machinery and Equipment	$16,750	$255.42	$1.61
Subtotal	*$50,569*	*$771.13*	*$4.86*
Livestock Herd Expenses			
Cows (Milking and Dry)	$10,444	$159.26	$1.00
Heifers	$4,407	$67.21	$0.42
Calves	$1,658	$25.28	$0.16
Dairy Bulls	$75	$1.15	$0.01
Subtotal	*$16,584*	*$252.90*	*$1.59*
Total Ownership Expenses	**$67,153**	**$1,024.03**	**$6.45**
Total Annual Cost	**$212,526**	**$3,240.87**	**$20.41**
Net Farm Income (NFI)	**-$41,859**	**-$638.31**	**-$4.02**
Return over Variable Cost (ROVC)	**$25,294**	**$385.72**	**$2.43**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$3,045.83	$19.18
Short-run to Cover Operating Costs		$2,021.80	$12.73

[a] Numbers may not sum due to rounding.

Central Maine Long-Term Coupled
Small Land-Coupled[a]

	Total	Per Cow	Per Cwt
Number of Cows	66	-	-
Annual Milk Shipment (cwt)	10,413	159	-
Annual Revenue			
Milk Receipts	$157,878	$2,407.52	$15.16
Crop and Hay Revenue	$4,059	$61.90	$0.39
Livestock Revenue	$8,730	$133.13	$0.84
"Other" Revenue	$0	$0	$0
Total Revenue	**$170,668**	**$2,602.56**	**$16.39**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$10,824	$165.07	$1.04
Subtotal	*$10,824*	*$165.07*	*$1.04*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$42,344	$645.72	$4.07
Subtotal	*$42,344*	*$645.72*	*$4.07*
Livestock Expenses			
Breeding Fees	$1,971	$30.06	$0.19
Veterinary and Medicine	$4,201	$64.06	$0.40
Bedding	$2,362	$36.02	$0.23
DHIA Expenses	$729	$11.12	$0.07
Livestock Insurance	$1,486	$22.66	$0.14
Subtotal	*$10,749*	*$163.91*	*$1.03*
Crop and Pasture Expenses			
Seeds	$3,234	$49.32	$0.31
Chemicals	$2,390	$36.45	$0.23
Fertilizer	$1,967	$29.99	$0.19
Lime	$1,919	$29.26	$0.18
Other	$5,028	$76.67	$0.48
Subtotal	*$14,537*	*$221.69*	*$1.40*
Maintenance and Equipment Expenses			
Fuel and Oil	$5,902	$90.00	$0.57
Machinery Repairs	$11,986	$182.78	$1.15
Subtotal	*$17,888*	*$272.78*	*$1.72*

Central Maine Long-Term Coupled
Small Land-Coupled Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$1,446	$22.05	$0.14
Hauling and Trucking	$6,404	$97.66	$0.62
Subtotal	*$7,850*	*$119.70*	*$0.75*
Interest (5.4% on 1/2 of total operating expense)	$2,813	$42.90	$0.27
Total Operating Expenses	**$107,006**	**$1,631.77**	**$10.28**
Annual Overhead Expenses			
Property Tax	$7,869	$120.00	$0.76
Farm Insurance	$7,883	$120.21	$0.76
Dues and Professional Fees	$1,018	$15.52	$0.10
Utilities	$6,362	$97.01	$0.61
Miscellaneous	$14,946	$227.91	$1.44
Total Overhead Expenses	**$38,078**	**$580.66**	**$3.66**
Annual Depreciation and Interest Expenses			
Land	$8,081	$123.23	$0.78
Buildings	$25,738	$392.48	$2.47
Machinery and Equipment	$16,750	$255.42	$1.61
Subtotal	*$50,569*	*$771.13*	*$4.86*
Livestock Herd Expenses			
Cows (Milking and Dry)	$10,444	$159.26	$1.00
Heifers	$4,407	$67.21	$0.42
Calves	$1,658	$25.28	$0.16
Dairy Bulls	$75	$1.15	$0.01
Subtotal	*$16,584*	*$252.90*	*$1.59*
Total Ownership Expenses	**$67,153**	**$1,024.03**	**$6.45**
Total Annual Cost	**$212,237**	**$3,236.46**	**$20.38**
Net Farm Income (NFI)	**-$41,569**	**-$633.90**	**-$3.99**
Return over Variable Cost (ROVC)	**$25,584**	**$390.13**	**$2.46**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$3,041.42	$19.15
Short-run to Cover Operating Costs		$2,017.39	$12.70

[a] Numbers may not sum due to rounding.

Central Maine Long-Term Coupled
Small Land/Feed-Coupled[a]

	Total	Per Cow	Per Cwt
Number of Cows	66	-	-
Annual Milk Shipment (cwt)	10,413	159	-
Annual Revenue			
Milk Receipts	$157,878	$2,407.52	$15.16
Crop and Hay Revenue	$4,059	$61.90	$0.39
Livestock Revenue	$8,730	$133.13	$0.84
"Other" Revenue	$0	$0	$0
Total Revenue	**$170,668**	**$2,602.56**	**$16.39**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$1,622	$24.74	$0.16
Subtotal	*$1,622*	*$24.74*	*$0.16*
Purchased Feed Expenses			
Dairy Forage	$49,170	$749.81	$4.72
Dairy Concentrate	$42,344	$645.72	$4.07
Subtotal	*$91,515*	*$1,395.53*	*$8.79*
Livestock Expenses			
Breeding Fees	$1,971	$30.06	$0.19
Veterinary and Medicine	$4,201	$64.06	$0.40
Bedding	$2,362	$36.02	$0.23
DHIA Expenses	$729	$11.12	$0.07
Livestock Insurance	$1,486	$22.66	$0.14
Subtotal	*$10,749*	*$163.91*	*$1.03*
Crop and Pasture Expenses			
Seeds	$0	$0	$0
Chemicals	$0	$0	$0
Fertilizer	$0	$0	$0
Lime	$0	$0	$0
Other	$0	$0	$0
Subtotal	*$0*	*$0*	*$0*
Maintenance and Equipment Expenses			
Fuel and Oil	$3,580	$54.59	$0.34
Machinery Repairs	$7,426	$113.25	$0.71
Subtotal	*$11,006*	*$167.84*	*$1.06*

Central Maine Long-Term Coupled
Small Land/Feed-Coupled Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$1,446	$22.05	$0.14
Hauling and Trucking	$6,404	$97.66	$0.62
Subtotal	*$7,850*	*$119.70*	*$0.75*
Interest (5.4% on 1/2 of total operating expense)	$3,314	$50.54	$0.32
Total Operating Expenses	**$126,056**	**$1,922.26**	**$12.11**
Annual Overhead Expenses			
Property Tax	$7,869	$120.00	$0.76
Farm Insurance	$6,810	$103.84	$0.65
Dues and Professional Fees	$1,018	$15.52	$0.10
Utilities	$6,362	$97.01	$0.61
Miscellaneous	$14,946	$227.91	$1.44
Total Overhead Expenses	**$37,004**	**$564.29**	**$3.55**
Annual Depreciation and Interest Expenses			
Land	$8,081	$123.23	$0.78
Buildings	$25,738	$392.48	$2.47
Machinery and Equipment	$7,658	$116.78	$0.74
Subtotal	*$41,477*	*$632.49*	*$3.98*
Livestock Herd Expenses			
Cows (Milking and Dry)	$10,444	$159.26	$1.00
Heifers	$4,407	$67.21	$0.42
Calves	$1,658	$25.28	$0.16
Dairy Bulls	$75	$1.15	$0.01
Subtotal	*$16,584*	*$252.90*	*$1.59*
Total Ownership Expenses	**$58,061**	**$885.39**	**$5.58**
Total Annual Cost	**$221,122**	**$3,371.94**	**$21.24**
Net Farm Income (NFI)	**-$50,454**	**-$769.39**	**-$4.85**
Return over Variable Cost (ROVC)	**$7,607**	**$116.01**	**$0.73**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$3,176.91	$20.01
Short-run to Cover Operating Costs		$2,291.51	$14.43

[a] Numbers may not sum due to rounding.

Central Maine Long-Term On-Farm Integrated Small[a]

	Total	Per Cow	Per Cwt
Number of Cows	66	-	-
Annual Milk Shipment (cwt)	10,413	159	-
Annual Revenue			
Milk Receipts	$157,878	$2,407.52	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$8,730	$133.13	$0.84
"Other" Revenue	$0	$0	$0
Total Revenue	**$166,608**	**$2,540.65**	**$16.00**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$11,943	$182.13	$1.15
Subtotal	*$11,943*	*$182.13*	*$1.15*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$639	$9.74	$0.06
Subtotal	*$639*	*$9.74*	*$0.06*
Livestock Expenses			
Breeding Fees	$1,971	$30.06	$0.19
Veterinary and Medicine	$4,201	$64.06	$0.40
Bedding	$2,362	$36.02	$0.23
DHIA Expenses	$729	$11.12	$0.07
Livestock Insurance	$1,486	$22.66	$0.14
Subtotal	*$10,749*	*$163.91*	*$1.03*
Crop and Pasture Expenses			
Seeds	$4,176	$63.68	$0.40
Chemicals	$2,645	$40.34	$0.25
Fertilizer	$1,898	$28.94	$0.18
Lime	$2,459	$37.50	$0.24
Other	$6,069	$92.54	$0.58
Subtotal	*$17,247*	*$263.00*	*$1.66*
Maintenance and Equipment Expenses			
Fuel and Oil	$7,048	$107.47	$0.68
Machinery Repairs	$14,015	$213.71	$1.35
Subtotal	*$21,062*	*$321.18*	*$2.02*

Central Maine Long-Term
On-Farm Integrated Small Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$1,446	$22.05	$0.14
Hauling and Trucking	$6,404	$97.66	$0.62
Subtotal	*$7,850*	*$119.70*	*$0.75*
Interest (5.4% on 1/2 of total operating expense)	$1,876	$28.61	$0.18
Total Operating Expenses	**$71,366**	**$1,088.28**	**$6.85**
Annual Overhead Expenses			
Property Tax	$8,162	$124.46	$0.78
Farm Insurance	$9,263	$141.25	$0.89
Dues and Professional Fees	$1,018	$15.52	$0.10
Utilities	$6,362	$97.01	$0.61
Miscellaneous	$15,496	$236.30	$1.49
Total Overhead Expenses	**$40,300**	**$614.54**	**$3.87**
Annual Depreciation and Interest Expenses			
Land	$9,061	$138.18	$0.87
Buildings	$25,738	$392.48	$2.47
Machinery and Equipment	$27,930	$425.91	$2.68
Subtotal	*$62,729*	*$956.57*	*$6.02*
Livestock Herd Expenses			
Cows (Milking and Dry)	$10,444	$159.26	$1.00
Heifers	$4,407	$67.21	$0.42
Calves	$1,658	$25.28	$0.16
Dairy Bulls	$75	$1.15	$0.01
Subtotal	*$16,584*	*$252.90*	*$1.59*
Total Ownership Expenses	**$79,313**	**$1,209.46**	**$7.62**
Total Annual Cost	**$190,978**	**$2,912.28**	**$18.34**
Net Farm Income (NFI)	**-$24,370**	**-$371.63**	**-$2.34**
Return over Variable Cost (ROVC)	**$54,943**	**$837.84**	**$5.28**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$2,779.15	$17.50
Short-run to Cover Operating Costs		$1,569.69	$9.89

[a] Numbers may not sum due to rounding.

Appendix C-2

CENTRAL MAINE MEDIUM-LARGE DAIRY WHOLE-FARM BUDGETS

Central Maine Conventional Medium-Large[a]

	Total	Per Cow	Per Cwt
Number of Cows	200	-	-
Annual Milk Shipment (cwt)	41,916	210	-
Annual Revenue			
Milk receipts	$635,516	$3,177.58	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$17,875	$89.38	$0.43
"Other" Revenue	$0	$0	$0
Total Revenue	**$653,391**	**$3,266.95**	**$15.59**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$31,616	$158.08	$0.75
Subtotal	*$31,616*	*$158.08*	*$0.75*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$182,400	$912.00	$4.35
Subtotal	*$182,400*	*$912.00*	*$4.35*
Livestock Expenses			
Breeding Fees	$9,527	$47.64	$0.23
Veterinary and Medicine	$15,319	$76.60	$0.37
Bedding	$5,704	$28.52	$0.14
DHIA Expenses	$2,934	$14.67	$0.07
Livestock Insurance	$4,841	$24.21	$0.12
Subtotal	*$38,325*	*$191.63*	*$0.91*
Crop and Pasture Expenses			
Seeds	$10,560	$52.80	$0.25
Chemicals	$7,805	$39.02	$0.19
Fertilizer	$10,840	$54.20	$0.26
Lime	$5,882	$29.41	$0.14
Other	$15,312	$76.56	$0.37
Subtotal	*$50,398*	*$251.99*	*$1.20*
Maintenance and Equipment Expenses			
Fuel and Oil	$22,823	$114.11	$0.54
Machinery Repairs	$32,000	$160.00	$0.76
Subtotal	*$54,823*	*$274.11*	*$1.31*

Central Maine Conventional
Medium-Large Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$4,192	$20.96	$0.10
Hauling and Trucking	$20,958	$104.79	$0.50
Subtotal	*$25,150*	*$125.75*	*$0.60*
Interest (5.4% on 1/2 of total operating expense)	$10,333	$51.67	$0.25
Total Operating Expenses	**$393,044**	**$1,965.22**	**$9.38**
Annual Overhead Expenses			
Property Tax	$18,751	$93.75	$0.45
Farm Insurance	$18,022	$90.11	$0.43
Dues and Professional Fees	$4,200	$21.00	$0.10
Utilities	$15,000	$75.00	$0.36
Miscellaneous	$38,519	$192.59	$0.92
Total Overhead Expenses	**$94,492**	**$472.46**	**$2.25**
Annual Depreciation and Interest Expenses			
Land	$17,274	$86.37	$0.41
Buildings	$61,646	$308.23	$1.47
Machinery and Equipment	$36,306	$181.53	$0.87
Subtotal	*$115,227*	*$576.13*	*$2.75*
Livestock Herd Expenses			
Cows (Milking and Dry)	$37,301	$186.51	$0.89
Heifers	$15,144	$75.72	$0.36
Calves	$2,761	$13.80	$0.07
Dairy Bulls	$159	$0.79	$0.004
Subtotal	*$55,364*	*$276.82*	*$1.32*
Total Ownership Expenses	**$170,591**	**$852.96**	**$4.07**
Total Annual Cost	**$658,128**	**$3,290.64**	**$15.70**
Net Farm Income (NFI)	**-$4,737**	**-$23.68**	**-$0.11**
Return over Variable Cost (ROVC)	**$165,854**	**$829.27**	**$3.96**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$3,201.26	$15.27
Short-run to Cover Operating Costs		$2,348.31	$11.20

[a] Numbers may not sum due to rounding.

Central Maine Long-Term Coupled
Medium-Large Land-Coupled[a]

	Total	Per Cow	Per Cwt
Number of Cows	200	-	-
Annual Milk Shipment (cwt)	41,916	210	-
Annual Revenue			
Milk receipts	$635,516	$3,177.58	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$17,875	$89.38	$0.43
"Other" Revenue	$0	$0	$0
Total Revenue	**$653,391**	**$3,266.95**	**$15.59**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$31,616	$158.08	$0.75
Subtotal	*$31,616*	*$158.08*	*$0.75*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$182,400	$912.00	$4.35
Subtotal	*$182,400*	*$912.00*	*$4.35*
Livestock Expenses			
Breeding Fees	$9,527	$47.64	$0.23
Veterinary and Medicine	$15,319	$76.60	$0.37
Bedding	$5,704	$28.52	$0.14
DHIA Expenses	$2,934	$14.67	$0.07
Livestock Insurance	$4,841	$24.21	$0.12
Subtotal	*$38,325*	*$191.63*	*$0.91*
Crop and Pasture Expenses			
Seeds	$10,560	$52.80	$0.25
Chemicals	$7,805	$39.02	$0.19
Fertilizer	$9,920	$49.60	$0.24
Lime	$5,882	$29.41	$0.14
Other	$15,312	$76.56	$0.37
Subtotal	*$49,478*	*$247.39*	*$1.18*
Maintenance and Equipment Expenses			
Fuel and Oil	$22,823	$114.11	$0.54
Machinery Repairs	$32,000	$160.00	$0.76
Subtotal	*$54,823*	*$274.11*	*$1.31*

Central Maine Long-Term Coupled
Medium-Large Land-Coupled Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$4,192	$20.96	$0.10
Hauling and Trucking	$20,958	$104.79	$0.50
Subtotal	*$25,150*	*$125.75*	*$0.60*
Interest (5.4% on 1/2 of total operating expense)	$10,308	$51.54	$0.25
Total Operating Expenses	**$392,100**	**$1,960.50**	**$9.35**
Annual Overhead Expenses			
Property Tax	$18,751	$93.75	$0.45
Farm Insurance	$18,022	$90.11	$0.43
Dues and Professional Fees	$4,200	$21.00	$0.10
Utilities	$15,000	$75.00	$0.36
Miscellaneous	$38,519	$192.59	$0.92
Total Overhead Expenses	**$94,492**	**$472.46**	**$2.25**
Annual Depreciation and Interest Expenses			
Land	$17,274	$86.37	$0.41
Buildings	$61,646	$308.23	$1.47
Machinery and Equipment	$36,306	$181.53	$0.87
Subtotal	*$115,227*	*$576.13*	*$2.75*
Livestock Herd Expenses			
Cows (Milking and Dry)	$37,301	$186.51	$0.89
Heifers	$15,144	$75.72	$0.36
Calves	$2,761	$13.80	$0.07
Dairy Bulls	$159	$0.79	$0.004
Subtotal	*$55,364*	*$276.82*	*$1.32*
Total Ownership Expenses	**$170,591**	**$852.96**	**$4.07**
Total Annual Cost	**$657,183**	**$3,285.91**	**$15.68**
Net Farm Income (NFI)	**-$3,792**	**-$18.96**	**-$0.09**
Return over Variable Cost (ROVC)	**$166,799**	**$834.00**	**$3.98**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$3,196.54	$15.25
Short-run to Cover Operating Costs		$2,343.58	$11.18

[a] Numbers may not sum due to rounding.

Central Maine Long-Term Coupled Medium-Large
Land/Feed-Coupled[a]

	Total	Per Cow	Per Cwt
Number of Cows	200	-	-
Annual Milk Shipment (cwt)	41,916	210	-
Annual Revenue			
Milk receipts	$635,516	$3,177.58	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$17,875	$89.38	$0.43
"Other" Revenue	$0	$0	$0
Total Revenue	**$653,391**	**$3,266.95**	**$15.59**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$8,524	$42.62	$0.20
Subtotal	*$8,524*	*$42.62*	*$0.20*
Purchased Feed Expenses			
Dairy Forage	$159,060	$795.30	$3.79
Dairy Concentrate	$182,400	$912.00	$4.35
Subtotal	*$341,460*	*$1,707.30*	*$8.15*
Livestock Expenses			
Breeding Fees	$9,527	$47.64	$0.23
Veterinary and Medicine	$15,319	$76.60	$0.37
Bedding	$5,704	$28.52	$0.14
DHIA Expenses	$2,934	$14.67	$0.07
Livestock Insurance	$4,841	$24.21	$0.12
Subtotal	*$38,325*	*$191.63*	*$0.91*
Crop and Pasture Expenses			
Seeds	$0	$0	$0
Chemicals	$0	$0	$0
Fertilizer	$0	$0	$0
Lime	$0	$0	$0
Other	$0	$0	$0
Subtotal	*$0*	*$0*	*$0*
Maintenance and Equipment Expenses			
Fuel and Oil	$14,825	$74.13	$0.35
Machinery Repairs	$22,859	$114.30	$0.55
Subtotal	*$37,685*	*$188.42*	*$0.90*

Central Maine Long-Term Coupled
Medium-Large Land/Feed-Coupled Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$4,192	$20.96	$0.10
Hauling and Trucking	$20,958	$104.79	$0.50
Subtotal	*$25,150*	*$125.75*	*$0.60*
Interest (5.4% on 1/2 of total operating expense)	$12,181	$60.90	$0.29
Total Operating Expenses	**$463,325**	**$2,316.62**	**$11.05**
Annual Overhead Expenses			
Property Tax	$18,751	$93.75	$0.45
Farm Insurance	$16,102	$80.51	$0.38
Dues and Professional Fees	$4,200	$21.00	$0.10
Utilities	$15,000	$75.00	$0.36
Miscellaneous	$38,519	$192.59	$0.92
Total Overhead Expenses	**$92,572**	**$462.86**	**$2.21**
Annual Depreciation and Interest Expenses			
Land	$17,274	$86.37	$0.41
Buildings	$61,646	$308.23	$1.47
Machinery and Equipment	$19,650	$98.25	$0.47
Subtotal	*$98,570*	*$492.85*	*$2.35*
Livestock Herd Expenses			
Cows (Milking and Dry)	$37,301	$186.51	$0.89
Heifers	$15,144	$75.72	$0.36
Calves	$2,761	$13.80	$0.07
Dairy Bulls	$159	$0.79	$0.004
Subtotal	*$55,364*	*$276.82*	*$1.32*
Total Ownership Expenses	**$153,934**	**$769.67**	**$3.67**
Total Annual Cost	**$709,831**	**$3,549.16**	**$16.93**
Net Farm Income (NFI)	**-$56,440**	**-$282.20**	**-$1.35**
Return over Variable Cost (ROVC)	**$97,494**	**$487.47**	**$2.33**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$3,459.78	$16.51
Short-run to Cover Operating Costs		$2,690.11	$12.84

[a] Numbers may not sum due to rounding.

Central Maine Long-Term On-Farm Integrated Medium-Large[a]

	Total	Per Cow	Per Cwt
Number of Cows	200	-	-
Annual Milk Shipment (cwt)	41,916	210	-
Annual Revenue			
Milk Receipts	$635,516	$3,177.58	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$17,875	$89.38	$0.43
"Other" Revenue	$0	$0	$0
Total Revenue	**$653,391**	**$3,266.95**	**$15.59**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$35,467	$177.33	$0.85
Subtotal	*$35,467*	*$177.33*	*$0.85*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$10,560	$52.80	$0.25
Subtotal	*$10,560*	*$52.80*	*$0.25*
Livestock Expenses			
Breeding Fees	$9,527	$47.64	$0.23
Veterinary and Medicine	$15,319	$76.60	$0.37
Bedding	$5,704	$28.52	$0.14
DHIA Expenses	$2,934	$14.67	$0.07
Livestock Insurance	$4,841	$24.21	$0.12
Subtotal	*$38,325*	*$191.63*	*$0.91*
Crop and Pasture Expenses			
Seeds	$13,684	$68.42	$0.33
Chemicals	$8,790	$43.95	$0.21
Fertilizer	$9,920	$49.60	$0.24
Lime	$7,701	$38.51	$0.18
Other	$18,962	$94.81	$0.45
Subtotal	*$59,056*	*$295.28*	*$1.41*
Maintenance and Equipment Expenses			
Fuel and Oil	$26,497	$132.49	$0.63
Machinery Repairs	$34,818	$174.09	$0.83
Subtotal	*$61,316*	*$306.58*	*$1.46*

Central Maine Long-Term
On-Farm Integrated Medium-Large Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$4,192	$20.96	$0.10
Hauling and Trucking	$20,958	$104.79	$0.50
Subtotal	*$25,150*	*$125.75*	*$0.60*
Interest (5.4% on 1/2 of total operating expense)	$6,207	$31.03	$0.15
Total Operating Expenses	**$236,080**	**$1,180.40**	**$5.63**
Annual Overhead Expenses			
Property Tax	$19,747	$98.74	$0.47
Farm Insurance	$20,138	$100.69	$0.48
Dues and Professional Fees	$4,200	$21.00	$0.10
Utilities	$15,000	$75.00	$0.36
Miscellaneous	$40,394	$201.97	$0.96
Total Overhead Expenses	**$99,479**	**$497.40**	**$2.37**
Annual Depreciation and Interest Expenses			
Land	$20,616	$103.08	$0.49
Buildings	$61,646	$308.23	$1.47
Machinery and Equipment	$49,564	$247.82	$1.18
Subtotal	*$131,826*	*$659.13*	*$3.15*
Livestock Herd Expenses			
Cows (Milking and Dry)	$37,301	$186.51	$0.89
Heifers	$15,144	$75.72	$0.36
Calves	$2,761	$13.80	$0.07
Dairy Bulls	$159	$0.79	$0.004
Subtotal	*$55,364*	*$276.82*	*$1.32*
Total Ownership Expenses	**$187,190**	**$935.95**	**$4.47**
Total Annual Cost	**$522,750**	**$2,613.75**	**$12.47**
Net Farm Income (NFI)	**$130,641**	**$653.21**	**$3.12**
Return over Variable Cost (ROVC)	**$317,832**	**$1,589.16**	**$7.58**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$2,524.37	$12.04
Short-run to Cover Operating Costs		$1,588.42	$7.58

[a] Numbers may not sum due to rounding.

Appendix C-3

AROOSTOOK SMALL DAIRY WHOLE-FARM BUDGETS

Aroostook County Conventional and Land-Coupled Small[a]

	Total	Per Cow	Per Cwt
Number of Cows	66	-	-
Annual Milk Shipment (cwt)	10,413	159	-
Annual Revenue			
Milk Receipts	$157,878	$2,407.52	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$8,730	$133.13	$0.84
"Other" Revenue	$0	$0	$0
Total Revenue	**$166,608**	**$2,540.65**	**$16.00**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$8,580	$130.85	$0.82
Subtotal	*$8,580*	*$130.85*	*$0.82*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$24,837	$378.74	$2.39
Subtotal	*$24,837*	*$378.74*	*$2.39*
Livestock Expenses			
Breeding Fees	$1,971	$30.06	$0.19
Veterinary and Medicine	$4,201	$64.06	$0.40
Bedding	$2,362	$36.02	$0.23
DHIA Expenses	$729	$11.12	$0.07
Livestock Insurance	$1,486	$22.66	$0.14
Subtotal	*$10,749*	*$163.91*	*$1.03*
Crop and Pasture Expenses			
Seeds	$1,531	$23.35	$0.15
Chemicals	$598	$9.11	$0.06
Fertilizer	$770	$11.74	$0.07
Lime	$1,710	$26.08	$0.16
Other	$9,119	$139.06	$0.88
Subtotal	*$13,728*	*$209.35*	*$1.32*
Maintenance and Equipment Expenses			
Fuel and Oil	$5,320	$81.12	$0.51
Machinery Repairs	$12,086	$184.31	$1.16
Subtotal	*$17,406*	*$265.43*	*$1.67*

Aroostook County Conventional and Land-Coupled Small Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$1,446	$22.05	$0.14
Hauling and Trucking	$10,413	$158.79	$1.00
Subtotal	*$11,859*	*$180.84*	*$1.14*
Interest (5.4% on 1/2 of total operating expense)	$2,353	$35.89	$0.23
Total Operating Expenses	**$89,512**	**$1,365.00**	**$8.60**
Annual Overhead Expenses			
Property Tax	$7,869	$120.00	$0.76
Farm Insurance	$7,943	$121.13	$0.76
Dues and Professional Fees	$1,018	$15.52	$0.10
Utilities	$6,362	$97.01	$0.61
Miscellaneous	$14,946	$227.91	$1.44
Total Overhead Expenses	**$38,138**	**$581.57**	**$3.66**
Annual Depreciation and Interest Expenses			
Land	$8,081	$123.23	$0.78
Buildings	$25,738	$392.48	$2.47
Machinery and Equipment	$17,124	$261.12	$1.64
Subtotal	*$50,942*	*$776.83*	*$4.89*
Livestock Herd Expenses			
Cows (Milking and Dry)	$10,444	$159.26	$1.00
Heifers	$4,407	$67.21	$0.42
Calves	$1,658	$25.28	$0.16
Dairy Bulls	$75	$1.15	$0.01
Subtotal	*$16,584*	*$252.90*	*$1.59*
Total Ownership Expenses	**$67,527**	**$1,029.73**	**$6.48**
Total Annual Cost	**$195,176**	**$2,976.30**	**$18.74**
Net Farm Income (NFI)	**-$28,568**	**-$435.64**	**-$2.74**
Return over Variable Cost (ROVC)	**$38,958**	**$594.09**	**$3.74**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$2,843.17	$17.91
Short-run to Cover Operating Costs		$1,813.44	$11.42

[a] Numbers may not sum due to rounding.

Aroostook County Small
Land/Feed-Coupled[a]

	Total	Per Cow	Per Cwt
Number of Cows	66	-	-
Annual Milk Shipment (cwt)	10,413	159	-
Annual Revenue			
Milk Receipts	$157,878	$2,407.52	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$8,730	$133.13	$0.84
"Other" Revenue	$0	$0	$0
Total Revenue	**$166,608**	**$2,540.65**	**$16.00**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$1,622	$24.74	$0.16
Subtotal	*$1,622*	*$24.74*	*$0.16*
Purchased Feed Expenses			
Dairy Forage	$47,105	$718.31	$4.52
Dairy Concentrate	$24,837	$378.74	$2.39
Subtotal	*$71,941*	*$1,097.05*	*$6.91*
Livestock Expenses			
Breeding Fees	$1,971	$30.06	$0.19
Veterinary and Medicine	$4,201	$64.06	$0.40
Bedding	$2,362	$36.02	$0.23
DHIA Expenses	$729	$11.12	$0.07
Livestock Insurance	$1,486	$22.66	$0.14
Subtotal	*$10,749*	*$163.91*	*$1.03*
Crop and Pasture Expenses			
Seeds	$0	$0	$0
Chemicals	$0	$0	$0
Fertilizer	$0	$0	$0
Lime	$0	$0	$0
Other	$0	$0	$0
Subtotal	*$0*	*$0*	*$0*
Maintenance and Equipment Expenses			
Fuel and Oil	$3,580	$54.59	$0.34
Machinery Repairs	$7,426	$113.25	$0.71
Subtotal	*$11,006*	*$167.84*	*$1.06*

Aroostook County Small
Land/Feed-Coupled Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$1,446	$22.05	$0.14
Hauling and Trucking	$10,413	$158.79	$1.00
Subtotal	*$11,859*	*$180.84*	*$1.14*
Interest (5.4% on 1/2 of total operating expense)	$2,894	$44.13	$0.28
Total Operating Expenses	**$110,071**	**$1,678.51**	**$10.57**
Annual Overhead Expenses			
Property Tax	$7,869	$120.00	$0.76
Farm Insurance	$7,014	$106.95	$0.67
Dues and Professional Fees	$1,018	$15.52	$0.10
Utilities	$6,362	$97.01	$0.61
Miscellaneous	$14,946	$227.91	$1.44
Total Overhead Expenses	**$37,208**	**$567.40**	**$3.57**
Annual Depreciation and Interest Expenses			
Land	$8,081	$123.23	$0.78
Buildings	$25,738	$392.48	$2.47
Machinery and Equipment	$9,571	$145.96	$0.92
Subtotal	*$43,390*	*$661.67*	*$4.17*
Livestock Herd Expenses			
Cows (Milking and Dry)	$10,444	$159.26	$1.00
Heifers	$4,407	$67.21	$0.42
Calves	$1,658	$25.28	$0.16
Dairy Bulls	$75	$1.15	$0.01
Subtotal	*$16,584*	*$252.90*	*$1.59*
Total Ownership Expenses	**$59,974**	**$914.56**	**$5.76**
Total Annual Cost	**$207,254**	**$3,160.47**	**$19.90**
Net Farm Income (NFI)	**-$40,646**	**-$619.82**	**-$3.90**
Return over Variable Cost (ROVC)	**$19,329**	**$294.75**	**$1.86**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$3,027.34	$19.07
Short-run to Cover Operating Costs		$2,112.77	$13.31

[a] Numbers may not sum due to rounding.

Aroostook County Small
Land/Feed-Coupled Start Up[a]

	Total	Per Cow	Per Cwt
Number of Cows	66	-	-
Annual Milk Shipment (cwt)	10,413	159	-
Annual Revenue			
Milk Receipts	$157,878	$2,407.52	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$8,730	$133.13	$0.84
"Other" Revenue	$0	$0	$0
Total Revenue	**$166,608**	**$2,540.65**	**$16.00**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$1,622	$24.74	$0.16
Subtotal	*$1,622*	*$24.74*	*$0.16*
Purchased Feed Expenses			
Dairy Forage	$47,105	$718.31	$4.52
Dairy Concentrate	$24,837	$378.74	$2.39
Subtotal	*$71,941*	*$1,097.05*	*$6.91*
Livestock Expenses			
Breeding Fees	$1,971	$30.06	$0.19
Veterinary and Medicine	$4,201	$64.06	$0.40
Bedding	$2,362	$36.02	$0.23
DHIA Expenses	$729	$11.12	$0.07
Livestock Insurance	$1,486	$22.66	$0.14
Subtotal	*$10,749*	*$163.91*	*$1.03*
Crop and Pasture Expenses			
Seeds	$0	$0	$0
Chemicals	$0	$0	$0
Fertilizer	$0	$0	$0
Lime	$0	$0	$0
Other	$0	$0	$0
Subtotal	*$0*	*$0*	*$0*
Maintenance and Equipment Expenses			
Fuel and Oil	$3,580	$54.59	$0.34
Machinery Repairs	$7,426	$113.25	$0.71
Subtotal	*$11,006*	*$167.84*	*$1.06*

Aroostook County Small
Land/Feed-Coupled Start Up Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$1,446	$22.05	$0.14
Hauling and Trucking	$10,413	$158.79	$1.00
Subtotal	*$11,859*	*$180.84*	*$1.14*
Interest (5.4% on 1/2 of total operating expense)	$2,894	$44.13	$0.28
Total Operating Expenses	**$110,071**	**$1,678.51**	**$10.57**
Annual Overhead Expenses			
Property Tax	$5,726	$87.31	$0.55
Farm Insurance	$5,416	$82.59	$0.52
Dues and Professional Fees	$1,018	$15.52	$0.10
Utilities	$6,362	$97.01	$0.61
Miscellaneous	$10,911	$166.38	$1.05
Total Overhead Expenses	**$29,432**	**$448.81**	**$2.83**
Annual Depreciation and Interest Expenses			
Land	$891	$13.59	$0.09
Buildings	$25,738	$392.48	$2.47
Machinery and Equipment	$9,571	$145.96	$0.92
Subtotal	*$36,200*	*$552.02*	*$3.48*
Livestock Herd Expenses			
Cows (Milking and Dry)	$10,444	$159.26	$1.00
Heifers	$4,407	$67.21	$0.42
Calves	$1,658	$25.28	$0.16
Dairy Bulls	$75	$1.15	$0.01
Subtotal	*$16,584*	*$252.90*	*$1.59*
Total Ownership Expenses	**$52,784**	**$804.92**	**$5.07**
Total Annual Cost	**$192,287**	**$2,932.24**	**$18.47**
Net Farm Income (NFI)	**-$25,679**	**-$391.59**	**-$2.47**
Return over Variable Cost (ROVC)	**$27,105**	**$413.33**	**$2.60**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$2,799.11	$17.63
Short-run to Cover Operating Costs		$1,994.19	$12.56

[a] Numbers may not sum due to rounding.

Aroostook County Long-Term On-Farm Integrated Small[a]

	Total	Per Cow	Per Cwt
Number of Cows	66	-	-
Annual Milk Shipment (cwt)	10,413	159	-
Annual Revenue			
Milk Receipts	$157,878	$2,407.52	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$8,730	$133.13	$0.84
"Other" Revenue	$0	$0	$0
Total Revenue	**$166,608**	**$2,540.65**	**$16.00**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$11,426	$174.24	$1.10
Subtotal	*$11,426*	*$174.24*	*$1.10*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$0	$0	$0
Subtotal	*$0*	*$0*	*$0*
Livestock Expenses			
Breeding Fees	$1,971	$30.06	$0.19
Veterinary and Medicine	$4,201	$64.06	$0.40
Bedding	$2,362	$36.02	$0.23
DHIA Expenses	$729	$11.12	$0.07
Livestock Insurance	$1,486	$22.66	$0.14
Subtotal	*$10,749*	*$163.91*	*$1.03*
Crop and Pasture Expenses			
Seeds	$2,049	$31.24	$0.20
Chemicals	$719	$10.97	$0.07
Fertilizer	$2,105	$32.10	$0.20
Lime	$2,485	$37.90	$0.24
Other	$11,873	$181.05	$1.14
Subtotal	*$19,231*	*$293.26*	*$1.85*
Maintenance and Equipment Expenses			
Fuel and Oil	$6,186	$94.34	$0.59
Machinery Repairs	$13,789	$210.28	$1.32
Subtotal	*$19,976*	*$304.62*	*$1.92*

Aroostook County Long-Term
On-Farm Integrated Small Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$1,446	$22.05	$0.14
Hauling and Trucking	$10,413	$158.79	$1.00
Subtotal	*$11,859*	*$180.84*	*$1.14*
Interest (5.4% on 1/2 of total operating expense)	$1,977	$30.16	$0.19
Total Operating Expenses	**$75,218**	**$1,147.02**	**$7.22**
Annual Overhead Expenses			
Property Tax	$8,328	$126.99	$0.80
Farm Insurance	$9,235	$140.82	$0.89
Dues and Professional Fees	$1,018	$15.52	$0.10
Utilities	$6,362	$97.01	$0.61
Miscellaneous	$15,808	$241.06	$1.52
Total Overhead Expenses	**$40,750**	**$621.41**	**$3.91**
Annual Depreciation and Interest Expenses			
Land	$9,618	$146.67	$0.92
Buildings	$25,738	$392.48	$2.47
Machinery and Equipment	$26,316	$401.30	$2.53
Subtotal	*$61,672*	*$940.45*	*$5.92*
Livestock Herd Expenses			
Cows (Milking and Dry)	$10,444	$159.26	$1.00
Heifers	$4,407	$67.21	$0.42
Calves	$1,658	$25.28	$0.16
Dairy Bulls	$75	$1.15	$0.01
Subtotal	*$16,584*	*$252.90*	*$1.59*
Total Ownership Expenses	**$78,256**	**$1,193.34**	**$7.52**
Total Annual Cost	**$194,224**	**$2,961.77**	**$18.65**
Net Farm Income (NFI)	**-$27,616**	**-$421.12**	**-$2.65**
Return over Variable Cost (ROVC)	**$50,640**	**$772.23**	**$4.86**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$2,828.64	$17.81
Short-run to Cover Operating Costs		$1,635.30	$10.30

[a] Numbers may not sum due to rounding.

Appendix C-4

AROOSTOOK MEDIUM-LARGE DAIRY WHOLE-FARM BUDGETS

Aroostook County Conventional and Land-Coupled Medium-Large[a]

	Total	Per Cow	Per Cwt
Number of Cows	200	-	-
Annual Milk Shipment (cwt)	41,916	210	-
Annual Revenue			
Milk Receipts	$635,516	$3,177.58	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$17,875	$89.38	$0.43
"Other" Revenue	$0	$0	$0
Total Revenue	**$653,391**	**$3,266.95**	**$15.59**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$20,724	$103.62	$0.49
Subtotal	*$20,724*	*$103.62*	*$0.49*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$118,750	$593.75	$2.83
Subtotal	*$118,750*	*$593.75*	*$2.83*
Livestock Expenses			
Breeding Fees	$9,527	$47.64	$0.23
Veterinary and Medicine	$15,319	$76.60	$0.37
Bedding	$5,704	$28.52	$0.14
DHIA Expenses	$2,934	$14.67	$0.07
Livestock Insurance	$4,841	$24.21	$0.12
Subtotal	*$38,325*	*$191.63*	*$0.91*
Crop and Pasture Expenses			
Seeds	$5,000	$25.00	$0.12
Chemicals	$1,951	$9.76	$0.05
Fertilizer	$5,045	$25.22	$0.12
Lime	$5,200	$26.00	$0.12
Other	$15,312	$76.56	$0.37
Subtotal	*$32,508*	*$162.54*	*$0.78*
Maintenance and Equipment Expenses			
Fuel and Oil	$21,216	$106.08	$0.51
Machinery Repairs	$32,040	$160.20	$0.76
Subtotal	*$53,256*	*$266.28*	*$1.27*

Aroostook County Conventional and
Land-Coupled Medium-Large Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$4,192	$20.96	$0.10
Hauling and Trucking	$41,916	$209.58	$1.00
Subtotal	*$46,108*	*$230.54*	*$1.10*
Interest (5.4% on 1/2 of total operating expense)	$8,361	$41.81	$0.20
Total Operating Expenses	**$318,031**	**$1,590.16**	**$7.59**
Annual Overhead Expenses			
Property Tax	$18,751	$93.75	$0.45
Farm Insurance	$18,046	$90.23	$0.43
Dues and Professional Fees	$4,200	$21.00	$0.10
Utilities	$15,000	$75.00	$0.36
Miscellaneous	$38,519	$192.59	$0.92
Total Overhead Expenses	**$94,516**	**$472.58**	**$2.25**
Annual Depreciation and Interest Expenses			
Land	$17,274	$86.37	$0.41
Buildings	$61,646	$308.23	$1.47
Machinery and Equipment	$36,531	$182.66	$0.87
Subtotal	*$115,452*	*$577.26*	*$2.75*
Livestock Herd Expenses			
Cows (Milking and Dry)	$37,301	$186.51	$0.89
Heifers	$15,144	$75.72	$0.36
Calves	$2,761	$13.80	$0.07
Dairy Bulls	$159	$0.79	$0.004
Subtotal	*$55,364*	*$276.82*	*$1.32*
Total Ownership Expenses	**$170,816**	**$854.08**	**$4.08**
Total Annual Cost	**$583,363**	**$2,916.82**	**$13.92**
Net Farm Income (NFI)	**$70,027**	**$350.14**	**$1.67**
Return over Variable Cost (ROVC)	**$240,844**	**$1,204.22**	**$5.75**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$2,827.44	$13.49
Short-run to Cover Operating Costs		$1,973.36	$9.42

[a] Numbers may not sum due to rounding.

Aroostook County Medium-Large
Land/Feed-Coupled[a]

	Total	Per Cow	Per Cwt
Number of Cows	200	-	-
Annual Milk Shipment (cwt)	41,916	210	-
Annual Revenue			
Milk Receipts	$635,516	$3,177.58	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$17,875	$89.38	$0.43
"Other" Revenue	$0	$0	$0
Total Revenue	**$653,391**	**$3,266.95**	**$15.59**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$3,599	$17.99	$0.09
Subtotal	*$3,599*	*$17.99*	*$0.09*
Purchased Feed Expenses			
Dairy Forage	$139,060	$695.30	$3.32
Dairy Concentrate	$118,750	$593.75	$2.83
Subtotal	*$257,810*	*$1,289.05*	*$6.15*
Livestock Expenses			
Breeding Fees	$9,527	$47.64	$0.23
Veterinary and Medicine	$15,319	$76.60	$0.37
Bedding	$5,704	$28.52	$0.14
DHIA Expenses	$2,934	$14.67	$0.07
Livestock Insurance	$4,841	$24.21	$0.12
Subtotal	*$38,325*	*$191.63*	*$0.91*
Crop and Pasture Expenses			
Seeds	$0	$0	$0
Chemicals	$0	$0	$0
Fertilizer	$0	$0	$0
Lime	$0	$0	$0
Other	$0	$0	$0
Subtotal	*$0*	*$0*	*$0*
Maintenance and Equipment Expenses			
Fuel and Oil	$13,803	$69.01	$0.33
Machinery Repairs	$22,859	$114.30	$0.55
Subtotal	*$36,662*	*$183.31*	*$0.87*

Aroostook County Medium-Large
Land/Feed-Coupled Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$4,192	$20.96	$0.10
Hauling and Trucking	$41,916	$209.58	$1.00
Subtotal	*$46,108*	*$230.54*	*$1.10*
Interest (5.4% on 1/2 of total operating expense)	$10,328	$51.64	$0.25
Total Operating Expenses	**$392,831**	**$1,964.16**	**$9.37**
Annual Overhead Expenses			
Property Tax	$18,751	$93.75	$0.45
Farm Insurance	$16,198	$80.99	$0.39
Dues and Professional Fees	$4,200	$21.00	$0.10
Utilities	$15,000	$75.00	$0.36
Miscellaneous	$38,519	$192.59	$0.92
Total Overhead Expenses	**$92,668**	**$463.34**	**$2.21**
Annual Depreciation and Interest Expenses			
Land	$17,274	$86.37	$0.41
Buildings	$61,646	$308.23	$1.47
Machinery and Equipment	$20,550	$102.75	$0.49
Subtotal	*$99,470*	*$497.35*	*$2.37*
Livestock Herd Expenses			
Cows (Milking and Dry)	$37,301	$186.51	$0.89
Heifers	$15,144	$75.72	$0.36
Calves	$2,761	$13.80	$0.07
Dairy Bulls	$159	$0.79	$0.004
Subtotal	*$55,364*	*$276.82*	*$1.32*
Total Ownership Expenses	**$154,835**	**$774.17**	**$3.69**
Total Annual Cost	**$640,334**	**$3,201.67**	**$15.28**
Net Farm Income (NFI)	**$13,057**	**$65.29**	**$0.31**
Return over Variable Cost (ROVC)	**$167,892**	**$839.46**	**$4.01**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$3,112.29	$14.85
Short-run to Cover Operating Costs		$2,338.12	$11.16

[a] Numbers may not sum due to rounding.

Aroostook County Medium-Large
Land/Feed-Coupled Start Up[a]

	Total	Per Cow	Per Cwt
Number of Cows	200	-	-
Annual Milk Shipment (cwt)	41,916	210	-
Annual Revenue			
Milk Receipts	$635,516	$3,177.58	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$17,875	$89.38	$0.43
"Other" Revenue	$0	$0	$0
Total Revenue	**$653,391**	**$3,266.95**	**$15.59**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$3,599	$17.99	$0.09
Subtotal	*$3,599*	*$17.99*	*$0.09*
Purchased Feed Expenses			
Dairy Forage	$139,060	$695.30	$3.32
Dairy Concentrate	$118,750	$593.75	$2.83
Subtotal	*$257,810*	*$1,289.05*	*$6.15*
Livestock Expenses			
Breeding Fees	$9,527	$47.64	$0.23
Veterinary and Medicine	$15,319	$76.60	$0.37
Bedding	$5,704	$28.52	$0.14
DHIA Expenses	$2,934	$14.67	$0.07
Livestock Insurance	$4,841	$24.21	$0.12
Subtotal	*$38,325*	*$191.63*	*$0.91*
Crop and Pasture Expenses			
Seeds	$0	$0	$0
Chemicals	$0	$0	$0
Fertilizer	$0	$0	$0
Lime	$0	$0	$0
Other	$0	$0	$0
Subtotal	*$0*	*$0*	*$0*
Maintenance and Equipment Expenses			
Fuel and Oil	$13,803	$69.01	$0.33
Machinery Repairs	$22,859	$114.30	$0.55
Subtotal	*$36,662*	*$183.31*	*$0.87*

Aroostook County Medium-Large
Land/Feed-Coupled Start Up Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$4,192	$20.96	$0.10
Hauling and Trucking	$41,916	$209.58	$1.00
Subtotal	*$46,108*	*$230.54*	*$1.10*
Interest (5.4% on 1/2 of total operating expense)	$10,328	$51.64	$0.25
Total Operating Expenses	**$392,831**	**$1,964.16**	**$9.37**
Annual Overhead Expenses			
Property Tax	$14,398	$71.99	$0.34
Farm Insurance	$12,954	$64.77	$0.31
Dues and Professional Fees	$4,200	$21.00	$0.10
Utilities	$15,000	$75.00	$0.36
Miscellaneous	$30,325	$151.63	$0.72
Total Overhead Expenses	**$76,876**	**$384.38**	**$1.83**
Annual Depreciation and Interest Expenses			
Land	$2,673	$13.37	$0.06
Buildings	$61,646	$308.23	$1.47
Machinery and Equipment	$20,550	$102.75	$0.49
Subtotal	*$84,869*	*$424.35*	*$2.02*
Livestock Herd Expenses			
Cows (Milking and Dry)	$37,301	$186.51	$0.89
Heifers	$15,144	$75.72	$0.36
Calves	$2,761	$13.80	$0.07
Dairy Bulls	$159	$0.79	$0.004
Subtotal	*$55,364*	*$276.82*	*$1.32*
Total Ownership Expenses	**$140,233**	**$701.17**	**$3.35**
Total Annual Cost	**$609,941**	**$3,049.70**	**$14.55**
Net Farm Income (NFI)	**$43,450**	**$217.25**	**$1.04**
Return over Variable Cost (ROVC)	**$183,684**	**$918.42**	**$4.38**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$2,960.33	$14.13
Short-run to Cover Operating Costs		$2,259.16	$10.78

[a] Numbers may not sum due to rounding.

Aroostook County Long-Term On-Farm Integrated Medium-Large[a]

	Total	Per Cow	Per Cwt
Number of Cows	200	-	-
Annual Milk Shipment (cwt)	41,916	210	-
Annual Revenue			
Milk Receipts	$635,516	$3,177.58	$15.16
Crop and Hay Revenue	$0	$0	$0
Livestock Revenue	$17,875	$89.38	$0.43
"Other" Revenue	$0	$0	$0
Total Revenue	**$653,391**	**$3,266.95**	**$15.59**
Annual Operating Expenses			
Labor Expenses			
Family	$0	$0	$0
Hired	$25,393	$126.96	$0.61
Subtotal	*$25,393*	*$126.96*	*$0.61*
Purchased Feed Expenses			
Dairy Forage	$0	$0	$0
Dairy Concentrate	$0	$0	$0
Subtotal	*$0*	*$0*	*$0*
Livestock Expenses			
Breeding Fees	$9,527	$47.64	$0.23
Veterinary and Medicine	$15,319	$76.60	$0.37
Bedding	$5,704	$28.52	$0.14
DHIA Expenses	$2,934	$14.67	$0.07
Livestock Insurance	$4,841	$24.21	$0.12
Subtotal	*$38,325*	*$191.63*	*$0.91*
Crop and Pasture Expenses			
Seeds	$8,194	$40.97	$0.20
Chemicals	$2,877	$14.38	$0.07
Fertilizer	$10,077	$50.39	$0.24
Lime	$7,441	$37.20	$0.18
Other	$26,924	$134.62	$0.64
Subtotal	*$55,513*	*$277.56*	*$1.32*
Maintenance and Equipment Expenses			
Fuel and Oil	$23,866	$119.33	$0.57
Machinery Repairs	$35,480	$177.40	$0.85
Subtotal	*$59,346*	*$296.73*	*$1.42*

Aroostook County Long-Term
On-Farm Integrated Medium-Large
Continued

	Total	Per Cow	Per Cwt
Deduction Expenses			
Milk Marketing	$4,192	$20.96	$0.10
Hauling and Trucking	$41,916	$209.58	$1.00
Subtotal	*$46,108*	*$230.54*	*$1.10*
Interest (5.4% on 1/2 of total operating expense)	$6,066	$30.33	$0.14
Total Operating Expenses	**$230,751**	**$1,153.76**	**$5.51**
Annual Overhead Expenses			
Property Tax	$20,013	$100.06	$0.48
Farm Insurance	$20,420	$102.10	$0.49
Dues and Professional Fees	$4,200	$21.00	$0.10
Utilities	$15,000	$75.00	$0.36
Miscellaneous	$40,894	$204.47	$0.98
Total Overhead Expenses	**$100,527**	**$502.63**	**$2.40**
Annual Depreciation and Interest Expenses			
Land	$21,507	$107.53	$0.51
Buildings	$61,646	$308.23	$1.47
Machinery and Equipment	$50,442	$252.21	$1.20
Subtotal	*$133,595*	*$667.98*	*$3.19*
Livestock Herd Expenses			
Cows (Milking and Dry)	$37,301	$186.51	$0.89
Heifers	$15,144	$75.72	$0.36
Calves	$2,761	$13.80	$0.07
Dairy Bulls	$159	$0.79	$0.004
Subtotal	*$55,364*	*$276.82*	*$1.32*
Total Ownership Expenses	**$188,959**	**$944.80**	**$4.51**
Total Annual Cost	**$520,237**	**$2,601.19**	**$12.41**
Net Farm Income (NFI)	**$133,154**	**$665.77**	**$3.18**
Return over Variable Cost (ROVC)	**$322,113**	**$1,610.57**	**$7.68**
Performance Measures			
Breakeven Revenue		$/cow	$/cwt
Long-run to Cover All Costs		$2,511.81	$11.98
Short-run to Cover Operating Costs		$1,567.01	$7.48

[a] Numbers may not sum due to rounding.

Appendix D-1

ADDITIONAL POTATO CROP ENTERPRISE BUDGETS

Conventional Small Grain Corn[a]

	Total	Per Acre	Per Bu
Number of Acres	160	-	-
Grain Corn Yield (bu)	16,000	100	-
Price ($/bu)	$2.50	-	-
Annual Revenue	**$40,000**	**$250.00**	**$2.50**
Annual Operating Expenses			
Seed	$4,290	$26.81	$0.27
Fertilizer	$10,464	$65.40	$0.65
Lime	$1,941	$12.13	$0.12
Chemicals	$3,902	$24.39	$0.24
Labor	$5,887	$36.80	$0.37
Diesel Fuel and Oil	$2,068	$12.92	$0.13
Maintenance and Upkeep	$3,785	$23.65	$0.24
Supplies	$1,600	$10.00	$0.10
Insurance	$53	$0.33	$0.003
Miscellaneous			
Utilities	$320	$2.00	$0.02
Rent or Lease	$2,000	$12.50	$0.13
Drying	$3,091	$19.32	$0.19
Interest	$1,088	$6.80	$0.07
Total Operating Expenses	**$40,489**	**$253.06**	**$2.53**
Annual Ownership Expenses			
Depreciation and Interest	$24,281	$151.76	$1.52
Tax and Insurance	$1,772	$11.08	$0.11
Total Ownership Expenses	**$26,054**	**$162.83**	**$1.63**
Total Annual Cost	**$66,543**	**$415.89**	**$4.16**
Net Farm Income (NFI)	**-$26,543**	**-$165.89**	**-$1.66**
Return over Variable Cost (ROVC)	**-$489**	**-$3.06**	**-$0.03**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$415.89	$4.16
Short-run to Cover Operating Costs		$253.06	$2.53

[a] Numbers may not sum due to rounding.

Conventional Medium-Large Grain Corn[a]

	Total	Per Acre	Per Bu
Number of Acres	320	-	-
Grain Corn Yield (bu)	32,000	100	-
Price ($/bu)	$2.50	-	-
Annual Revenue	**$80,000**	**$250.00**	**$2.50**
Annual Operating Expenses			
Seed	$8,580	$26.81	$0.27
Fertilizer	$20,928	$65.40	$0.65
Lime	$3,882	$12.13	$0.12
Chemicals	$7,805	$24.39	$0.24
Labor	$11,318	$35.37	$0.35
Diesel Fuel and Oil	$4,136	$12.92	$0.13
Maintenance and Upkeep	$5,169	$16.15	$0.16
Supplies	$3,200	$10.00	$0.10
Insurance	$106	$0.33	$0.003
Miscellaneous			
Utilities	$640	$2.00	$0.02
Rent or Lease	$4,000	$12.50	$0.13
Drying	$6,182	$19.32	$0.19
Interest	$2,097	$6.55	$0.07
Total Operating Expenses	**$78,044**	**$243.89**	**$2.44**
Annual Ownership Expenses			
Depreciation and Interest	$33,783	$105.57	$1.06
Tax and Insurance	$2,575	$8.05	$0.08
Total Ownership Expenses	**$36,358**	**$113.62**	**$1.14**
Total Annual Cost	**$114,401**	**$357.50**	**$3.58**
Net Farm Income (NFI)	**-$34,401**	**-$107.50**	**-$1.08**
Return over Variable Cost (ROVC)	**$1,956**	**$6.11**	**$0.06**
Performance Measures			
Breakeven Revenue		$/acre	$/bu
Long-run to Cover All Costs		$357.50	$3.58
Short-run to Cover Operating Costs		$243.89	$2.44

[a] Numbers may not sum due to rounding.

Appendix D-2

ADDITIONAL DAIRY CROP ENTERPRISE BUDGETS

Conventional and Coupled Small Dry Hay[a]

	Total	Per Acre	Per Ton
Number of Acres	73	-	-
Hay Yield (tons)	256	3.5	-
Price ($/ton)	$64.50	-	-
Annual Revenue	**$16,480**	**$225.75**	**$64.50**
Annual Operating Expenses			
Seed[b]	$0	$0	$0
Fertilizer	$840	$11.50	$3.29
Lime	$730	$10.00	$2.86
Chemicals	$0	$0	$0
Labor	$3,528	$48.32	$13.81
Diesel Fuel and Oil	$764	$10.46	$2.99
Maintenance and Upkeep	$1,942	$26.60	$7.60
Supplies	$730	$10.00	$2.86
Insurance	$24	$0.33	$0.09
Miscellaneous			
Rent or Lease	$913	$12.50	$3.57
Storage and Warehousing	$73	$1.00	$0.29
Other Expenses	$365	$5.00	$1.43
Interest	$230	$3.15	$0.90
Total Operating Expenses	**$10,138**	**$138.88**	**$39.68**
Annual Ownership Expenses			
Depreciation and Interest	$11,179	$153.14	$43.75
Tax and Insurance	$857	$11.74	$3.35
Total Ownership Expenses	**$12,036**	**$164.88**	**$47.11**
Total Annual Cost	**$22,174**	**$303.75**	**$86.79**
Net Farm Income (NFI)	**-$5,694**	**-$78.00**	**-$22.29**
Return over Variable Cost (ROVC)	**$6,342**	**$86.87**	**$24.82**
Performance Measures			
Breakeven Revenue		$/acre	$/ton
Long-run to Cover All Costs		$303.75	$86.79
Short-run to Cover Operating Costs		$138.88	$39.68

[a] Numbers may not sum due to rounding.
[b] Establishment costs not included for acreage in silage corn the previous year.

Conventional and Coupled Medium-Large Haylage[a]

	Total	Per Acre	Per Ton
Number of Acres	200	-	-
Haylage Yield (tons)	1,200	6	-
Price ($/ton)	$32.55	-	-
Annual Revenue	**$39,060**	**$195.30**	**$32.55**
Annual Operating Expenses			
Seed[b]	$0	$0	$0
Fertilizer	$6,240	$31.20	$5.20
Lime	$2,000	$10.00	$1.67
Chemicals	$0	$0	$0
Labor	$7,725	$38.63	$6.44
Diesel Fuel and Oil	$2,910	$14.55	$2.42
Maintenance and Upkeep	$2,945	$14.72	$2.45
Supplies	$2,000	$10.00	$1.67
Insurance	$66	$0.33	$0.06
Miscellaneous			
Rent or Lease	$2,500	$12.50	$2.08
Storage and Warehousing	$200	$1.00	$0.17
Other Expenses	$1,000	$5.00	$0.83
Interest	$534	$2.67	$0.45
Total Operating Expenses	**$28,120**	**$140.60**	**$23.43**
Annual Ownership Expenses			
Depreciation and Interest	$17,696	$88.48	$14.75
Tax and Insurance	$1,409	$7.04	$1.17
Total Ownership Expenses	**$19,105**	**$95.52**	**$15.92**
Total Annual Cost	**$47,225**	**$236.12**	**$39.35**
Net Farm Income (NFI)	**-$8,165**	**-$40.82**	**-$6.80**
Return over Variable Cost (ROVC)	**$10,940**	**$54.70**	**$9.12**
Performance Measures			
Breakeven Revenue		$/acre	$/ton
Long-run to Cover All Costs		$236.12	$39.35
Short-run to Cover Operating Costs		$140.60	$23.43

[a] Numbers may not sum due to rounding.
[b] Establishment costs not included for acreage in silage corn the previous year.

Appendix E

EPIC CROP YIELD SIMULATIONS OF CONVENTIONAL AND INTEGRATED SYSTEMS

This section models and compares simulated potato and potato rotation crop yields for integrated and non-integrated agricultural systems in central and northern Maine. Simulation modeling was conducted using the Environmental Policy Integrated Climate (EPIC) model. Potential impacts on crop yields in integrated and non-integrated potato and dairy systems in Maine were estimated using EPIC simulations. Crop yields were validated with data from the Maine Potato Ecosystem Project (1991 to 2003) in Presque Isle. Yields over a 30-year simulation period were then compared.

Representative budget comparisons of current and hypothetical potato and dairy systems in Maine initially assumed that crop yields did not change due to integration. Sensitivity analyses were conducted to determine impacts on profitability from increases and decreases in baseline potato yields that could realistically be ascribed to changes in soil moisture retention and plant disease, respectively. Extensive long-term field research for potatoes has been limited to Presque Isle in central Aroostook County. Successful EPIC validation for potato and barley unamended and amended with manure in Presque Isle would allow better prediction of potato yield response in integrated systems in other parts of the state and with different potato rotation crops such as livestock forage and crops used for concentrated feed.

Biophysical Simulation Modeling

Crop biophysical simulation models can estimate soil erosion, nutrient cycling, and crop growth and yields to complement results from field experiments. However these models must be validated with experimental data prior to simulation. Numerous models, such as EPIC, Agricultural Policy EXtender (APEX), Water Erosion Prediction Project (WEPP), and Wind Erosion Prediction System (WEPS) can be used (Gassman et al., 2004; Williams et al., 1996). Models like EPIC use a single crop growth module with flexible parameters varying by crop. Crop-specific simulation models also exist, such as CERES for grains, CROPGROW for grain legumes, and DSSAT for root and tuber crops (Tsuji et al., 1998). The SUBSTOR module in DSSAT is used for potatoes (Bowen et al., 1999).

Although individual crop and livestock simulation models have been extensively used, modeling of coupled and on-farm integrated agricultural systems has been limited (Thornton and Herrero, 2001). Dalton (1996) used EPIC to show positive impacts of manure amendment on dry-land crops in Mali, Africa. More recently, I-FARM has been developed at Iowa State to model integrated and non-integrated crop and livestock systems (Van Ouwerkerk, 2005).

EPIC Model Background

The Environmental Policy Integrated Climate model was previously called the Erosion Productivity Impact Calculator. The EPIC model was developed in the early 1980's to estimate soil erosion for field-scale simulation areas (Williams et al., 1984) and has since been validated and used in the U.S. and internationally (Williams, 1990). Applications of the EPIC model include crop growth and yield, nutrient cycling and loss, water and wind erosion, agricultural regional assessments, climate change (Gassman et al., 2004; Feng et al., 2004), and historical agroecology (Bernardos et al., 2001).

The EPIC model operates on a daily time step with components for crop growth and management, soil erosion and temperature, nutrient cycling, hydrology, weather, and economics (Williams et al., 1984; Williams, 1990; Jones et al., 1991; USDA-ARS, 2003) and uses a single crop growth module with parameters unique to each crop (USDA-ARS, 2003). Average crop yields and variance for corn, soybeans, potatoes, barley, and alfalfa have been successfully simulated by EPIC. Corn has been extensively modeled in EPIC. Potatoes, barley, soybeans, and alfalfa have been modeled less, as has been the application of manure to annual and perennial crops.

The EPIC model accurately predicts long-term grain corn yields (Williams et al., 1989; Chung et al., 2001) but has been less successful simulating annual yield variation. Although goodness of fit (R^2) for observed versus simulated grain corn yield regressions can be high, ranging from 0.65 to 0.86 (Williams et al., 1989; Bryant et al., 1992), EPIC did not predict year-to-year yield variability of Iowa grain corn (Chung et al., 2002). In a similar Iowa grain corn study, R^2 values under 0.50 were attributed to the model not accounting for heterogeneous field conditions like slope (Chung et al., 1999).

The EPIC model underestimated silage corn yields in Connecticut, likely due to the inability of the model in accounting for upward movement of water through soil layers, where R^2 for observed versus simulated yield was 0.49 (Warner et al., 1997a). Silage corn soil nitrate concentrations were also under predicted (Warner et al., 1997b). Additionally, the EPIC model does not account for different stages of crop development. For crops like corn that are drought sensitive during anthesis, EPIC yield simulations improved when growth stages were modeled (Quinones and Cabelguenne, 1990).

Potatoes and other crops like barley, soybeans, and alfalfa have been less extensively modeled in EPIC. Validation of potato production in Chile (Meza and Wilks, 2004) and Mexico (Adams et al., 2002) was limited by lack of field data, while Chinese models for potatoes relied on historical yields (Wang et al., 2002). Idaho seed potato yields under variable nitrogen applications were calibrated but not validated with representative farm data (Watkins et al., 1998).

Regressions of observed and simulated yields for barley and soybeans grown in France and for Iowa soybeans had lower R^2 of 0.20 (Williams et al., 1989). Percent error between simulated and observed alfalfa yields in Minnesota from 1990 to 1993 was 14% (Chung et al., 2001). Colorado alfalfa yields were used to validate an EPIC model for simulation of forage production in California's Imperial Valley. Simulated alfalfa yields were less accurate with greater water stress during irrigation (Tayfur et al., 1995).

Simulation by EPIC of nutrient runoff and movement from poultry manure applications on tall fescue in Arkansas has been relatively successful (D.R. Edwards et al., 1994). However, phosphorus runoff from tall fescue and Bermuda grass in Georgia was underestimated (Pierson et al., 2001). Grain corn yields in Virginia with hog manure from 1978 to 1993 were reasonably simulated using EPIC; the R^2 values ranged from 0.42 to 0.89 for observed versus simulated yields (Parsons and Pease, 1995).

Dalton (1996) used EPIC to model cotton, corn, sorghum, groundnuts, and legumes in two production environments and with different combinations of organic fertilizer (manure and crop residues) and chemical fertilization in Mali, Africa. In this study, R^2 values for observed and simulated soil nutrients (nitrogen and phosphorus) and soil carbon for rotations ranged from 0.26 to 0.91. Similar regressions for sigmoidal yield equations for these rotations ranged from 0.06 to 0.84 for intermediate chemical fertilization and 0.05 to 0.86 for 1.6 to 2.2 tons/acre of organic fertilizer applied over three years in addition to chemical fertilization. There were higher average and lower variance of crop yields and net returns for amended systems.

EPIC Methodology

Default parameter values for all EPIC version 3060[16] components were obtained from the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS) at the Blackland Research Center in Temple, Texas (USDA-ARS, 2003), and from CARD at Iowa State University (Gassman and Campbell, 2003). University of Maine and USDA researchers updated crop growth and management data. Soil characteristics for Caribou loam were upgraded from USDA's Natural Resources and Conservation Service (NRCS) STATSGO soil data file (USDA-NRCS, 2003a). The EPIC model's daily weather parameters included precipitation, temperature, wind velocity and direction, relative humidity, and solar radiation. Most weather parameters were updated with data from the National Climatic Data Center (NCDC) website (NCDC, 2004) and obtained from Greg Porter (2005) at the University of Maine.

This study assumed a homogeneous field area of 300 acres, allowing rotation between 81 possible annual and perennial crops (USDA-ARS, 2003). The EPIC model simulates crop yields as dry matter, not fresh (Williams, 2005). Validation of EPIC was

[16] All versions of EPIC can be run through an interactive program called i_EPIC, which uses an Access database to store input and output data files. The i_EPIC program running EPIC version 0250 was obtained from Philip Gassman and Todd Campbell (2003) at the Center for Agriculture and Rural Development (CARD) at Iowa State University. Once available, a newer version of i_EPIC running EPIC version 3060 was installed from CARD with all Maine records and runs updated (Gassman and Campbell, 2005). The i_EPIC program allows users to make quick changes to parameters, run multiple simulations, and to view output such as crop yields, nutrient dynamics, and soil characteristics in tables and graphs (Gassman et al., 2003). Changes to i_EPIC input and output files are automatically updated in Access.

Table E.1. Major EPIC crop parameter assumptions.

Crop Parameter	Unit	Potato (POTA)	Grain Corn (GCORN)	Silage Corn (SCORN)	Alfalfa (ALFA)	Barley (BARL)	Soybeans (SOYB)
		Crops					
Biomass Energy	lb/ac/cal	0.05	0.09	0.10	0.12	0.07	0.11
(NRG) Ratio[a]	(kg/ha/MJ)	(14)	(25)	(25.5)	(31)	(20)	(30)
Harvest Index[b]	Prop.	0.80	0.50	0.85	0.50	0.40	0.30
Growth Temperature							
Minimum	°F (°C)	41 (5)	46 (8)	46 (8)	34 (1)	32 (0)	50 (10)
Optimal	°F (°C)	64 (18)	77 (25)	77 (25)	59 (15)	59 (15)	77 (25)
Maximum Leaf Area Index[c]	Prop.	6.5	6.0	6.0	5.0	6.0	5.0
Leaf Area Develop. Curve[d]							
First Point	%.%	15.01	15.05	15.05	15.01	15.01	15.01
Second Point	%.%	50.95	50.95	50.95	50.95	50.95	50.95
Growing Season Area Decline[e]	Prop.	0.75	0.80	0.80	0.90	0.80	0.90
Leaf Area Index Decline Rate[f]	Prop.	0.50	1.00	1.00	0.50	1.00	1.00
Biomass NRG Ratio Decline Rate[g]	Prop.	1.00	1.00	1.00	0.50	1.00	1.00
Plant Population	Count/yd^2	2	5	6	376	280	31
	(Count/m^2)	(2)	(6)	(7)	(450)	(335)	(37)
Dry Matter Content	%	23	84.5	36.4	45	88	88

[a] Non-stressed crop dry matter growth rate per unit of photosynthetically active radiation intercepted.
[b] This was crop yield over total biomass.
[c] Total leaf area per unit ground area expressed as a proportion.
[d] Controlled non-stressed leaf area growth where percentage to the decimal's left was the percentage of the growing season, while the percentage to the decimal's right was the percentage of maximum leaf area growth. First and second points were the bottom and top inflection points of an S-shaped growth curve.
[e] Percentage of the growing season where leaf area started to decline due to senescence of leaves.
[f] Controlled how quickly leaf area declined after senescence. If this parameter was one, then leaf area decline was linear. If it was less than one, the rate of decline was initially slow and then speeded up.
[g] Controlled potential radiation use efficiency (RUE) decline after senescence. If this parameter was one, then RUE decline was linear. If it was less than one, decline was initially slow and then speeded up.

conducted for a conventional potato-barley rotation in Presque Isle, Maine, both with and without potato amendments of 20 tons/acre of solid beef manure and 9 tons/acre of compost consistent with the first six years (1991 to 1996) of the Maine Potato Ecosystem Project (Gallandt et al., 1998).

Simulations were run for potato and dairy feed rotations representing potential integrated and non-integrated systems in central Maine and Aroostook County. The system simulated for central Maine was a potato-corn rotation with and without applied manure. A coupled four-year rotation of potatoes, silage corn, barley, and soybeans was also simulated for central Maine, in addition to an on-farm integrated dairy rotation of silage corn, barley, and soybeans. Aroostook County rotations were modeled from the experimental design of the Maine Potato Ecosystem Project. Hypothetical coupled potato and dairy rotations in Aroostook County (potato-soybean-potato-barley and potato-soybean-barley-alfalfa) represented LF-coupled potato farms. An on-farm integrated dairy rotation of alfalfa, barley, and soybeans was also simulated.

Major crop growth parameters for barley, grain corn, soybeans, and alfalfa used EPIC default values (Table E.1). Tim Griffin (2004) and Greg Porter (2004) at the University of Maine updated potato parameters from default values. Silage corn, which was added in i_EPIC, had parameters similar to those for grain corn with the exception of biomass energy ratio, harvest index, and plant population. Secondary potato parameters kept at default values included aluminum tolerance, maximum stomatal conductance, critical aeration factor, crop height, maximum rooting depth, contents of nutrients, frost damage, salinity tolerance, and other growth parameters. The biomass energy ratio was adjusted as needed for all crops after changing other parameters.

A general soil classification dataset from USDA Natural Resource and Conservation Service (NRCS) called STATSGO was used for default soil parameters (USDA-NRCS, 2003a). STATSGO contained 1994 generalized soil data for Maine (MOGIS, 1994). Characteristic soil layer data included depth, bulk density, pH, cation exchange capacity, as well as course fragment, sand, and silt content (USDA-NRCS, 2003b). Wilting point and field capacity were not available from STATSGO and were

Table E.2. Major EPIC soil layer parameter assumptions.

Soil Layer Parameter	Unit	Soil Layer One	Two	Three
Depth	m	0.000-0.330	0.330-0.914	0.914-1.651
	(in)	(0-13)	(13-36)	(36-65)
Bulk Density (BD) [a]	Mt/m^3	1.125	1.25	1.475
	(lb/ft^3)	(70)	(78)	(92)
Permanent Wilting Point (PWP) [b]	m/m	0.9	0.9	0.9
	(kPa)	(-1500)	(-1500)	(-1500)
Field Capacity (FC) [c]	m/m	2	2	2
	(kPa)	(-33)	(-33)	(-33)
Particle Content (PC) [d]				
Sand	%	52	52	52
Silt	%	40	40	40
pH [e]	pH	5.8	4.8	4.8
Organic Carbon (OC) [f]	%	3.3	1.95	0.3
Cation Exchange Capacity (CEC) [g]	cmol/kg	7.3	2	2

[a] BD was the mass of soil per unit volume (Fetter, 1988).
[b] Soil water content where wilted plants did not recover with added water (Loomis & Connor, 1992).
[c] FC was the amount of soil water that can be held by the soil following drainage (Ibid.).
[d] Percent of total soil PC for each particle type. Remaining PC was coarse fragments and clay. Sand particle diameters were 0.053 to 2 mm, while silt diameter range was 0.45 μm to 0.053 mm (Fetter, 1988).
[e] General pH scale from 0 to 14. A soil pH of 7 was neutral, while a pH below and above 7 were increasingly acid and alkaline respectively. Typical plant soil pH of 5 to 8 (Loomis & Connor, 1992).
[f] Percent OC divided percent organic material of soil by 1.72 (Gassman and Campbell, 2003).
[g] CEC was cation-holding capacity in centimoles of charge per kg of soil (Loomis & Connor, 1992).

instead simulated by EPIC. Caribou loam soil parameters (Table E.2) were updated by Tim Griffin (2004).

The EPIC model randomly generates sampled values of precipitation, temperature, wind velocity and direction, relative humidity, and solar radiation based on characteristics of the historical distributions of these weather variables for 13 weather stations in Maine obtained from the Blackland Research Center at Texas A&M in Temple, Texas (USDA-ARS, 2003). For validation of EPIC, observed weather data for Presque Isle, Maine, from 1991 to 2003 was used in place of randomly generated values.

Validation weather variables were compiled from various sources. Presque Isle precipitation, temperature, relative humidity, and wind velocity data unavailable from Greg Porter (Porter, 2005), predominantly in later years, was supplemented from the

Table E.3. Total monthly precipitation for Presque Isle, Maine, 1991 to 2003.

Year	---------------------------- Monthly Precipitation (Inches)[a] ----------------------------											Annual Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
1991	1.5	0.6	4.5	2.5	3.2	0.8	0.8	8.5	3.8	3.7	1.6	1.6	33.0
1992	3.5	2.3	1.8	1.8	1.5	4.2	3.7	5.1	2.1	4.1	1.6	1.3	33.0
1993	1.6	2.0	1.0	3.3	3.3	5.6	2.0	3.0	5.1	4.6	2.0	5.5	38.9
1994	4.2	1.0	2.2	3.7	4.5	4.7	3.2	1.3	3.6	1.1	3.2	**1.9**	34.4
1995	4.0	1.7	1.6	1.5	2.3	1.5	2.4	2.4	2.2	6.2	-[b]	**1.0**	26.8
1996	5.4	**2.7**	1.2	2.6	4.0	3.7	5.1	2.6	4.0	3.4	1.5	3.8	39.9
1997	3.1	2.6	**2.7**	1.4	5.4	2.4	2.9	4.4	2.5	1.3	**2.0**	2.3	33.1
1998	**3.6**	**1.9**	2.6	2.3	3.7	3.3	5.5	2.5	3.1	4.0	**2.1**	**1.4**	35.8
1999	**3.3**	**1.4**	**2.3**	**1.4**	1.4	4.1	2.5	4.5	9.4	4.3	**2.4**	**3.1**	40.1
2000	**2.3**	**2.2**	**2.1**	**5.4**	4.6	2.5	2.6	3.0	1.4	2.3	**2.3**	**3.7**	34.4
2001	**0.3**	**1.8**	**1.8**	**1.0**	**2.0**	**2.3**	**3.3**	**1.8**	**4.5**	**2.1**	**1.6**	**0.8**	23.2
2002	**1.2**	**2.1**	**2.5**	**2.9**	3.6	2.2	6.3	1.5	4.0	2.6	3.2	**2.3**	34.3
2003	**0.7**	**1.4**	**2.7**	**1.5**	**2.6**	**3.7**	**4.6**	**3.3**	**1.7**	**6.2**	**4.3**	**3.0**	35.6
Avg	2.7	1.8	2.2	2.4	3.2	3.1	3.4	3.4	3.6	3.5	2.3	2.4	34.0

[a] Precipitation data from Greg Porter (2005) and from the NCDC (2004) if in bold face.
[b] Precipitation for November 1995 was not available (Porter, 2005; NCDC, 2004).

Table E.4. Average monthly maximum temperature for Presque Isle, Maine, 1991 to 2003.

Year	------------------- Average Maximum Monthly Temperature (°F)[a] -------------------											Annual Avg
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
1991	19	28	36	49	65	74	78	78	64	55	41	24	51
1992	21	22	32	47	67	72	72	74	69	50	37	28	49
1993	21	16	36	50	62	72	76	78	66	49	39	28	49
1994	12	20	34	47	59	76	80	75	65	57	44	**28**	50
1995	24	24	43	46	62	77	81	82	69	57	-[b]	**23**	53
1996	22	**23**	**34**	**49**	60	74	75	77	67	52	37	35	50
1997	23	26	**31**	47	61	75	79	75	67	51	**37**	27	50
1998	**23**	**32**	37	50	69	72	79	77	66	**52**	**37**	**33**	52
1999	**22**	**30**	**39**	**49**	72	79	80	75	74	52	**43**	**30**	54
2000	**21**	**29**	**42**	**49**	62	73	76	75	68	55	**41**	**24**	51
2001	**25**	**25**	**33**	**49**	**72**	**76**	**76**	**83**	**71**	**60**	**43**	**35**	54
2002	**26**	**27**	**36**	**48**	62	69	75	79	71	49	36	**27**	50
2003	**16**	**20**	**33**	**45**	**63**	**77**	**77**	**77**	**72**	**55**	**42**	**30**	51
Avg	21	25	36	48	64	74	77	77	68	53	40	29	51

[a] Maximum temperature data from Greg Porter (2005) and from the NCDC (2004) if in bold face.
[b] Maximum temperature for November 1995 was not available (Porter, 2005; NCDC, 2004).

Table E.5. Average monthly minimum temperature for Presque Isle, Maine, 1991 to 2003.

	Average Minimum Monthly Temperature (°F)[a]												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Avg
1991	-1	5	19	30	40	49	55	55	43	37	27	6	30
1992	3	3	11	28	40	51	51	56	46	34	24	14	30
1993	1	-6	13	30	41	50	55	56	45	31	23	14	29
1994	-11	-2	19	29	39	54	60	52	44	37	26	**12**	30
1995	9	0	18	26	40	51	59	56	43	38	-[b]	**7**	32
1996	0	**7**	**16**	**31**	40	52	57	55	46	34	23	21	32
1997	2	2	**9**	28	39	49	55	54	47	34	**23**	8	29
1998	**5**	**10**	19	32	47	52	57	53	48	**38**	**25**	**16**	34
1999	**2**	**10**	**24**	**31**	44	54	57	53	53	33	**30**	**17**	34
2000	**3**	**5**	**21**	**30**	39	48	53	53	43	35	**30**	**8**	31
2001	**2**	**3**	**14**	**27**	**43**	**52**	**55**	**56**	**49**	**38**	**30**	**21**	33
2002	**9**	**7**	**17**	**31**	39	47	56	55	48	33	22	**10**	31
2003	**-2**	**-2**	**13**	**24**	**39**	**51**	**57**	**57**	**49**	**37**	**27**	**15**	30
Avg	2	3	16	29	41	51	56	55	46	35	26	13	31

[a] Minimum temperature data from Greg Porter (2005) and from the NCDC (2004) if in bold face.
[b] Minimum temperature for November 1995 was not available (Porter, 2005; NCDC, 2004).

Table E.6. Average monthly relative humidity for Presque Isle, Maine, 1991 to 2003.

	Average Relative Humidity (%)[a]												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Avg
1991	69	65	62	33	-[b]	69	69	81	82	87	83	78	71
1992	75	77	66	65	54	71	76	78	75	76	78	76	72
1993	71	67	58	69	67	65	67	60	55	58	87	90	68
1994	83	75	85	82	81	85	89	87	91	80	84	**74**	83
1995	91	77	82	75	72	63	63	56	53	73	74	**76**	71
1996	59	**75**	**64**	**68**	73	85	92	90	91	89	90	93	81
1997	83	85	**65**	64	74	69	71	77	84	76	**76**	83	76
1998	**72**	**72**	74	66	73	77	72	70	76	**70**	**75**	**71**	72
1999	**65**	**68**	**68**	**62**	61	67	75	72	76	81	**76**	**80**	71
2000	**74**	**70**	**69**	**69**	66	63	76	78	72	75	**81**	**74**	72
2001	**74**	**69**	**66**	**62**	**59**	**69**	**74**	**66**	**76**	**76**	**73**	**74**	70
2002	**80**	**70**	**67**	**68**	64	70	79	71	78	77	79	**72**	73
2003	**69**	**61**	**70**	**60**	**65**	**65**	**74**	**77**	**75**	**76**	**75**	**73**	70
Avg	74	72	69	65	67	70	75	74	76	76	79	78	73

[a] Relative humidity data from Greg Porter (2005) and from the NCDC (2004) if in bold face.
[b] Relative humidity for May 1992 was not available (Porter, 2005; NCDC, 2004).

Table E.7. Average monthly wind velocity for Presque Isle, Maine, 1991 to 2003.

	Average Wind Velocity (mph)[a]												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann -ual Avg
1991	5.8	5.1	6.1	4.9	6.0	4.8	4.4	4.4	4.2	5.6	5.0	5.7	5.2
1992	6.5	7.2	5.9	5.7	5.7	4.5	4.0	3.9	4.2	4.4	4.2	5.1	5.1
1993	5.3	4.5	5.0	5.7	5.2	4.7	4.3	3.5	4.5	5.6	6.1	5.1	5.0
1994	6.3	5.8	5.7	5.6	6.1	5.1	3.9	4.3	3.7	4.8	6.9	**7.3**	5.5
1995	5.1	6.6	5.9	5.5	4.7	4.0	4.2	4.2	4.4	**7.3**	**7.7**	**8.0**	5.6
1996	6.0	**7.4**	6.2	6.6	5.8	4.5	4.6	2.7	3.6	5.2	4.9	5.2	5.2
1997	7.1	4.2	**9.5**	6.7	6.1	3.9	4.4	3.6	3.7	4.6	**7.2**	4.6	5.5
1998	**5.8**	**5.7**	5.6	6.5	4.9	4.2	4.0	3.7	**6.6**	**10.1**	**8.1**	**8.1**	6.1
1999	**7.9**	**8.0**	**11.6**	**10.0**	**7.8**	6.3	4.8	5.0	6.8	8.5	**8.7**	**8.1**	7.8
2000	**8.3**	**7.8**	**8.1**	**8.9**	**7.5**	**7.0**	**5.5**	**5.3**	**7.0**	**8.1**	**7.2**	**8.8**	7.5
2001	**5.3**	**8.8**	**8.3**	**9.2**	**8.1**	**8.5**	**7.7**	**8.2**	**8.6**	**8.0**	**9.4**	**8.8**	8.2
2002	**8.1**	**8.1**	**9.2**	**8.7**	8.7	5.2	4.6	4.3	4.7	6.5	7.8	**7.6**	7.0
2003	**6.5**	**8.8**	**8.2**	**7.2**	**6.1**	**6.2**	**5.9**	**5.5**	**5.2**	**7.2**	**8.2**	**8.7**	7.0
Avg	6.4	6.8	7.3	7.0	6.4	5.3	4.8	4.5	5.2	6.6	7.0	7.0	6.2

[a] Wind velocity data from Greg Porter (2005) and from the NCDC (2004) if in bold face.

Table E.8. Total monthly solar radiation for Presque Isle, Maine, 1991 to 2003.

	Total Monthly Solar Radiation (kWh/ft^2)[a]												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Sum
1991	44	59	93	129	155	171	168	135	105	56	33	33	1181
1992	41	65	109	137	175	153	155	131	105	63	39	28	1201
1993	42	66	127	113	148	159	162	152	106	60	34	27	1197
1994	41	71	89	112	133	158	160	143	89	62	-[b]	-[b]	1057
1995	-[b]	-[b]	-[b]	-[b]	-[b]	183	168	164	119	-[b]	-[b]	-[b]	633
1996	42	-[b]	112	110	148	147	146	151	99	72	40	28	1095
1997	41	60	-[b]	135	142	212	**209**	**159**	105	73	-[b]	-[b]	1137
1998	-[b]	-[b]	-[b]	**135**	**158**	**166**	**194**	**155**	-[b]	-[b]	-[b]	-[b]	808
1999	**42**	**56**	**100**	**130**	**185**	**183**	**170**	**142**	**108**	**64**	**36**	**30**	1246
2000	**41**	**60**	**113**	**116**	**156**	**176**	**159**	**139**	**109**	**63**	**31**	**33**	1196
2001	-[b]	-[b]	-[b]	**133**	**176**	**176**	**167**	**165**	**121**	**81**	-[b]	-[b]	1019
2002	-	**60**	**99**	**127**	**156**	**140**	**130**	**141**	**86**	**64**	**36**	-[b]	1039
2003	-[b]	-[b]	-[b]	**113**	**125**	**155**	**142**	**127**	-[b]	-[b]	**34**	**22**	717
Avg	42	62	105	124	155	168	164	146	105	66	35	29	

[a] Solar radiation data in kilowatt-hours per square foot (kWh/ft^2) from Greg Porter (2005). Monthly totals in bold face used data from Richard Perez (2005) for 1999 to 2000 and from William L. Bland and Rick Wayne (2005) for other years.

[b] Monthly total solar radiation unavailable due to snow cover or insufficient data (Porter, 2005; Perez, 2005; Bland and Wayne, 2005).

NCDC. Presque Isle solar radiation data was supplemented from the State University of New York (SUNY) at Albany, and the University of Wisconsin. Total monthly and average precipitation for Presque Isle over the validation period was summarized (Table E.3) along with maximum and minimum monthly temperatures (Tables E.4 and E.5). Supplemental data from the NCDC (2004) were noted.

Relative humidity and wind velocity monthly data for Presque Isle over the validation period was also summarized (Table E.6 and E.7). Supplemental precipitation and daily temperature were available, while hourly relative humidity and wind velocity

Table E.9. Average monthly weather variables used for EPIC simulations in Presque Isle, Maine.

Weather Variable	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Avg
TEMP[a] (°F)													
Maximum	23	23	35	47	61	74	77	73	66	54	38	25	50
Minimum	5	2	16	28	38	50	54	52	43	36	25	10	30
Std.Dev. Max	42	42	41	40	42	40	38	38	41	42	41	43	41
Std.Dev. Min	44	46	45	40	39	39	39	39	41	41	43	45	42
Dew Point	8	6	16	28	38	49	55	54	47	36	27	13	31
RAIN[b]													
Average (in)	2.2	1.4	1.8	1.7	2.7	2.2	4.4	3.9	3.9	3.1	4.2	2.8	2.9
Std.Dev. (in)	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.3	0.5	0.4	0.4	0.2	0.3
Skew Coeff.	0.8	2.1	0.5	0.1	0.8	0.2	1.5	1.2	2.2	3.3	1.4	0.4	1.2
Prob.Dry Wet	0.4	0.3	0.3	0.2	0.4	0.3	0.5	0.4	0.4	0.3	0.4	0.3	0.3
Prob.Wet Wet	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.5	0.5
Avg Rain Days	12	10	10	9	13	11	15	15	12	13	14	13	12
½ Max (in)	0.3	0.1	0.2	0.2	0.5	0.5	0.9	1.2	0.5	0.2	0.2	0.2	0.4
RAD[c] (kWh/ft^2)	35	62	96	107	128	126	136	120	90	57	30	29	85
RH[d] (%)	78	76	66	69	63	63	69	73	75	71	84	81	72
WV[e] (mph)	8.7	8.7	8.7	8.9	8.5	7.7	7.1	6.8	7.6	8.1	8.2	8.2	8.1

[a] Temperature (TEMP) variables included temperature maximum, minimum, standard deviation of maximum, and standard deviation of minimum in degrees Fahrenheit (°F).
[b] Precipitation (RAIN) variables were rainfall average (inches), standard deviation (inches), skewness coefficient, probability of dry followed by wet day, probability of wet followed by wet day, average number of days with rain, and half of the maximum daily rainfall (inches). Average total annual rainfall was 34.3 inches. Average total rainfall from May to September was 17 inches.
[c] Average daily solar radiation (RAD) in kilowatt-hours per square foot (kWh/ft^2).
[d] Average daily relative humidity (RH) as a percentage.
[e] Average daily wind velocity (WV) in miles per hour (mph).

Table E.10. Average monthly weather variables used for EPIC simulations in Corinna, Maine.

Weather Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Avg
	------ Month ------												
TEMP[a] (°F)													
Maximum	26	30	40	53	67	75	79	78	69	57	44	32	54
Minimum	1	4	17	30	41	50	56	53	44	33	25	10	30
Std.Dev. Max	42	41	42	42	42	40	38	38	39	40	41	41	41
Std.Dev. Min	45	45	44	39	39	39	38	39	40	40	40	44	41
Dew Point	11	11	17	28	36	46	52	53	46	36	27	15	31
RAIN[b]													
Average (in)	3.4	2.5	3.6	3.7	3.7	3.8	3.3	3.5	3.8	3.9	3.9	3.4	3.6
Std.Dev. (in)	1.8	1.1	1.2	2.0	2.0	1.6	1.5	2.1	1.9	2.1	1.5	1.6	1.7
Skew Coeff.	0.6	0.3	-0.6	1.5	0.4	1.0	0.6	0.4	0.8	0.8	1.3	0.7	0.6
Prob.Dry Wet	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Prob.Wet Wet	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2
Avg Rain Days	10	8	10	11	12	12	11	9	9	10	11	10	10
½ Max (in)	0.9	1.0	1.2	1.6	1.3	1.3	1.6	1.4	1.7	1.2	1.2	1.0	1.3
RAD[c] (kWh/ft^2)	38	62	93	108	131	136	142	124	97	67	38	34	89
RH[d] (%)	88	79	62	58	51	54	57	62	66	71	72	77	66
WV[e] (mph)	8.9	8.8	9.6	9.2	8.8	7.8	7.3	7.1	7.2	8.0	8.1	8.4	8.3

[a] Temperature (TEMP) variables included temperature maximum, minimum, standard deviation of maximum, and standard deviation of minimum in degrees Fahrenheit (°F).
[b] Precipitation (RAIN) variables were rainfall average (inches), standard deviation (inches), skewness coefficient, probability of dry followed by wet day, probability of wet followed by wet day, average number of days with rain, and half of the maximum daily rainfall (inches). Average total annual precipitation was 42.7 inches. Average total rainfall from May to September was 18.2 inches.
[c] Bangor average daily solar radiation (RAD) in kilowatt-hours per square foot (kWh/ft^2) used as proxy.
[d] Bangor average daily relative humidity (RH) as a percentage used as proxy.
[e] Bangor average daily wind velocity (WV) in miles per hour (mph) used as proxy.

were aggregated to a daily time step for use in EPIC (NCDC, 2004). For solar radiation (Table E.8), observed Presque Isle data was not available after 1997. Modeled solar radiation was used from Richard Perez (2005) for 1999 and 2000 and from William L. Bland and Rick Wayne (2005) for missing months from 1997 to 2003. Modeled solar radiation was averaged for 1999 and 2000.

EPIC crop rotation simulations used historical weather parameters downloaded from the Blackland Research Center in Temple, Texas, for Presque Isle (Table E.9) and Corinna (Table E.10), Maine (USDA-ARS, 2003). Summary statistics for precipitation, temperature, relative humidity, wind velocity, and solar radiation, based on historical averages were used as input parameters for EPIC rather than observed daily weather statistics for Presque Isle (1991 to 2003). These average parameter values were consistent with 30-year (1974-2003) averages for precipitation and temperature (NCDC, 2004) and observed 1991 to 2003 Presque Isle weather data (Porter, 2005). Precipitation and temperature data for Corinna were available, while 30-year (1974-2003) averages for relative humidity, wind velocity, and solar radiation from Bangor (NCDC, 2004) were used as proxies due to lack of these weather variables for Corinna.

The current EPIC 3060 version allowed five choices for equations that estimated evapotranspiration (ET). ET specifies the total evaporation or condensation of water from both crop leaves and the soil surface (Loomis and Connor, 1992). ET equation choices in EPIC included 1) Penman-Montieth, 2) Penman, 3) Priestly-Taylor, 4) Hargreaves, and 5) Baier-Robertson. Hargreaves was used for model runs since this equation was used by Williams (2005) when checking preliminary Maine runs.

Manure and fertilizer applications used in EPIC were the same as those for coupled potato and dairy farms in central Maine (Table 4.6) and Aroostook County (Table 7.3) and for on-farm integrated farms in both areas of Maine (Table 8.2). Exceptions were for EPIC validation of amended (manure and compost) and unamended potatoes in the Maine Potato Ecosystem Project (MPEP). Here, average fertilizer, compost, and manure applications for the first six years of the MPEP (1991 to 1996) were used. Unamended potatoes received 1204 lb/acre of 10-10-10 and 126 lb/acre of 32-0-0, while amended potatoes fertilizer applications were reduced to 475 lb/acre of 10-10-10 and 52 lb/acre of 32-0-0 due to the addition of 20 tons/acre of solid manure and 9 tons/acre of compost (Gallandt et al., 1998).

Unlike validation of MPEP results, where manure and compost were applied to amended potatoes, EPIC simulations of integrated cropping systems in Maine did not apply manure to potatoes directly; instead applications occurred during the rotation year(s). Average compost and solid manure nutrient analysis from the MPEP (1991 to 1994) was specified in EPIC (Porter, 1996). The MPEP's solid manure analysis was used for solid manure applications for simulations of small integrated farms. Simulations for medium-large farms assumed liquid manure applications. Tim Griffin provided nutrient analysis for liquid manure sampled from one of the cooperating dairy farmers in central Maine as well as organic nitrogen, phosphorus, and carbon estimates for all soil amendments (Griffin, 2004). Nutrient and organic carbon contents on a dry matter basis are provided for all compost and manures in Table E.11.

Table E.11. Dry matter analysis for nutrients and organic carbon in compost and manure.

Moisture, Nutrient,	Soil Amendment		
and Carbon Content	Compost[a]	Solid Manure[a]	Liquid Manure[b]
Percent Moisture	69	62	82
Percent of Dry Matter			
Nitrogen (N)	2.64	1.39	1.30
Ammonium (NH_4)	0.22	0.35	0.75
Phosphorus (P)	1.02	0.51	0.57
Potassium (K)	1.92	0.56	0.79
Organic Nitrogen	2.42	1.05	0.56
Organic Phosphorus	0.15	0.08	0.09
Organic Carbon	31.50	35.00	35.00

[a] Average for beef manure from the Maine Potato Ecosystem Project, 1991 to 1994 (Porter, 1996).
[b] Average for liquid manure samples taken from a cooperating dairy farmer (Griffin, 2004).

EPIC Modeling Results

Validation of EPIC for Presque Isle, Maine compared observed and simulated potato and barley yields. Observed yields (1991-2003) were from the MPEP provided by Greg Porter (2005). Model simulations were run for integrated and non-integrated crop rotations in Corinna and Presque Isle, Maine. Simulations were run for 30 years with 20 random draws of weather taken each year. Simulated rotations were row crops grown in central Maine (potatoes, grain corn, silage corn, barley, and soybeans) and Aroostook County (potatoes, barley, alfalfa, and soybeans) for coupled and on-farm integrated systems. Perennial forage grass was not modeled in EPIC.

Validation

Potato yields modeled by EPIC were compared to historical (1991 to 2002) total Maine potato yields obtained from the National Agricultural Statistics Service (USDA, NASS, 2004) and total yields (1991 to 2003) from MPEP plots (Porter, 2004). NASS historical yield data for barley was not available for Maine. From 1991 to 1998, the MPEP studied two commonly grown round-white potatoes (Atlantic and Superior). From 1999 to present, only Atlantic was grown, which tended to be more disease resistant than Superior (Marra, 1996). Pest management[17] (conventional, reduced input, and biological) and soil amendment[18] (unamended and amended) also varied. Reduced input Atlantic was assumed to be most similar to potatoes currently grown by farmers in central Maine and Aroostook County. Model validation runs matched typical MPEP crop management.

[17] Reduced input pest management used less pesticides and fungicides than conventional and was more representative of current typical industry practices. Biological pest management used biological pest controls such as *Bacillus thuringiensis* (Bt) and *Beauveria bassiana* (Marra, 1996).
[18] Unamended potato-barley rotations received typical fertilizer. Amended potatoes had compost and beef manure applications. From 1991 to 1992, the amended potato rotation crop was barley. From 1993 to 1998, the amended rotation crop was a pea, vetch, and oat cover crop.

Figure E.1. Observed historical compared to simulated unamended potato yields for Presque Isle, Maine, 1991 to 2003.

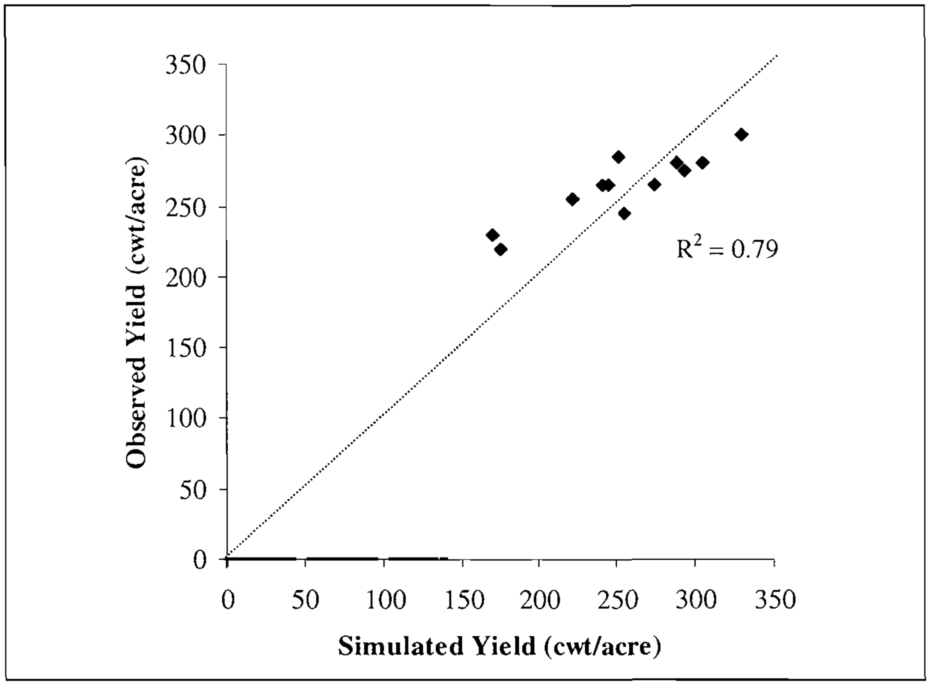


Figure E.2. Maine Potato Ecosystem Project unamended, reduced-input Atlantic compared to simulated unamended potato yields for Presque Isle, Maine, 1991 to 2003.

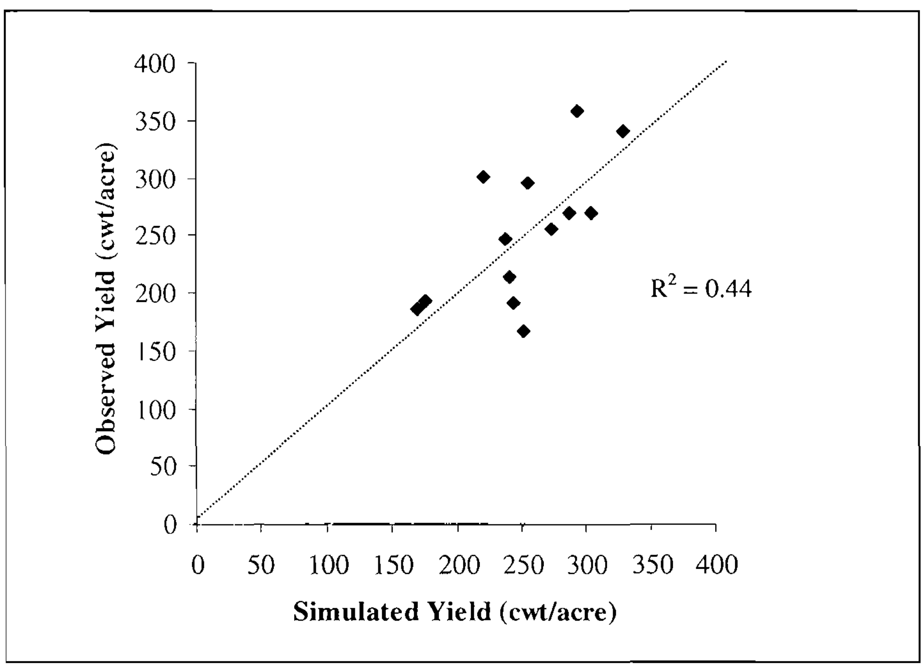


Figure E.3. Maine Potato Ecosystem Project amended, reduced-input Atlantic compared to simulated amended potato yields for Presque Isle, Maine, 1991 to 2003.

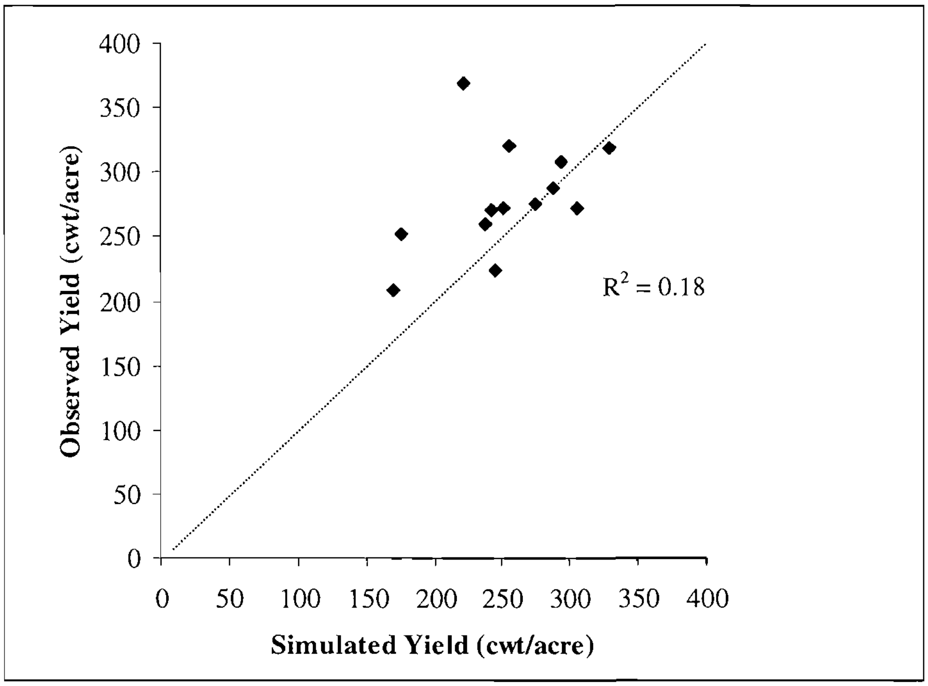


Figure E.4. Maine Potato Ecosystem Project unamended, reduced-input barley rotated with Atlantic compared to simulated unamended barley yields for Presque Isle, Maine, 1991 to 2003.

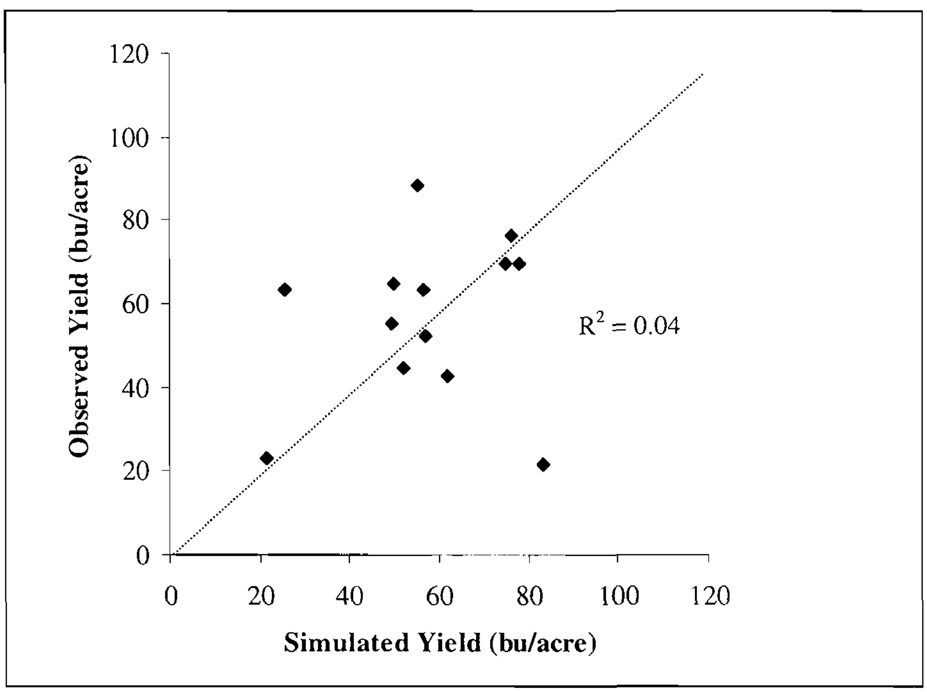
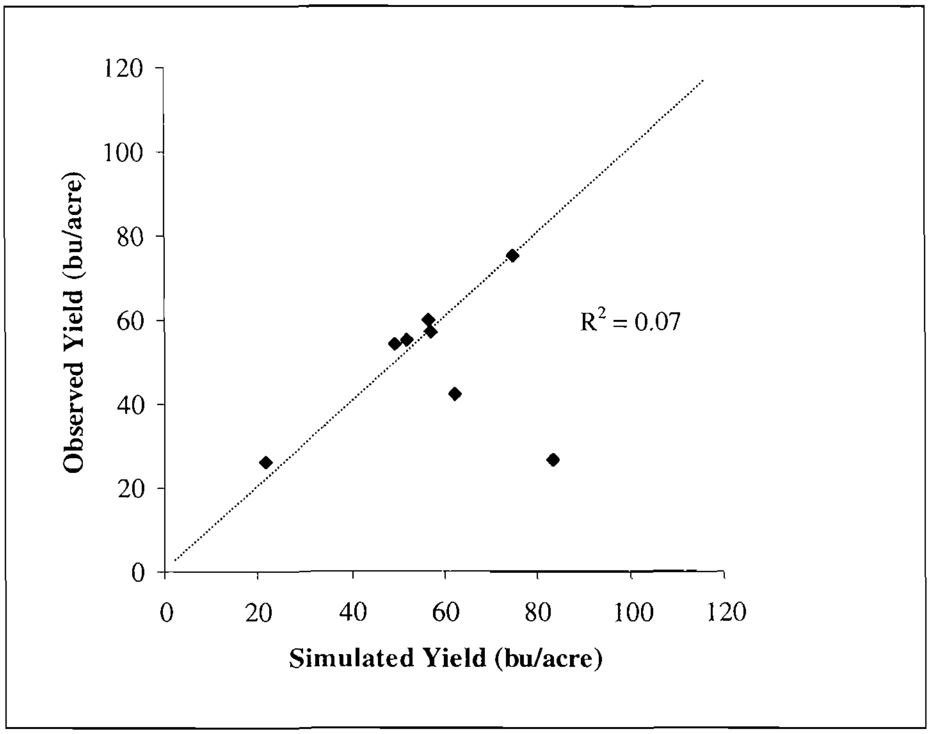


Figure E.5. Maine Potato Ecosystem Project amended, reduced-input barley rotated with Atlantic compared to simulated amended barley yields for Presque Isle, Maine, 1991 to 2003.



Unamended potato yields in EPIC were compared to historical yields (Figure E.1) and MPEP unamended, reduced input Atlantic total yields (Figure E.2). Similarly, amended EPIC potato yields were compared to MPEP amended, reduced input Atlantic total yields (Figure E.3). Similar comparisons were made for unamended (Figure E.4) and amended (Figure E.5) barley. Perfect correspondence of observed and modeled crop yields would be on the dotted line at a 45° angle from the graph origin. Conventional pest management and Superior were compared in Tables E.12 and E.13.

Observed and validation mean potato and barley yields were tested for significant differences using either pooled or un-pooled t-tests depending on if yield variances were statistically equal or not (Table E.12). Observed crop yields were also regressed on

Table E.12. Observed and simulated yields in Presque Isle, Maine, 1991 to 2003, for potato (cwt/acre) and barley (bu/acre) validation.

Crop	Soil Mng.[a]	Obs. Type[b]	Obs. Mean	Model Mean	Prob. T-Stat.[c]	Obs. Var.	Model Var.	Prob. F-Stat.[c]
Potato	-	Hist.	264	253.9	0.5349	14	61	0.0215
		RIA	253	252.6	0.9938	96	56	0.3671
		RICA	258	252.6	0.8031	84	56	0.4921
		RIAS	243	252.6	0.6566	109	56	0.2619
		RICAS	246	252.6	0.7670	94	56	0.3800
	+	Hist.	264	254.5	0.5459	14	61	0.0215
		RIA	280	253.2	0.1358	46	56	0.7449
		RICA	281	253.2	0.1088	42	56	0.6240
		RIAS	267	253.2	0.4475	58	56	0.9621
		RICAS	270	253.2	0.3609	52	56	0.9087
Barley	-	RIA	57	56.9	0.9628	18	17	0.8813
		RICA	59	58	0.9185	26	28	0.9321
		RIAS	58	58	0.9763	26	28	0.9148
		RICAS	58	58	0.9950	23	28	0.8275
	+	RIA	55	57.2	0.8006	15	16	0.9507
		RICA	44	60	0.5508	33	53	0.7700
		RIAS	43	60	0.5357	35	53	0.7918
		RICAS	42	60	0.5226	36	53	0.8126

[a] Soil management was unamended (-) and amended (+) with compost and beef manure.
[b] Observed crop yields for potatoes included historical (Hist.) Maine yields (USDA, NASS, 2004). Observed crop yields used from the Maine Potato Ecosystem Project (MPEP) were reduced input Atlantic (RIA) and averages for reduced input and conventional Atlantic (RICA), reduced input Atlantic and Superior (RIAS), and reduced input and conventional Atlantic and Superior (RICAS) potatoes (Porter, 2004).
[c] Probability of acceptance of the null hypotheses of equal means and variances of crop yields that were observed historically and during the MPEP versus those that were simulated during validation.

modeled yields for unamended and amended potatoes and barley using the model:

$$Y_{obs} = \alpha + \beta Y_{sim} + \varepsilon \tag{1}$$

Joint F-tests were conducted where the null hypotheses tested were if the slope (β) of the regression line was significantly different from one and if the intercept (α) was equal to zero, corresponding to a perfect fit of observed and simulated crop yields.

$$H_0:\ \alpha = 0 \ \textit{and}\ \beta = 1 \tag{2}$$

Table E.13. Regression results for observed versus simulated potato and barley yields in Presque Isle, Maine, 1991 to 2003, during validation.

Crop	Soil Mng.[a]	Obs. Type[b]	# of Obs.	R^2	Prob. F Stat.[c]	Inter-cept	Slope	Prob. F Stat. $\alpha=0$ & $\beta=1$[c]
Potato	-	Hist.	12	0.79	0.0001	155.6	0.43	0.0001
		RIA	13	0.44	0.0140	34.8	0.86	0.8990
		RICA	13	0.29	0.0592	92.0	0.66	0.5290
		RIAS	13	0.40	0.0197	18.6	0.89	0.7493
		RICAS	13	0.31	0.0462	62.5	0.73	0.6488
	+	Hist.	12	0.80	< 0.0001	155.3	0.43	0.0001
		RIA	13	0.18	0.1505	182.8	0.38	0.0176
		RICA	13	0.23	0.0933	175.3	0.42	0.0107
		RIAS	13	0.30	0.0523	126.4	0.56	0.1515
		RICAS	13	0.24	0.0905	150.3	0.47	0.0801
Barley	-	RIA	13	0.04	0.5374	45.4	0.20	0.0722
		RICA	8	0.05	0.6082	47.1	0.21	0.2015
		RIAS	8	0.04	0.6345	47.2	0.19	0.1899
		RICAS	8	0.04	0.6342	47.2	0.18	0.1651
	+	RIA	8	0.07	0.5328	40.2	0.25	0.2230
		RICA[d]	3	-	-	-	-	-
		RIAS[d]	3	-	-	-	-	-
		RICAS[d]	3	-	-	-	-	-

[a] Soil management was unamended (-) and amended (+) with compost and beef manure.
[b] Observed crop yields for potatoes included historical (Hist.) Maine yields (USDA, NASS, 2004). Observed crop yields used from the MPEP were reduced input Atlantic (RIA) and averages for reduced input and conventional Atlantic (RICA), reduced input Atlantic and Superior (RIAS), and reduced input and conventional Atlantic and Superior (RICAS) potatoes (Porter, 2004).
[c] Probability of acceptance of the null hypothesis of no explanatory power of simulated by observed crop yields and of the null hypothesis of the regression line having an intercept at the origin and a slope of one.
[d] Too few observations to conduct statistical tests.

Results from regression analyses are summarized in Table E.13. All statistical analyses were run using SAS (1999) software.

Potato and barley yield mean and variance during validation were statistically equal to observed historical yields and those from the MPEP. Two exceptions were the variance of observed historical potato yields, which were statistically less than variance of potato yields during validation. Mean potato yield from validation was generally less than observed yield except for those including unamended Superior, while variance was higher than historical, lower for unamended, and mixed for amended. Barley yield mean and variance were similar for unamended and higher for amended (Table E.12).

Regression analysis of observed and validation yields showed better fit and significance for potatoes than for barley (Table E.13). Goodness of fit (R^2) was quite high for historical potato yields for both unamended and amended (0.79 to 0.80). However, under- and over-estimation of historical potato yields by the model was apparent (Figure E.1) and confirmed by rejection of the null hypotheses of an intercept of zero and slope of one for the regression line. The R^2 values for MPEP yields were higher for unamended (0.29 to 0.44) compared to amended (0.18 to 0.30). The model underestimated yields for amended potato (Figure E.3) with two out of four rejections ($\alpha = 0.05$) of the joint *F*-test specified in equation (2). The R^2 values for barley were quite low, with amended being higher (0.07) than unamended (0.04 to 0.05). All regressions were not significant for barley with both under-estimation and over-estimation of yields (Figures E.4 and E.5).

The EPIC model did not show a positive potato yield response (0.22%) to soil amendment (Table E.12) consistent with an average increase in observed MPEP total potato yield of about 11% from 1991 to 2003. Potato yield response from amendment was more consistent in later years for both total (Figure E.6) and US #1 (Figure E.7) potato yield. However, average yield response for marketable US #1 potato yield from 1991 to 2003 was lower at about 6%.

Amended barley yield from the MPEP was lower than unamended. Barley yields during validation were slightly higher for amended (Table E.12). As earlier noted, compost and beef manure applications were specified as fertilizer with suggested nutrient

Figure E.6. Amended and unamended reduced input Atlantic total potato yields, Presque Isle, Maine, 1991 to 2003 (Porter, 2004).

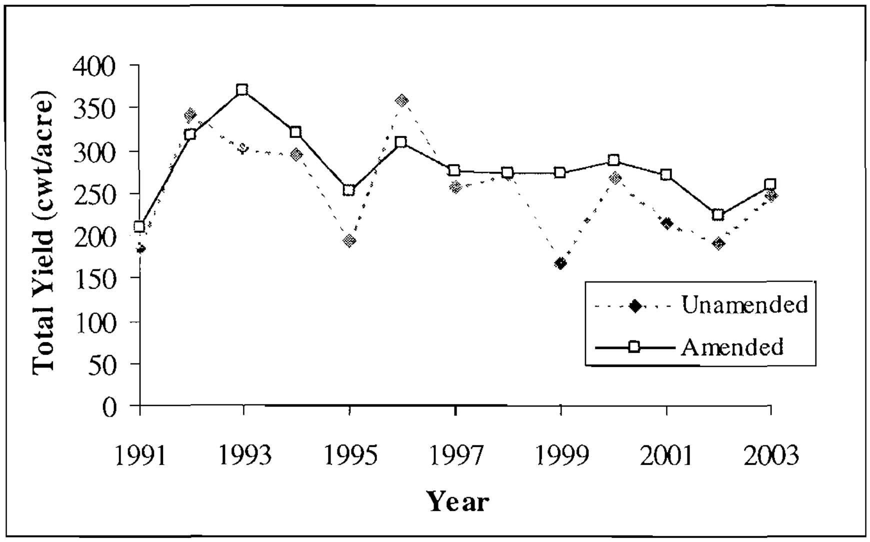
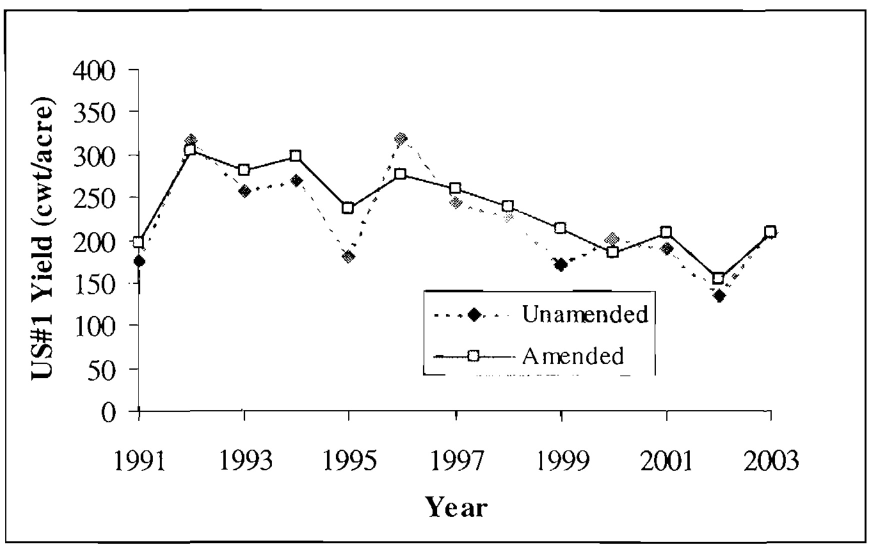


Figure E.7. Amended and unamended reduced input Atlantic U.S. #1 potato yields, Presque Isle, Maine, 1991 to 2003 (Porter, 2004).



parameters and both amendments were applied to potatoes in the model. Potato and barley yields simulated during validation were the same even when using the automatic manure application function.

Although a cover crop of peas, vetch, and oats (PVO) was used as the amended rotation crop for potatoes in the MPEP from 1993 to 1998, barley was used in EPIC since PVO was not specified as a crop in EPIC. Barley amended with 10 tons/acre of compost was the amended rotation crop for potatoes during 1991 and 1992. Future model runs should include PVO as an amended rotation crop for potatoes in EPIC.

Simulation

EPIC simulations were run for non-integrated (conventional) and integrated (coupled and on-farm) potato and dairy rotations in central Maine (Corinna) and Aroostook County (Presque Isle). Simulations were based on typical crop rotations outlined in chapters 5, 7, and 8 and on the treatments and systems in the MPEP. Rotation length ranged from two to four years and cropping sequence varied (Table E.14).

Table E.14. Crop rotation summary for integrated and non-integrated agricultural systems simulated in EPIC.

		---------- Crop Rotation -------------	
Location	Farm Type	Length (Years)	Crop Sequence[a]
Central Maine	Conventional	2	P-GC
	Coupled	2	P-SC
	On-Farm (Potato)	4	P-S-B-SC
	On-Farm (Dairy)	3	SC-S-B
Aroostook County	Conventional	2	P-B
	Coupled	2	P-A
	Diversified	4	P-S-P-B
	On-Farm (Potato)	4	P-S-B-A
	On-Farm (Dairy)	3	A-S-B

[a] Crops were potatoes (P), grain corn (GC), silage corn (SC), soybeans (S), barley (B), and alfalfa (A).

The on-farm integrated potato rotation was managed by coupled potato and dairy farms raising forage plus barley and soybean for use or for sale as concentrated feed. The on-farm integrated dairy farm rotation was managed by an uncoupled dairy farm growing forage and crops for concentrated feed. Aroostook County simulations also included a diversified potato rotation of two years potato and one year each of barley and soybeans. This represented a potato farm growing crops for sale into commodity markets or as concentrated livestock feed (barley and soybeans).

EPIC simulations were run over 30 years with 20 random draws from weather distributions in each year. Between 15 to 20 draws, the variance of crop yields for each successive draw remained below 2.5% for all crops. Potato yields were significantly lower for integrated rotations compared to conventional for Corinna. Silage corn yields were significantly lower for on-farm integrated compared to coupled rotations, while integrated barley and soybeans yields were similar (Table E.15). In Presque Isle, potato and barley yields for integrated rotations were slightly higher compared to conventional, while on-farm integrated yields for alfalfa and soybeans were higher than coupled. However, these differences in crop yields were not significant (Tables E.16 and E.17). In the case of potatoes and Presque Isle barley, baseline yields were non-integrated conventional. For other crops, baseline yields were from short-term integrated rotations with no manure nutrient credits taken.

In Corinna, integrated crop yields had similar variances compared to baseline yields with the exception of silage corn, which had lower variances (Table E.15). Crop variances in Presque Isle were also similar (Tables E.16 and E.17). In both locations, long-term integrated crop yields were similar to those in the short term. Simulations did not match reports of crop yield increases reported by long-term integrated cooperating farmers. Means and variances of all simulated crop yields did not appear to change over

Table E.15. Comparison of crop yield simulations in Corinna, Maine, for potatoes (cwt/acre), silage corn (tons/acre), and barley and soybeans (bu/acre).

Crop	Size[a]	Farm Type[b]	Time Integ.[c]	Base Mean[d]	Integ. Mean	Prob. T-Stat.[e]	Base Var.[d]	Integ. Var.	Prob. F-Stat.[e]
Potato	S	Coup	ST	225	221	0.0488	35	34	0.5878
			LT	225	221	0.0435	35	33	0.5750
		On-Farm	ST	225	212.3	< 0.0001	35	33	0.5702
		(Potato)	LT	225	212.2	< 0.0001	35	34	0.5906
	ML	Coup	ST	225	220.5	0.0250	35	33	0.5336
			LT	225	220.4	0.0220	35	33	0.5210
		On-Farm	ST	225	212.1	< 0.0001	35	34	0.6150
		(Potato)	LT	225	212.1	< 0.0001	35	34	0.6118
Silage Corn	S	Coup	LT	14.94	14.93	0.9825	6.923	6.921	0.9963
		On-Farm	ST	14.94	14.42	0.0014	6.92	5.92	0.0571
		(Potato)	LT	14.94	14.41	0.0011	6.92	5.92	0.0559
		On-Farm	ST	14.94	14.48	0.0042	6.92	5.86	0.0408
		(Dairy)	LT	14.94	14.48	0.0042	6.92	5.86	0.0408
	ML	Coup	LT	14.92	14.92	0.9858	6.88	6.87	0.9907
		On-Farm	ST	14.92	14.40	0.0012	6.88	5.89	0.0589
		(Potato)	LT	14.92	14.40	0.0012	6.88	5.89	0.0586
		On-Farm	ST	14.92	14.47	0.0058	6.88	5.85	0.0491
		(Dairy)	LT	14.92	14.47	0.0058	6.88	5.85	0.0491
Barley	S	On-Farm (Potato)	LT	43.69	43.49	0.8194	10.63	10.56	0.9317
		On-Farm	ST	43.69	43.92	0.7974	10.63	11.07	0.6178
		(Dairy)	LT	43.69	43.80	0.9031	10.63	10.94	0.7246
	ML	On-Farm (Potato)	LT	43.93	43.66	0.7504	10.7	10.6	0.8935
		On-Farm	ST	43.93	43.63	0.7297	10.7	11.0	0.7326
		(Dairy)	LT	43.93	43.86	0.9365	10.7	11.1	0.6793
Soy-beans	S	On-Farm (Potato)	LT	43.03	42.98	0.9198	5.14	5.13	0.9811
		On-Farm	ST	43.03	42.83	0.7105	5.14	5.15	0.9742
		(Dairy)	LT	43.03	42.83	0.7105	5.14	5.15	0.9742
	ML	On-Farm (Potato)	LT	42.93	42.92	0.9971	5.118	5.116	0.9955
		On-Farm	ST	42.93	42.82	0.8454	5.118	5.148	0.9452
		(Dairy)	LT	42.93	42.82	0.8454	5.118	5.148	0.9452

[a] Sizes for farms were small (S) and medium/large (ML).
[b] Integration types were conventional (non-integrated) and coupled and on-farm integrated. On-farm integrated farms included a potato farm (Potato) growing dairy forage and concentrated feed as well as a dairy farm (Dairy) raising crops for concentrated feed.
[c] Duration of integration ranged from short-term (ST) to long-term (LT).
[d] Means and variances of base yields were different for potatoes (conventional), silage corn (short-term coupled), and barley and soybeans (short-term on-farm integrated potato farm).
[e] Probability of acceptance of the null hypotheses of equal means and variances of observed and simulated crop yields.

Table E.16. Comparison of crop yield simulations in Presque Isle, Maine, for potatoes (cwt/acre) and alfalfa (tons/acre).

Crop	Size[a]	Farm Type[b]	Time Integ.[c]	Base Mean[d]	Integ. Mean	Prob. T-Stat.[e]	Base Var.[d]	Integ. Var.	Prob. F-Stat.[e]
Potato	S/ML	Amended	LT	264.3	264.4	0.9648	41	40	0.7475
	S	Coup	ST	264	266	0.4111	41	40	0.9104
			LT	264	266	0.4108	41	40	0.9105
		Diversified	ST	264	269	0.0631	41	40	0.9032
			LT	264	269	0.0631	41	40	0.9032
		On-Farm	ST	264	267	0.2503	41	40	0.9071
		(Potato)	LT	264	267	0.2503	41	40	0.9073
	ML	Coup	ST	264	266	0.4002	40.6	40.3	0.9090
			LT	264	266	0.3998	40.6	40.3	0.9083
		Diversified	ST	264	269	0.0625	40.6	40.2	0.9001
			LT	264	269	0.0624	40.6	40.2	0.9005
		On-Farm	ST	264	267	0.2411	40.6	40.2	0.9040
		(Potato)	LT	264	267	0.2542	40.6	40.3	0.9075
Alfalfa	S	Coup	LT	5.86	5.86	0.9997	1.61	1.61	0.9988
		On-Farm	ST	5.86	5.88	0.7172	1.61	1.62	0.9224
		(Potato)	LT	5.86	5.88	0.7171	1.61	1.62	0.9224
		On-Farm	ST	5.86	5.90	0.5312	1.61	1.63	0.8693
		(Dairy)	LT	5.86	5.90	0.5312	1.61	1.63	0.8693
	ML	Coup	LT	5.86	5.86	0.9996	1.61	1.61	0.9999
		On-Farm	ST	5.86	5.88	0.7142	1.61	1.62	0.9211
		(Potato)	LT	5.86	5.88	0.7370	1.61	1.62	0.9253
		On-Farm	ST	5.86	5.90	0.5380	1.61	1.63	0.8683
		(Dairy)	LT	5.86	5.90	0.5382	1.61	1.63	0.8678

[a] Sizes for farms were small (S) and medium/large (ML).
[b] Integration types were conventional (non-integrated) and coupled and on-farm integrated. On-farm integrated farms included a potato farm (Potato) growing dairy forage and concentrated feed as well as a dairy farm (Dairy) raising crops for concentrated feed.
[c] Duration of integration ranged from short-term (ST) to long-term (LT).
[d] Means and variances of base yields were conventional for potatoes and short-term coupled for alfalfa.
[e] Probability of acceptance of the null hypotheses of equal means and variances of observed and simulated crop yields.

the 30-year period (1997 to 2026), including those between unamended and amended treatments for potatoes in Presque Isle (Figures E.8 and E.9).

Central Maine simulated yields per acre (Table E.15) were similar to those reported by central Maine cooperating farmers for silage corn (15 tons), but were slightly lower for potatoes (279 cwt total and 240 cwt marketable). Central Maine simulated yields per acre were similar to average Maine yields for soybeans (45 bu) but were lower

Table E.17. Comparison of crop yield simulations in Presque Isle, Maine, for barley and soybeans (bu/acre).

Crop	Size[a]	Farm Type[b]	Time Integ.[c]	Base Mean[d]	Integ. Mean	Prob. T-Stat.[e]	Base Var.[d]	Integ. Var.	Prob. F-Stat.[e]
Barley	S/ML	Amended	LT	52.8	53.1	0.7274	9.8	9.9	0.9003
	S	Diversified	ST	52.8	52.9	0.8432	9.8	9.8	0.9331
			LT	52.8	52.9	0.8431	9.8	9.8	0.9330
		On-Farm	ST	52.8	53.3	0.5192	9.8	9.9	0.8107
		(Potato)	LT	52.8	53.3	0.5190	9.8	9.9	0.8104
		On-Farm	ST	52.8	53.6	0.2994	9.8	10.1	0.7138
		(Dairy)	LT	52.8	53.6	0.2994	9.8	10.1	0.7138
	ML	Diversified	ST	52.8	52.9	0.8369	9.8	9.8	0.9312
			LT	52.8	52.9	0.8368	9.8	9.8	0.9312
		On-Farm	ST	52.8	53.3	0.5105	9.8	9.9	0.8097
		(Potato)	LT	52.8	53.3	0.5357	9.8	9.9	0.8127
		On-Farm	ST	52.8	53.7	0.2853	9.8	10.0	0.7149
		(Dairy)	LT	52.8	53.7	0.2853	9.8	10.0	0.7148
Soy-beans	S	Diversified	LT	37.2	37.2	0.9997	5.59	5.59	0.9999
		On-Farm	ST	37.2	37.3	0.8923	5.59	5.61	0.9520
		(Potato)	LT	37.2	37.3	0.8924	5.59	5.61	0.9519
		On-Farm	ST	37.2	37.5	0.5504	5.59	5.71	0.7881
		(Dairy)	LT	37.2	37.5	0.5504	5.59	5.71	0.7881
	ML	Diversified	LT	37.2	37.2	0.9999	5.59	5.59	0.9999
		On-Farm	ST	37.2	37.3	0.8958	5.59	5.62	0.9521
		(Potato)	LT	37.2	37.3	0.8985	5.59	5.61	0.9566
		On-Farm	ST	37.2	37.6	0.5472	5.59	5.71	0.7805
		(Dairy)	LT	37.2	37.6	0.5473	5.59	5.71	0.7803

[a] Sizes for farms were small (S) and medium/large (ML).
[b] Integration types were conventional (non-integrated) and coupled and on-farm integrated. On-farm integrated farms included a potato farm (Potato) growing dairy forage and concentrated feed as well as a dairy farm (Dairy) raising crops for concentrated feed.
[c] Duration of integration ranged from short-term (ST) to long-term (LT).
[d] Means and variances of base yields were conventional for barley and diversified (MPEP) for soybeans.
[e] Probability of acceptance of the null hypotheses of equal means and variances of observed and simulated crop yields.

than average Maine yields for barley (71 bu). Aroostook County simulated crop yields per acre (Tables E.16 and E.17) were similar to alfalfa yields (6.25 tons) reported by cooperating producers and average Maine soybean yields. Simulated yields per acre for potatoes were lower than typical yields in Aroostook County (328 cwt total and 283 cwt marketable) and average Maine barley yields.

Figure E.8. Simulated potato yields for unamended potatoes in Presque Isle, 1997 to 2026.

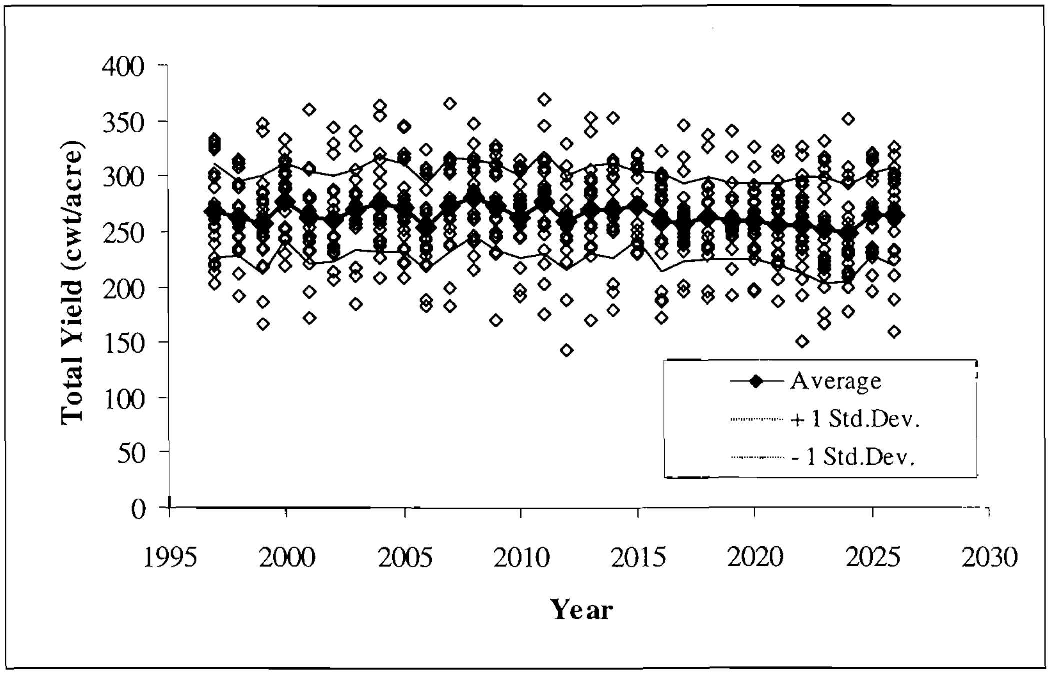
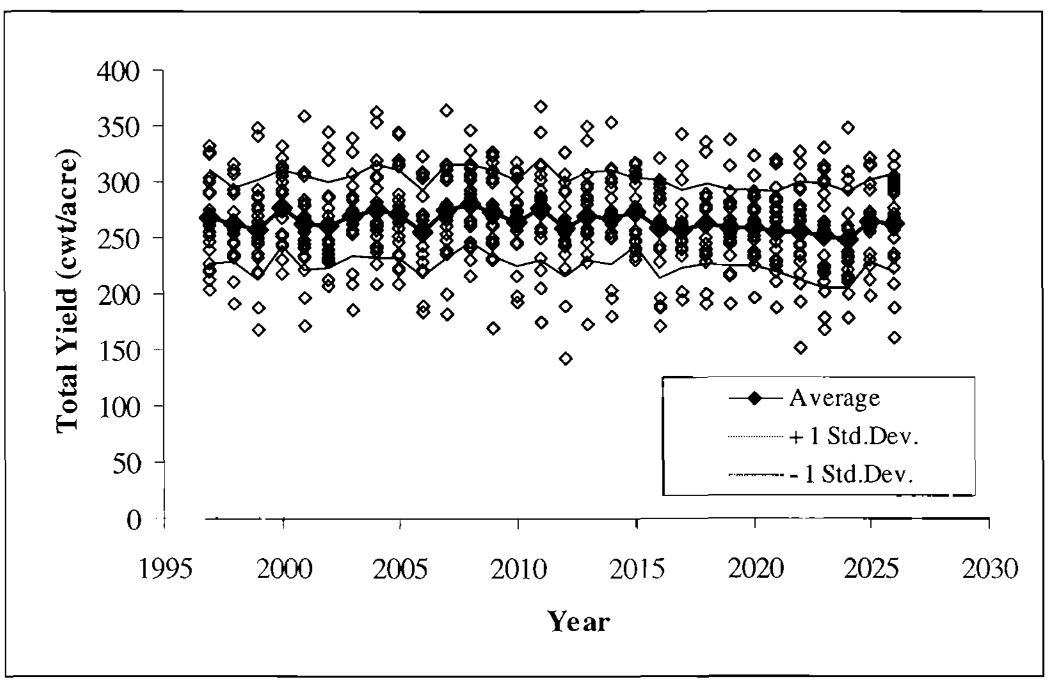


Figure E.9. Simulated potato yields for amended potatoes in Presque Isle, 1997 to 2026.



Further improvements in validating potato and barley yields are required to better model yield responses from manure and compost amendments observed in the MPEP from 1991 to 2003. Simulated unamended potato yields in EPIC had reasonable fits compared to historical and MPEP observed yields. Model validation was less robust for barley. Subsequently, crop simulations did not support farmer reported crop yield increases for integrated rotations. In some cases, such as potatoes and silage corn in central Maine, integrated yields in EPIC were actually lower than non-integrated ones.

Current application of EPIC for Maine potato rotations requires improvement in modeling 1) potato yields and 2) amendment with manure and compost. The model's over- and under-prediction of potato yields compared to historical averages suggests that it was too sensitive to environmental, soil, or crop parameters. Not accounting for upward capillary movement of moisture in the soil profile may account for under-prediction of potato yields in dry years but such water movement has recently been incorporated into EPIC (Williams, 2005). Technical errors downloading i_EPIC may be causing these problems and runs should be checked on other computers.

EPIC's under-prediction of amended potato yields could be due to of crop parameter misspecification requiring more sensitivity analyses. Current model runs assume manure and fertilizer management for the first two years of the project are repeated over all validation years (1991 to 2003). However, from 1993 to1997, PVO was used as the amended potato rotation crop instead of barley. In years since 1998, 30 and 20 tons/acre of manure were applied to potatoes and barley, respectively, and chemical fertilization was decreased. Such different crop and fertilization management from year to year can and should be specified in EPIC. Future validation of the model should also adjust soil parameters for amended systems. This analysis assumed soil parameters like bulk density, pH, and cation exchange capacity did not change with amendment.

Due to the poor simulation of amended potato systems in EPIC, the observed marketable potato yield response of about 6% from the Maine Potato Ecosystem Project was used. Thus, an average marketable potato yield response from long-term integration of 5% was assumed for representative potato budget sensitivity analyses in central Maine (Table 5.7) and Aroostook County (Table 7.14).

Appendix F-1: CENTRAL MAINE SHORT-TERM COUPLED INDICATOR RANKINGS

ECONOMIC									
Profitability						Efficiency			
NFI[a]	Farm Type	ROVC[a]	Farm Type	POR	Farm Type	ATR	Farm Type	OER	Farm Type
$208	LF-CoupPotML	$443	LF-CoupPotML	0.134	LF-CoupPotML	0.507	L-CoupPotML	0.541	ConvPotS
$127	L-CoupPotML	$335	LF-CoupPotS	0.098	L-CoupPotML	0.451	LF-CoupPotML	0.559	LF-CoupPotS
$57	LF-CoupPotS	$334	L-CoupPotML	0.043	LF-CoupPotS	0.416	L-CoupPotS	0.559	ConvPotML
$18	ConvPotML	$262	L-CoupPotS	0.019	ConvPotML	0.373	LF-CoupPotS	0.571	L-CoupPotS
$12	L-CoupPotS	$225	ConvPotML	0.010	L-CoupPotS	0.348	ConvPotML	0.572	LF-CoupPotML
-$51	ConvPotS	$200	ConvPotS	-0.054	ConvPotS	0.306	ConvPotS	0.595	L-CoupPotML
-$9	L-CoupDairyML	$319	L-CoupDairyML	-0.007	L-CoupDairyML	0.346	LF-CoupDairyML	0.235	L-CoupDairyS
-$9	ConvDairyML	$319	ConvDairyML	-0.007	ConvDairyML	0.319	L-CoupDairyML	0.235	ConvDairyS
-$109	LF-CoupDairyML	$187	LF-CoupDairyML	-0.086	LF-CoupDairyML	0.319	ConvDairyML	0.340	L-CoupDairyML
-$245	L-CoupDairyS	$148	L-CoupDairyS	-0.245	L-CoupDairyS	0.235	LF-CoupDairyS	0.340	ConvDairyML
-$245	ConvDairyS	$148	ConvDairyS	-0.245	ConvDairyS	0.210	L-CoupDairyS	0.398	LF-CoupDairyS
-$295	LF-CoupDairyS	$44	LF-CoupDairyS	-0.296	LF-CoupDairyS	0.210	ConvDairyS	0.474	LF-CoupDairyML
SUSTAINABILITY									
FVA[a]	Farm Type	FVAp	Farm Type	NRG	Farm Type	SLF	Farm Type	FB[b]	Farm Type
$464	LF-CoupPotML	0.300	LF-CoupPotML	0.481	LF-CoupPotML	0.261	LF-CoupPotML	-	L-CoupPotS
$341	L-CoupPotML	0.262	L-CoupPotML	0.508	L-CoupPotML	0.222	L-CoupPotML	-	LF-CoupPotS
$304	LF-CoupPotS	0.228	LF-CoupPotS	0.549	LF-CoupPotS	0.187	LF-CoupPotS	-	L-CoupPotML
$225	L-CoupPotS	0.193	L-CoupPotS	0.576	L-CoupPotS	0.150	L-CoupPotS	-	LF-CoupPotML
$179	ConvPotML	0.188	ConvPotML	0.577	ConvPotML	0.145	ConvPotML	-	ConvPotS
$126	ConvPotS	0.132	ConvPotS	0.633	ConvPotS	0.086	ConvPotS	-	ConvPotML
$92	L-CoupDairyML	0.073	L-CoupDairyML	0.316	LF-CoupDairyML	0.041	L-CoupDairyML	-0.224	L-CoupDairyS
$92	ConvDairyML	0.073	ConvDairyML	0.405	L-CoupDairyML	0.041	ConvDairyML	-0.224	ConvDairyS
-$56	LF-CoupDairyML	-0.045	LF-CoupDairyML	0.405	ConvDairyML	-0.073	LF-CoupDairyML	-0.279	L-CoupDairyML
-$131	L-CoupDairyS	-0.132	L-CoupDairyS	0.442	LF-CoupDairyS	-0.182	L-CoupDairyS	-0.279	ConvDairyML
-$131	ConvDairyS	-0.132	ConvDairyS	0.574	L-CoupDairyS	-0.182	ConvDairyS	-0.512	LF-CoupDairyS
-$240	LF-CoupDairyS	-0.240	LF-CoupDairyS	0.574	ConvDairyS	-0.286	LF-CoupDairyS	-0.523	LF-CoupDairyML

[a] NFI, ROVC, and FVA in $/acre. Acreage in denominator included potatoes and barley for potato farms.
For dairy farms, crop acreage included just silage corn and hay/haylage, not pasture.

[b] Feed balance comparison not applicable for potato farms since no feed was purchased and indicator values were equal to +1.

Appendix F-2: CENTRAL MAINE LONG-TERM COUPLED INDICATOR RANKINGS

ECONOMIC									
Profitability						Efficiency			
NFI[a]	Farm Type	ROVC[a]	Farm Type	POR	Farm Type	ATR	Farm Type	OER	Farm Type
$285	LF-CoupPotML	$520	LF-CoupPotML	0.184	LF-CoupPotML	0.507	L-CoupPotML	0.509	LF-CoupPotS
$203	L-CoupPotML	$409	L-CoupPotML	0.156	L-CoupPotML	0.451	LF-CoupPotML	0.516	L-CoupPotS
$124	LF-CoupPotS	$402	LF-CoupPotS	0.093	LF-CoupPotS	0.416	L-CoupPotS	0.522	LF-CoupPotML
$76	L-CoupPotS	$327	L-CoupPotS	0.065	L-CoupPotS	0.373	LF-CoupPotS	0.536	L-CoupPotML
$18	ConvPotML	$225	ConvPotML	0.019	ConvPotML	0.348	ConvPotML	0.541	ConvPotS
-$51	ConvPotS	$200	ConvPotS	-0.054	ConvPotS	0.306	ConvPotS	0.559	ConvPotML
-$7	L-CoupDairyML	$321	L-CoupDairyML	-0.006	L-CoupDairyML	0.346	LF-CoupDairyML	0.234	L-CoupDairyS
-$9	ConvDairyML	$319	ConvDairyML	-0.007	ConvDairyML	0.319	L-CoupDairyML	0.235	ConvDairyS
-$109	LF-CoupDairyML	$187	LF-CoupDairyML	-0.086	LF-CoupDairyML	0.319	ConvDairyML	0.339	L-CoupDairyML
-$243	L-CoupDairyS	$150	L-CoupDairyS	-0.244	L-CoupDairyS	0.235	LF-CoupDairyS	0.340	ConvDairyML
-$245	ConvDairyS	$148	ConvDairyS	-0.245	ConvDairyS	0.210	L-CoupDairyS	0.398	LF-CoupDairyS
-$295	LF-CoupDairyS	$44	LF-CoupDairyS	-0.296	LF-CoupDairyS	0.210	ConvDairyS	0.474	LF-CoupDairyML

SUSTAINABILITY									
FVA[a]	Farm Type	FVAp	Farm Type	NRG	Farm Type	SLF	Farm Type	FB[b]	Farm Type
$541	LF-CoupPotML	0.349	LF-CoupPotML	0.433	LF-CoupPotML	0.311	LF-CoupPotML	-	L-CoupPotS
$417	L-CoupPotML	0.321	L-CoupPotML	0.451	L-CoupPotML	0.280	L-CoupPotML	-	LF-CoupPotS
$370	LF-CoupPotS	0.278	LF-CoupPotS	0.501	LF-CoupPotS	0.237	LF-CoupPotS	-	L-CoupPotML
$289	L-CoupPotS	0.248	L-CoupPotS	0.521	L-CoupPotS	0.205	L-CoupPotS	-	LF-CoupPotML
$179	ConvPotML	0.188	ConvPotML	0.577	ConvPotML	0.145	ConvPotML	-	ConvPotS
$126	ConvPotS	0.132	ConvPotS	0.633	ConvPotS	0.086	ConvPotS	-	ConvPotML
$94	L-CoupDairyML	0.075	L-CoupDairyML	0.316	LF-CoupDairyML	0.043	L-CoupDairyML	-0.224	L-CoupDairyS
$92	ConvDairyML	0.073	ConvDairyML	0.404	L-CoupDairyML	0.041	ConvDairyML	-0.224	ConvDairyS
-$56	LF-CoupDairyML	-0.045	LF-CoupDairyML	0.405	ConvDairyML	-0.073	LF-CoupDairyML	-0.279	L-CoupDairyML
-$130	L-CoupDairyS	-0.130	L-CoupDairyS	0.442	LF-CoupDairyS	-0.180	L-CoupDairyS	-0.279	ConvDairyML
-$131	ConvDairyS	-0.132	ConvDairyS	0.572	L-CoupDairyS	-0.182	ConvDairyS	-0.512	LF-CoupDairyS
-$240	LF-CoupDairyS	-0.240	LF-CoupDairyS	0.574	ConvDairyS	-0.286	LF-CoupDairyS	-0.523	LF-CoupDairyML

[a] NFI, ROVC, and FVA in $/acre. Acreage in denominator included potatoes and barley for potato farms.
For dairy farms, crop acreage included just silage corn and hay/haylage, not pasture.
[b] Feed balance comparison not applicable for potato farms since no feed was purchased and indicator values were equal to +1.

Appendix F-3: AROOSTOOK COUNTY SHORT-TERM COUPLED INDICATOR RANKINGS

ECONOMIC									
Profitability						Efficiency			
NFI[a]	Farm Type	ROVC[a]	Farm Type	POR	Farm Type	ATR	Farm Type	OER	Farm Type
$187	LF-CpPotML	$395	LF-CpPotML	0.158	LF-CpPotML	0.426	L-CpPotML	0.498	LF-CpPotML SU
$152	LF-CpPotML SU	$382	LF-CpPotML SU	0.128	LF-CpPotML SU	0.426	LF-CpPotML	0.500	LF-CpPotS SU
$98	L-CpPotML	$303	LF-CpPotS	0.101	L-CpPotML	0.381	L-CpPotS	0.502	LF-CpPotML
$54	LF-CpPotS	$294	LF-CpPotS SU	0.050	LF-CpPotS	0.380	LF-CpPotML SU	0.503	LF-CpPotS
$33	L-CpPotS	$266	L-CpPotML	0.038	ConvPotML	0.355	LF-CpPotS	0.517	ConvPotS
$33	ConvPotML	$232	ConvPotML	0.036	L-CpPotS	0.353	ConvPotML	0.521	ConvPotML
$31	LF-CpPotS SU	$229	L-CpPotS	0.029	LF-CpPotS SU	0.331	LF-CpPotS SU	0.557	L-CpPotS
-$30	ConvPotS	$209	ConvPotS	-0.034	ConvPotS	0.296	ConvPotS	0.564	L-CpPotML
$135	L-Cp&ConvDairyML	$463	L-Cp&ConvDairyML	0.107	L-Cp&ConvDairyML	0.386	LF-CpDairyML SU	0.132	L-Cp&ConvDairyS
$84	LF-CpDairyML SU	$353	LF-CpDairyML SU	0.066	LF-CpDairyML SU	0.344	LF-CpDairyML	0.225	L-Cp&ConvDairyML
$25	LF-CpDairyML	$323	LF-CpDairyML	0.020	LF-CpDairyML	0.319	L-Cp&ConvDairyML	0.301	LF-CpDairyS
-$150	LF-CpDairyS SU	$228	L-Cp&ConvDairyS	-0.154	LF-CpDairyS SU	0.260	LF-CpDairyS SU	0.344	LF-CpDairyS SU
-$167	L-Cp&ConvDairyS	$159	LF-CpDairyS SU	-0.171	L-Cp&ConvDairyS	0.225	LF-CpDairyS	0.364	LF-CpDairyML
-$238	LF-CpDairyS	$113	LF-CpDairyS	-0.244	LF-CpDairyS	0.203	L-Cp&ConvDairyS	0.387	LF-CpDairyML SU

SUSTAINABILITY									
FVA[a]	Farm Type	FVAp	Farm Type	NRG	Farm Type	SLF	Farm Type	FB[b]	Farm Type
$375	LF-CpPotML	0.316	LF-CpPotML	0.486	LF-CpPotML	0.282	LF-CpPotML	-	L-CpPotS
$342	LF-CpPotML SU	0.288	LF-CpPotML SU	0.486	LF-CpPotML SU	0.253	LF-CpPotML SU	-	LF-CpPotS
$255	L-CpPotML	0.263	L-CpPotML	0.517	L-CpPotML	0.226	L-CpPotML	-	LF-CpPotS SU
$249	LF-CpPotS	0.230	LF-CpPotS	0.553	LF-CpPotS	0.193	LF-CpPotS	-	L-CpPotML
$227	LF-CpPotS SU	0.216	L-CpPotS	0.553	LF-CpPotS SU	0.177	L-CpPotS	-	LF-CpPotML
$202	L-CpPotS	0.210	LF-CpPotS SU	0.562	L-CpPotS	0.171	LF-CpPotS SU	-	LF-CpPotML SU
$178	ConvPotML	0.204	ConvPotML	0.573	ConvPotML	0.164	ConvPotML	-	ConvPotS
$120	ConvPotS	0.138	ConvPotS	0.639	ConvPotS	0.108	ConvPotS	-	ConvPotML
$213	L-Cp&ConvDairyML	0.169	L-Cp&ConvDairyML	0.316	LF-CpDairyML SU	0.139	L-Cp&ConvDairyML	-0.149	L-Cp&ConvDairyS
$118	LF-CpDairyML SU	0.094	LF-CpDairyML SU	0.316	LF-CpDairyML	0.072	LF-CpDairyML SU	-0.182	L-Cp&ConvDairyML
$68	LF-CpDairyML	0.054	LF-CpDairyML	0.385	L-Cp&ConvDairyML	0.025	LF-CpDairyML	-0.395	LF-CpDairyML
-$69	L-Cp&ConvDairyS	-0.071	L-Cp&ConvDairyS	0.464	LF-CpDairyS SU	-0.120	L-Cp&ConvDairyS	-0.395	LF-CpDairyML SU
-$107	LF-CpDairyS SU	-0.110	LF-CpDairyS SU	0.464	LF-CpDairyS	-0.144	LF-CpDairyS SU	-0.432	LF-CpDairyS
-$182	LF-CpDairyS	-0.187	LF-CpDairyS	0.566	L-Cp&ConvDairyS	-0.234	LF-CpDairyS	-0.432	LF-CpDairyS SU

[a] NFI, ROVC, and FVA in $/acre. Acreage in denominator included potatoes and barley for potato farms.
For dairy farms, crop acreage included just silage corn and hay/haylage, not pasture.

[b] Feed balance comparison not applicable for potato farms since no feed was purchased and indicator values were equal to +1.

Appendix F-4: AROOSTOOK COUNTY LONG-TERM COUPLED INDICATOR RANKINGS

ECONOMIC									
Profitability						Efficiency			
NFI[a]	Farm Type	ROVC[a]	Farm Type	POR	Farm Type	ATR	Farm Type	OER	Farm Type
$236	LF-CpPotML	$445	LF-CpPotML	0.199	LF-CpPotML	0.426	L-CpPotML	0.455	LF-CpPotS SU
$201	LF-CpPotML SU	$431	LF-CpPotML SU	0.169	LF-CpPotML SU	0.426	LF-CpPotML	0.456	LF-CpPotML SU
$147	L-CpPotML	$351	LF-CpPotS	0.152	L-CpPotML	0.381	L-CpPotS	0.458	LF-CpPotS
$102	LF-CpPotS	$342	LF-CpPotS SU	0.094	LF-CpPotS	0.380	LF-CpPotML SU	0.461	LF-CpPotML
$81	L-CpPotS	$315	L-CpPotML	0.087	L-CpPotS	0.355	LF-CpPotS	0.505	L-CpPotS
$79	LF-CpPotS SU	$277	L-CpPotS	0.073	LF-CpPotS SU	0.353	ConvPotML	0.513	L-CpPotML
$33	ConvPotML	$232	ConvPotML	0.038	ConvPotML	0.331	LF-CpPotS SU	0.517	ConvPotS
-$30	ConvPotS	$209	ConvPotS	-0.034	ConvPotS	0.296	ConvPotS	0.521	ConvPotML
$135	L-Cp&ConvDairyML	$463	L-Cp&ConvDairyML	0.107	L-Cp&ConvDairyML	0.386	LF-CpDairyML SU	0.132	L-Cp&ConvDairyS
$84	LF-CpDairyML SU	$353	LF-CpDairyML SU	0.066	LF-CpDairyML SU	0.344	LF-CpDairyML	0.225	L-Cp&ConvDairyML
$25	LF-CpDairyML	$323	LF-CpDairyML	0.020	LF-CpDairyML	0.319	L-Cp&ConvDairyML	0.301	LF-CpDairyS
-$150	LF-CpDairyS SU	$228	L-Cp&ConvDairyS	-0.154	LF-CpDairyS SU	0.260	LF-CpDairyS SU	0.344	LF-CpDairyS SU
-$167	L-Cp&ConvDairyS	$159	LF-CpDairyS SU	-0.171	L-Cp&ConvDairyS	0.225	LF-CpDairyS	0.364	LF-CpDairyML
-$238	LF-CpDairyS	$113	LF-CpDairyS	-0.244	LF-CpDairyS	0.203	L-Cp&ConvDairyS	0.387	LF-CpDairyML SU

SUSTAINABILITY									
FVA[a]	Farm Type	FVAp	Farm Type	NRG	Farm Type	SLF	Farm Type	FB[b]	Farm Type
$424	LF-CpPotML	0.357	LF-CpPotML	0.446	LF-CpPotML	0.324	LF-CpPotML	-	L-CpPotS
$391	LF-CpPotML SU	0.330	LF-CpPotML SU	0.446	LF-CpPotML SU	0.294	LF-CpPotML SU	-	LF-CpPotS
$304	L-CpPotML	0.314	L-CpPotML	0.468	L-CpPotML	0.277	L-CpPotML	-	LF-CpPotS SU
$296	LF-CpPotS	0.275	LF-CpPotS	0.510	LF-CpPotS	0.237	LF-CpPotS	-	L-CpPotML
$275	LF-CpPotS SU	0.268	L-CpPotS	0.510	LF-CpPotS SU	0.229	L-CpPotS	-	LF-CpPotML
$250	L-CpPotS	0.254	LF-CpPotS SU	0.512	L-CpPotS	0.215	LF-CpPotS SU	-	LF-CpPotML SU
$178	ConvPotML	0.204	ConvPotML	0.573	ConvPotML	0.164	ConvPotML	-	ConvPotS
$120	ConvPotS	0.138	ConvPotS	0.639	ConvPotS	0.108	ConvPotS	-	ConvPotML
$213	L-Cp&ConvDairyML	0.169	L-Cp&ConvDairyML	0.316	LF-CpDairyML SU	0.139	L-Cp&ConvDairyML	-0.149	L-Cp&ConvDairyS
$118	LF-CpDairyML SU	0.094	LF-CpDairyML SU	0.316	LF-CpDairyML	0.072	LF-CpDairyML SU	-0.182	L-Cp&ConvDairyML
$68	LF-CpDairyML	0.054	LF-CpDairyML	0.385	L-Cp&ConvDairyML	0.025	LF-CpDairyML	-0.395	LF-CpDairyML
-$69	L-Cp&ConvDairyS	-0.071	L-Cp&ConvDairyS	0.464	LF-CpDairyS SU	-0.120	L-Cp&ConvDairyS	-0.395	LF-CpDairyML SU
-$107	LF-CpDairyS SU	-0.110	LF-CpDairyS SU	0.464	LF-CpDairyS	-0.144	LF-CpDairyS SU	-0.432	LF-CpDairyS
-$182	LF-CpDairyS	-0.187	LF-CpDairyS	0.566	L-Cp&ConvDairyS	-0.234	LF-CpDairyS	-0.432	LF-CpDairyS SU

[a] NFI, ROVC, and FVA in $/acre. Acreage in denominator included potatoes and barley for potato farms.
For dairy farms, crop acreage included just silage corn and hay/haylage, not pasture.
[b] Feed balance comparison not applicable for potato farms since no feed was purchased and indicator values were equal to +1.

Appendix F-5: SHORT-TERM ON-FARM INTEGRATED INDICATOR RANKINGS

	ECONOMIC									
	Profitability						Efficiency			
Location	NFI[a]	Farm Type	ROVC[a]	Farm Type	POR	Farm Type	ATR	Farm Type	OER	Farm Type
Central ME	$194	OnFarmDairyML	$473	OnFarmDairyML	0.198	OnFarmDairyML	0.319	ConvDairyML	-0.046	OnFarmDairyS
	-$9	ConvDairyML	$319	ConvDairyML	-0.007	ConvDairyML	0.291	OnFarmDairyML	0.076	OnFarmDairyML
	-$115	OnFarmDairyS	$254	OnFarmDairyS	-0.148	OnFarmDairyS	0.210	ConvDairyS	0.235	ConvDairyS
	-$245	ConvDairyS	$148	ConvDairyS	-0.245	ConvDairyS	0.178	OnFarmDairyS	0.340	ConvDairyML
Aroo-stook	$186	OnFarmDairyML	$463	ConvDairyML	0.202	OnFarmDairyML	0.319	ConvDairyML	-0.016	OnFarmDairyS
	$135	ConvDairyML	$452	OnFarmDairyML	0.107	ConvDairyML	0.289	OnFarmDairyML	0.066	OnFarmDairyML
	-$117	OnFarmDairyS	$228	ConvDairyS	-0.168	OnFarmDairyS	0.203	ConvDairyS	0.132	ConvDairyS
	-$167	ConvDairyS	$210	OnFarmDairyS	-0.171	ConvDairyS	0.180	OnFarmDairyS	0.225	ConvDairyML

	SUSTAINABILITY									
Location	FVA	Model	FVAp	Model	NRG	Model	SLF	Model	FB	Model
Central ME	$280	OnFarmDairyML	0.288	OnFarmDairyML	0.405	ConvDairyML	0.253	OnFarmDairyML	-0.004	OnFarmDairyS
	$92	ConvDairyML	0.073	ConvDairyML	0.445	OnFarmDairyML	0.041	ConvDairyML	-0.016	OnFarmDairyML
	-$17	OnFarmDairyS	-0.022	OnFarmDairyS	0.574	ConvDairyS	-0.076	OnFarmDairyS	-0.224	ConvDairyS
	-$131	ConvDairyS	-0.132	ConvDairyS	0.684	OnFarmDairyS	-0.182	ConvDairyS	-0.279	ConvDairyML
Aroo-stook	$252	OnFarmDairyML	0.274	OnFarmDairyML	0.385	ConvDairyML	0.240	OnFarmDairyML	0.000	OnFarmDairyS
	$213	ConvDairyML	0.169	ConvDairyML	0.436	OnFarmDairyML	0.139	ConvDairyML	0.000	OnFarmDairyML
	-$32	OnFarmDairyS	-0.047	OnFarmDairyS	0.566	ConvDairyS	-0.099	OnFarmDairyS	-0.149	ConvDairyS
	-$69	ConvDairyS	-0.071	ConvDairyS	0.662	OnFarmDairyS	-0.120	ConvDairyS	-0.182	ConvDairyML

[a] NFI, ROVC, and FVA in $/acre. For conventional dairy farms, acreage in denominator included silage corn and hay/haylage but not pasture. For on-farm integrated dairy farms, crop acreage also included crops grown for concentrated feed in addition to forage.

Appendix F-6: LONG-TERM ON-FARM INTEGRATED INDICATOR RANKINGS

	ECONOMIC									
	Profitability						Efficiency			
Location	NFI[a]	Farm Type	ROVC[a]	Farm Type	POR	Farm Type	ATR	Farm Type	OER	Farm Type
Central	$195	OnFarmDairyML	$474	OnFarmDairyML	0.200	OnFarmDairyML	0.319	ConvDairyML	-0.048	OnFarmDairyS
ME	-$9	ConvDairyML	$319	ConvDairyML	-0.007	ConvDairyML	0.291	OnFarmDairyML	0.075	OnFarmDairyML
	-$113	OnFarmDairyS	$256	OnFarmDairyS	-0.146	OnFarmDairyS	0.210	ConvDairyS	0.235	ConvDairyS
	-$245	ConvDairyS	$148	ConvDairyS	-0.245	ConvDairyS	0.178	OnFarmDairyS	0.340	ConvDairyML
Aroo-	$188	OnFarmDairyML	$463	ConvDairyML	0.204	OnFarmDairyML	0.319	ConvDairyML	-0.018	OnFarmDairyS
stook	$135	ConvDairyML	$454	OnFarmDairyML	0.107	ConvDairyML	0.289	OnFarmDairyML	0.064	OnFarmDairyML
	-$115	OnFarmDairyS	$228	ConvDairyS	-0.166	OnFarmDairyS	0.203	ConvDairyS	0.132	ConvDairyS
	-$167	ConvDairyS	$211	OnFarmDairyS	-0.171	ConvDairyS	0.180	OnFarmDairyS	0.225	ConvDairyML

	SUSTAINABILITY									
Location	FVA	Model	FVAp	Model	NRG	Model	SLF	Model	FB	Model
Central	$282	OnFarmDairyML	0.289	OnFarmDairyML	0.405	ConvDairyML	0.254	OnFarmDairyML	-0.004	OnFarmDairyS
ME	$92	ConvDairyML	0.073	ConvDairyML	0.444	OnFarmDairyML	0.041	ConvDairyML	-0.016	OnFarmDairyML
	-$16	OnFarmDairyS	-0.020	OnFarmDairyS	0.574	ConvDairyS	-0.075	OnFarmDairyS	-0.224	ConvDairyS
	-$131	ConvDairyS	-0.132	ConvDairyS	0.683	OnFarmDairyS	-0.182	ConvDairyS	-0.279	ConvDairyML
Aroo-	$254	OnFarmDairyML	0.276	OnFarmDairyML	0.385	ConvDairyML	0.243	OnFarmDairyML	0.000	OnFarmDairyS
stook	$213	ConvDairyML	0.169	ConvDairyML	0.434	OnFarmDairyML	0.139	ConvDairyML	0.000	OnFarmDairyML
	-$31	OnFarmDairyS	-0.044	OnFarmDairyS	0.566	ConvDairyS	-0.097	OnFarmDairyS	-0.149	ConvDairyS
	-$69	ConvDairyS	-0.071	ConvDairyS	0.660	OnFarmDairyS	-0.120	ConvDairyS	-0.182	ConvDairyML

[a] NFI, ROVC, and FVA in $/acre. For conventional dairy farms, acreage in denominator included silage corn and hay/haylage but not pasture. For on-farm integrated dairy farms, crop acreage also included crops grown for concentrated feed in addition to forage.

BIOGRAPHY OF THE AUTHOR

Aaron K. Hoshide was born in Honolulu, Hawaii on September 2, 1972. He lived with his parents in Palolo Valley in Honolulu. Tokiko, Aaron's mother, died from pancreatic cancer on May 19, 1980. After living with his father, Henry, for three years, Henry unexpectedly died from a fall fixing the family lanai, or balcony, on July 28, 1983. In August of 1983, he moved to Simi Valley, California with his uncle Bob and aunt Georgian. Aaron attended high school at the Northfield Mount Hermon School in Northfield, Massachusetts where he graduated in June of 1990. He attended Wesleyan University in Middletown, Connecticut and graduated in June of 1994 with a Bachelor of Arts degree with Honors in Earth Science. He worked at the Brian House, Inc. as a cook and organic farm assistant from November of 1994 until May of 1999. After investigating the Sustainable Agriculture program at The University of Maine, he graduated in August 2002 with a Master of Science in Resource Economics and Policy with a concentration in Agricultural Economics. Aaron is a candidate for the Doctor of Philosophy degree in Ecology and Environmental Science from the University of Maine in August, 2005.