Potato Farms in Maine: Geospatial Assessments of Land Use Dynamics and Economies of Scale

Patrick English[1], Sherri DeFauw[2], Aaron Hoshide[3] and Andrew Plant[4]

[1]Mississippi State University, Delta Research & Extension Center, Stoneville MS [2] Pennsylvania State University, Dept of Agricultural Economics, Sociology & Education, University Park PA [3]University of Maine, School of Economics, Orono ME [4]University of Maine Cooperative Extension, Houlton ME

INTRODUCTION Sustainability of Maine's potato production systems has been of major concern for at least the past 50 years. A key historical challenge is the identification of profitable rotation crops. Geospatial frameworks help resolve patterns and trends in production environments at multiple scales; these assessments may, in turn, enable improvements in adaptive management strategies which enhance potato yield, increase whole-farm profitability, and foster sustainable land use. The objectives of this investigation were to: (1) assess farm size classes, field clustering and typologies using USDA, Common Land Unit (CLU), Cropland Data Layer (CDL) and National Agriculture Imagery Program (NAIP) products; (2) extract crop sequences in potato systems based on CDL (2008-2011) and NAIP classified imagery (2009, 2011); and (3) evaluate potential economic impacts of select alternate crops identified in potato production fields (from 2008-2010) using various farm-size models.

MATERIALS and METHODS Georeferenced data for cropland/land use patterns (based on CDL/NLCD classifiers – Fig. 1,2), farmland delineations (CLU), soils (SSURGO), DEM and NAIP datasets were integrated in a GIS. CLU datasets were aggregated and recoded; geometric frequency distribution of hectarage was used to resolve farmscape groupings. The standard distance function (ArcGIS v10) was used to calculate field dispersion for each group. Representative enterprise and whole-farm economic budgets were engineered for each of the five farm-size classes to determine economies of scale. Detailed outcomes for small, medium and large farms (ranked by crop profitability) are summarized and discussed here. Net farm income (NFI) was calculated in Excel spreadsheets for both individual crop enterprises (for the top 12 detected) as well as whole-farm scenarios. Representative enterprise and whole-farm budgets were constructed for potatoes and potato rotation crops (Fig. 3). "Short-run" (S-R) and "long-run" (L-R) analyses were conducted in an attempt to account for potential yield impacts associated with rotation length. S-R assumed constant potato yields (31.66 Mg ha^{-1}); L-R assumed an increase 28.6% in 3-yr versus the traditional (or baseline) 2-yr rotations, whereas potato-potato-crop X (PPX) and continuous potatoes are expected to have potato yields that are 14.3% and 28.6% lower than potato-crop X two-year rotations (Myers et al. 2008; Mohr et al. 2011).

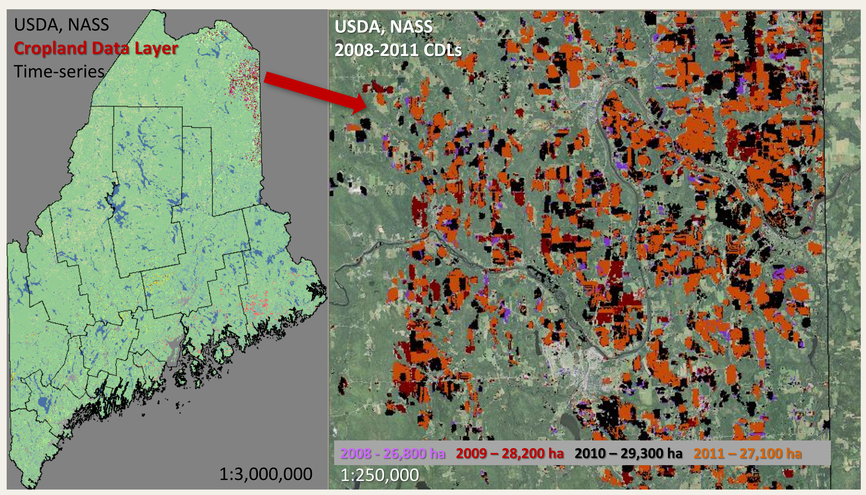

Figure 1. Cropland data layer (CDL) time-series with inset (on right) showing 4-yr mosaic of potato fields (around Caribou and Presque Isle, Aroostook County, ME). NAIP image acquisition dates for the scene (on right) were 17 Aug – 2 Sep 2011.

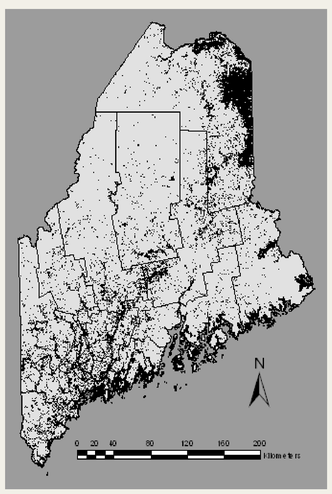

Figure 2. Four-year production footprint for potato (2008-2011) was used to extract crop sequences.

RESULTS Geospatial integration of CDLs and CLUs from Maine revealed a 4-year potato systems footprint estimated at ~56,000 ha, ranging from 24,000-25,000 ha detected per annum. Yields varied from 29.7-32.5 Mg ha^{-1} (USDA, NASS 2011). As of 2011, 524 potato farms were resolved into five farmscape groupings based on geometric frequency distribution of hectarage. Categories were extra-small (μ=40 ha), small (65 ha), medium (120 ha), large (324 ha), and extra-large (>580 ha). Mean field dispersions for farmscape groups 1 through 5 were 1.4, 1.7, 3.7, 7.8, and 18.0 km, respectively. Enterprise budgets for row and forage crop alternatives indicate positive NFIs for broccoli, soybean, alfalfa, corn silage, and canola (Table 1). NFI crop-rotation specifics are summarized in Tables 2, 3, and 4.

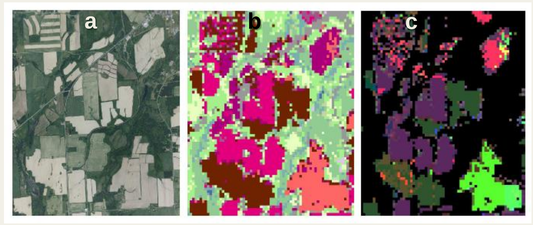

Figure 3. Comparison of raster scenes including: **a** USDA, FSA, NAIP 18 June 2009 (1 m resolution); **b** CDL 2009 (56 m) with B=deep pink, Br=orange, P=brown, R=purple; **c** RGB composite showing crop sequence mosaic from 2008-10 CDLs with P-B-P (purple), P-Br-B (bright green), B-P-B (dark green), Br-R-P (bright red). Scale:1:24,000.

Table 1. Net farm income (NFI) ha^{-1} for row and forage crop enterprises (listed by production scale) for Maine farms.

Crop	Yield (Mg ha^{-1})	Price ($ Mg^{-1})	NFI 324-ha ($ ha^{-1})	NFI 120-ha ($ ha^{-1})	NFI 65-ha ($ ha^{-1})
Broccoli	8.97	$551	$1,277	$1,046	$1,034
Potato	31.66	$187	$928	$517	$415
Soybeans	2.81	$474	$542	$468	$296
Alfalfa, perennial[a]	14.11	$101	$471	$373	$251
Corn silage	36.48	$51	$426	$356	$192
Canola	1.68	$617	$113	$60	-$117
Barley grain + straw[b]	6.31	$171	$44	-$34	-$180
Wheat grain + straw[b]	7.16	$171	$42	-$14	-$183
Clover, perennial[a]	7.49	$83	-$35	-$206	-$389
Barley grain	3.39	$225	-$90	-$161	-$315
Pasture, perennial[a]	4.51	$61	-$111	-$106	-$144
Wheat grain[c]	3.03	$263	-$186	-$235	-$412
Clover, est year[a,d]	5.45	$83	-$271	-$453	-$641
Haylage, perennial[a]	13.54	$61	-$276	-$516	-$839
Oat grain + straw[b]	6.63	$111	-$277	-$355	-$501
Corn grain	6.28	$157	-$295	-$367	-$531
Rye grain + straw[b]	4.83	$137	-$331	-$408	-$554
Pasture, est year[a,d]	3.11	$61	-$356	-$356	-$401
Alfalfa, est. year[a,d]	9.73	$101	-$373	-$480	-$608
Dry hay, perennial[a]	5.76	$91	-$386	-$650	-$975
Rye grain	1.73	$211	-$493	-$564	-$718
Oat grain	2.56	$141	-$508	-$578	-$732
Dry hay, est year[a,d]	3.97	$91	-$560	-$831	-$1,163
Haylage, est year[a,d]	9.34	$61	-$694	-$944	-$1,273

[a] Assumes perennial stand (years) for alfalfa, haylage, dry hay, and pasture (5), and clover (3).

[b] Dry hay and straw harvested as round bales. For small grain+ straw, yield per hectare and price per metric ton for both straw and grain.

[c] Spring wheat.

[d] Establishment year only.

Table 2. NFI ha^{-1} for potato rotations on a 65-ha Maine farm.

System	Percent potato in rotation	Potato	Crop X hectares	Crop Y	Crop rotation	Short Run[f] for all crops PPX ($ ha^{-1})	Short Run[f] NFI for all crops PX or PXY ($ ha^{-1})	Long Run[g] for all crops PPX ($ ha^{-1})	Long Run[g] NFI for all crops PX or PXY ($ ha^{-1})
Potato	100	65	-	-	Potato	$415	-	-$1,250	-
Potato - Potato - Crop X (PPX)[a] or Potato - Crop X (PX)[b]	66.7	43	22	-	Potato - Broccoli	$287	$321	-$269	$321
					Potato - Soybean	$95	-$7	-$461	-$7
					Potato - Alfalfa	$69	-$38	-$486	-$38
					Potato - Corn silage	$16	-$93	-$539	-$93
					Potato - Canola	-$26	-$198	-$581	-$198
	50	32.5	32.5	-	Potato - Clover	-$52	-$239	-$606	-$239
					Potato - Wheat grain + straw[d]	-$61	-$241	-$616	-$241
					Potato - Barley grain + straw[d]	-$68	-$245	-$623	-$245
					Potato - Pasture	-$96	-$339	-$651	-$339
					Potato - Barley	-$100	-$303	-$655	-$303
					Potato - Wheat[e]	-$125	-$346	-$680	-$346
					Potato - Dry hay[d]	-$163	-$421	-$720	-$421
					Potato - Haylage	-$166	-$392	-$722	-$392
					Potato - Oat grain + straw[d]	-$175	-$406	-$730	-$406
					Potato - Corn grain	-$183	-$421	-$738	-$421
					Potato - Rye grain + straw[d]	-$192	-$432	-$747	-$432
					Potato - Rye	-$234	-$505	-$790	-$505
					Potato - Oat	-$239	-$512	-$795	-$512
Potato - Crop X - Crop Y (PXY)[c]	33.3	21.67	21.67	21.67	Potato - Soybean - Broccoli	-	-$39	-	$518
					Potato - Barley - Broccoli	-	-$235	-	$323
					Potato - Alfalfa - Corn silage	-	-$266	-	$291
					Potato - Soybean - Canola	-	-$269	-	$288
					Potato - Rye - Broccoli	-	-$369	-	$188
					Potato - Oat - Broccoli	-	-$374	-	$183
					Potato - Canola - Wheat grain + straw[d]	-	-$415	-	$141
					Potato - Canola - Wheat grain	-	-$480	-	$77
					Potato - Barley - Clover	-	-$560	-	-$6
					Potato - Oat - Clover	-	-$699	-	-$145

Table 3. NFI ha^{-1} for potato rotations on a 120-ha Maine farm.

System	Percent potato in rotation	Potato	Crop X hectares	Crop Y	Crop rotation	Short Run[f] for all crops PPX ($ ha^{-1})	Short Run[f] NFI for all crops PX or PXY ($ ha^{-1})	Long Run[g] for all crops PPX ($ ha^{-1})	Long Run[g] NFI for all crops PX or PXY ($ ha^{-1})
Potato	100	120	-	-	Potato	$517	-	-$1,147	-
Potato - Potato - Crop X (PPX)[a] or Potato - Crop X (PX)[b]	66.7	80	40	-	Potato - Broccoli	$377	$378	-$182	$378
					Potato - Soybean	$181	$76	-$374	$76
					Potato - Canola	$124	$13	-$431	$13
					Potato - Alfalfa	$106	-$4	-$449	-$4
					Potato - Corn silage	$65	-$111	-$491	-$111
	50	60	60	-	Potato - Wheat grain + straw[d]	$15	-$167	-$540	-$167
					Potato - Pasture	$6	-$242	-$548	-$242
					Potato - Barley grain + straw[d]	-$14	-$194	-$569	-$194
					Potato - Clover	-$27	-$223	-$581	-$223
					Potato - Barley	-$32	-$239	-$587	-$239
					Potato - Wheat[e]	-$34	-$260	-$589	-$260
					Potato - Corn grain	-$106	-$348	-$662	-$348
					Potato - Dry hay[d]	-$107	-$368	-$663	-$368
					Potato - Haylage	-$121	-$346	-$677	-$346
					Potato - Oat grain + straw[d]	-$121	-$354	-$676	-$354
					Potato - Rye grain + straw[d]	-$138	-$381	-$693	-$381
					Potato - Rye	-$166	-$441	-$721	-$441
					Potato - Oat	-$171	-$448	-$726	-$448
Potato - Crop X - Crop Y (PXY)[c]	33.3	40	40	40	Potato - Soybean - Broccoli	-	$7	-	$571
					Potato - Alfalfa - Corn silage	-	-$169	-	$388
					Potato - Soybean - Canola	-	-$186	-	$370
					Potato - Barley - Broccoli	-	-$206	-	$358
					Potato - Rye - Broccoli	-	-$340	-	$223
					Potato - Canola - Wheat grain + straw[d]	-	-$342	-	$214
					Potato - Oat - Broccoli	-	-$345	-	$218
					Potato - Canola - Wheat grain	-	-$392	-	$164
					Potato - Barley - Clover	-	-$572	-	-$18
					Potato - Oat - Clover	-	-$711	-	-$157

Table 4. NFI ha^{-1} for potato rotations on a 324-ha Maine farm.

System	Percent potato in rotation	Potato	Crop X hectares	Crop Y	Crop rotation	Short Run[f] for all crops PPX ($ ha^{-1})	Short Run[f] NFI for all crops PX or PXY ($ ha^{-1})	Long Run[g] for all crops PPX ($ ha^{-1})	Long Run[g] NFI for all crops PX or PXY ($ ha^{-1})
Potato	100	324	-	-	Potato	$928	-	-$737	-
Potato - Potato - Crop X (PPX)[a] or Potato - Crop X (PX)[b]	66.7	216	108	-	Potato - Broccoli	$883	$886	$326	$886
					Potato - Soybean	$584	$474	$29	$474
					Potato - Alfalfa	$530	$416	-$25	$416
					Potato - Canola	$517	$400	-$38	$400
					Potato - Corn silage	$453	$270	-$102	$270
	50	162	162	-	Potato - Wheat grain + straw[d]	$409	$219	-$146	$219
					Potato - Pasture	$404	$145	-$151	$145
					Potato - Barley grain + straw[d]	$401	$213	-$154	$213
					Potato - Barley	$376	$161	-$179	$161
					Potato - Clover	$367	$161	-$188	$161
					Potato - Wheat[e]	$353	$120	-$202	$120
					Potato - Dry hay[d]	$339	$78	-$216	$78
					Potato - Haylage	$307	$81	-$249	$81
					Potato - Corn grain	$295	$48	-$260	$48
					Potato - Oat grain + straw[d]	$294	$53	-$261	$53
					Potato - Rye grain + straw[d]	$276	$26	-$279	$26
					Potato - Rye	$241	-$40	-$314	-$40
					Potato - Oat	$236	-$48	-$319	-$48
Potato - Crop X - Crop Y (PXY)[c]	33.3	108	108	108	Potato - Soybean - Broccoli	-	$516	-	$1,076
					Potato - Barley - Broccoli	-	$307	-	$868
					Potato - Alfalfa - Corn silage	-	$252	-	$808
					Potato - Soybean - Canola	-	$205	-	$761
					Potato - Rye - Broccoli	-	$173	-	$733
					Potato - Oat - Broccoli	-	$168	-	$728
					Potato - Canola - Wheat grain + straw[d]	-	$41	-	$596
					Potato - Canola - Wheat grain	-	-$16	-	$540
					Potato - Barley - Clover	-	-$186	-	$369
					Potato - Oat - Clover	-	-$325	-	$230

[a] Two years of potatoes followed by a third year of rotation crop. [b] One year of potatoes followed by second year of rotation crop. [c] One year of potatoes followed by two years of rotation crops.
[d] Dry hay and straw harvested as round bales. [e] Spring wheat. [f] Short-run assumes potato yields are the same across rotations. Yields of other crops in rotation with potatoes are held constant.
[g] Long-run assumes potato yields are impacted by rotation effects on potato yield. Three-year rotations assume 28.6% higher yield than two-year rotations, while PPX and continuous potatoes have 14.3% and 28.6% lower yields than two-year rotations respectively (Myers et al. 2008, Mohr et al. 2011). Yields of other crops in rotation with potatoes are held constant.

CONCLUDING REMARKS A key historical challenge has been the identification of profitable rotation crops. Across three years (2008-2010 CDLs) ~1,800 ha was detected in 'continuous' potato (~3% of cropping system extent – DeFauw et al. 2012); after four years, ~600 ha remained. Potato cropping systems detected in 2-year rotations now involve ~14,000 ha suggesting farmers have diversified their operations and appear to be shifting to rotations of 3+ years. NFIs for 65 to 120-ha farms are predominantly negative; however, 3-year cropping systems generated positive returns (assuming 28.6% higher potato yields in the L-R) compared to the traditional tightly-coupled (2-yr) potato-small grains or haylage. Work is underway to further refine the economic models for smaller farms (≤ 120 ha) considering that many grow potatoes for tablestock and seed rather than for processing and they have expanded time horizons for equipment. Development of an interactive, user-friendly, web-based version of these farm budget models would encourage more farmers and researchers to evaluate the relative profitability of alternative cropping strategies to improve the financial viability of farming in Aroostook County and elsewhere in Maine.

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ACKNOWLEDGEMENTS One of the co-authors (SLD) gratefully acknowledges funding from the USDA's National Institute of Food and Agriculture (NIFA) under grant no. 2011-68004-30057. Scott A. Samson (Geosystems Research Institute, Mississippi State University) supplied timely advice that was genuinely appreciated. Lindsay Hodgman and Tara King (USDA, NRCS – Bangor, ME) are kindly thanked for their assistance with SSURGO-related concerns.