Maine Potato Farms: Remotely-Sensed Cropping System Dynamics and Applied Econometrics

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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 interdependencies of cropping systems as well as intensities of key enterprises linked to farm sizes are often overlooked components of agricultural sustainability. We have developed a remotely-sensed framework for bridging the gap between agronomic and econometric modeling families to evaluate fine-scale systems-level dynamics and farming community-based economic geography The objectives of this investigation were to: (1) profile potato cropping systems for three sentinel counties in Maine (Aroostook, Penobscot and Oxford) using Cropland Data Layer (CDL, 2008-2012), National Agricultural Imagery Program (NAIP, 2009 and 2011), Common Land Unit (CLU), soils (SSURGO), and PRISM climate (1981-2010) datasets; (2) assess dominant crop sequences and geo-spatial relationships of remotely-sensed enterprises; and (3) evaluate potential economic impacts of select alternate crops across 5 years using 3 potato farm model sizes.

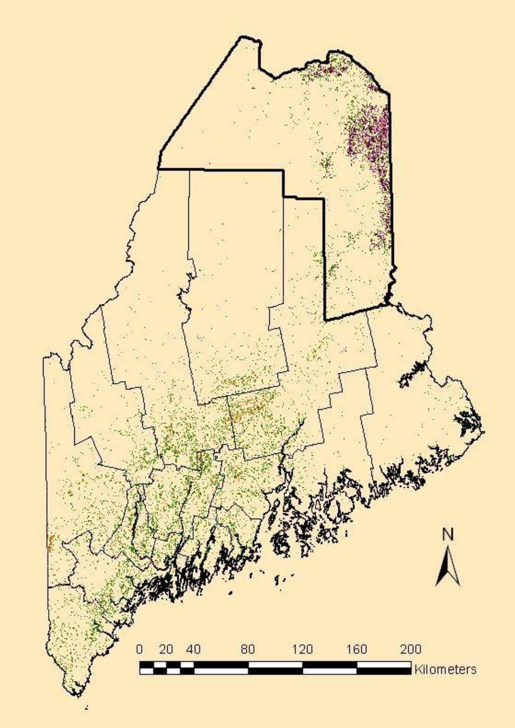


Figure 1. Five-year production footprints for indicator crops (detected in CDLs); key crops (w/ code(s)) include broccoli (214), corn (001), potato (043), small grains (5 codes tracked), soybean (005), & forages - alfalfa (036), 'other hay' (037).

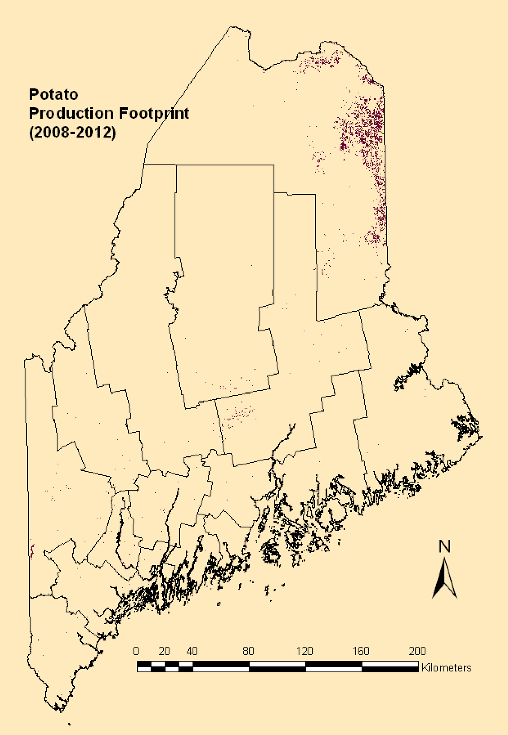


Figure 2. Five-year production footprint for potato (derived from 2008-2012 CDLs) was used to extract dominant crop sequences.

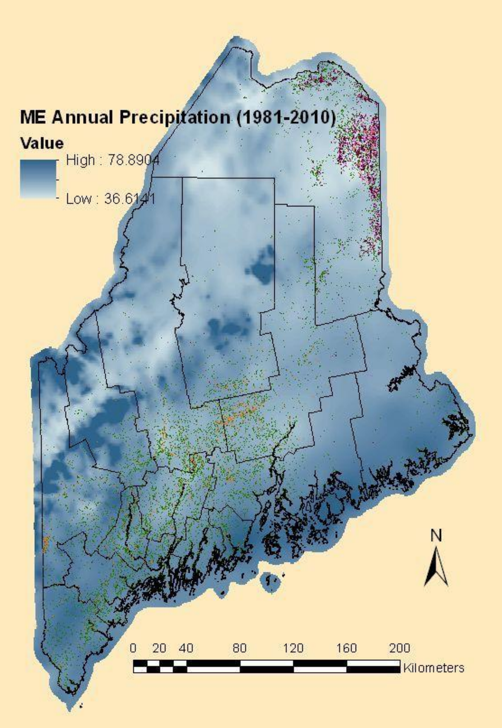


Figure 3. Five-year production footprints for indicator crops (detected in CDL time series 2008-2012) overlain on 30-year average annual precipitation grid (PRISM climate dataset 1981-2010). Precipitation values are in inches.

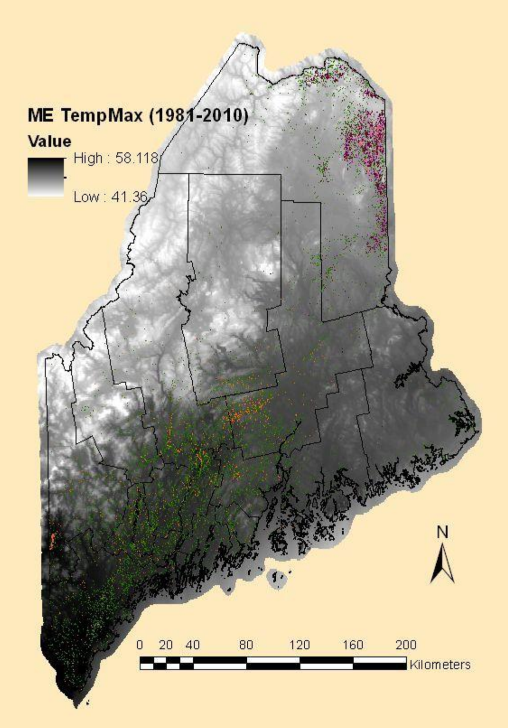
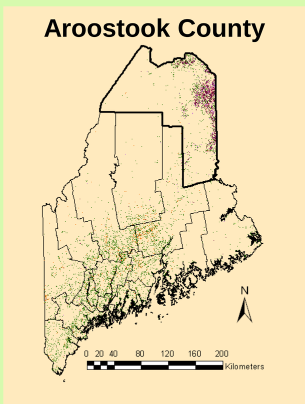


Figure 4. Five-year production footprints for indicator crops (detected in CDL time series 2008-2012) overlain on 30-year average maximum temperature grid (PRISM climate dataset 1981-2010). Temperature values are in degrees F.

MATERIALS and METHODS Georeferenced data for cropland/land use patterns (based on CDL/NLCD codes), farmland delineations (CLU), RGB and color infra-red (CIR) imagery (NAIP), soils, and PRISM climate datasets were integrated in a GIS (Figs 1-4). Key indicator crops extracted from 2008-2012 CDLs included broccoli, corn, soybean, forages (alfalfa and 'other hay'), potato and an assemblage of small grains. A 5-year potato production footprint was constructed from the CDL time series. 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. Farmland delineations (CLUs) were used to constrain and partially correct remotely-sensed crop recognition errors. Implementation of a decision tree algorithm further improved "stray" pixel capture and removal from farm fields. Available NAIP images (2009, 2011) were classified and compared with CDL-derived versions of field-scale activities detected. Representative enterprise and whole-farm budgets were constructed for the 5 farm-size classes resolved. Net farm income (NFI) was calculated in Excel spreadsheets for individual crop enterprises (top 12 detected) and whole-farm scenarios to examine economies of scale. Methodological details for 3-year crop sequences are in DeFauw et al. (2012).



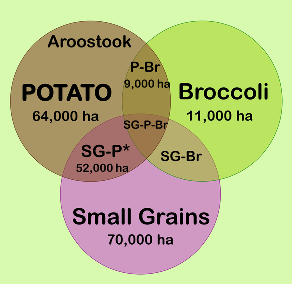


Fig. 5. Spatial interdependencies for key crops in Aroostook County. Raw values (CDLs) rounded to nearest 1000 ha.

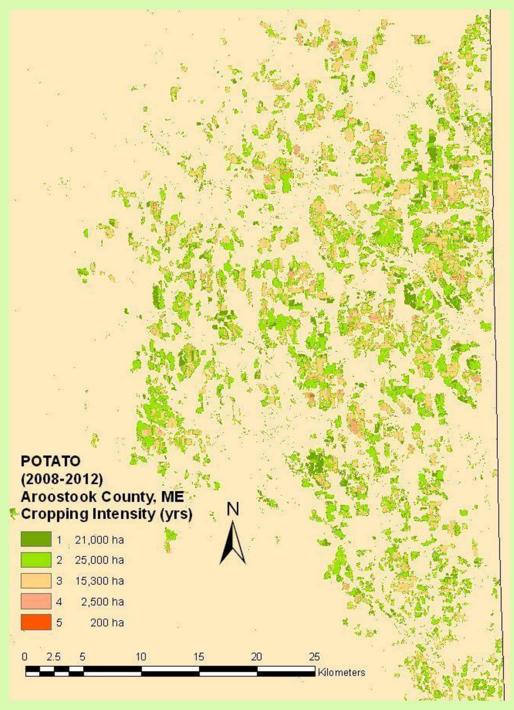


Figure 6. Five-year production footprint for potato in Aroostook County (2008-2012 CDLs - raw data shown) geoprocessed to reveal crop intensity.

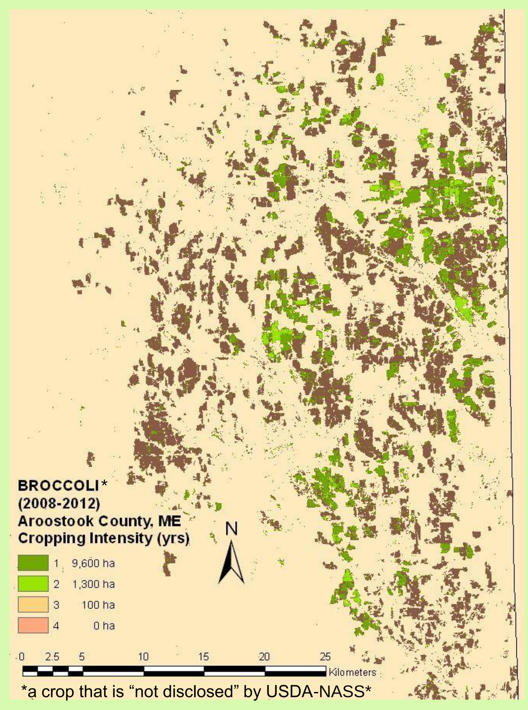


Figure 7. Five-year production footprint for broccoli overlain on potato (CDL raw data shown) geoprocessed to reveal crop intensity. All values rounded to the nearest hundred (ha).

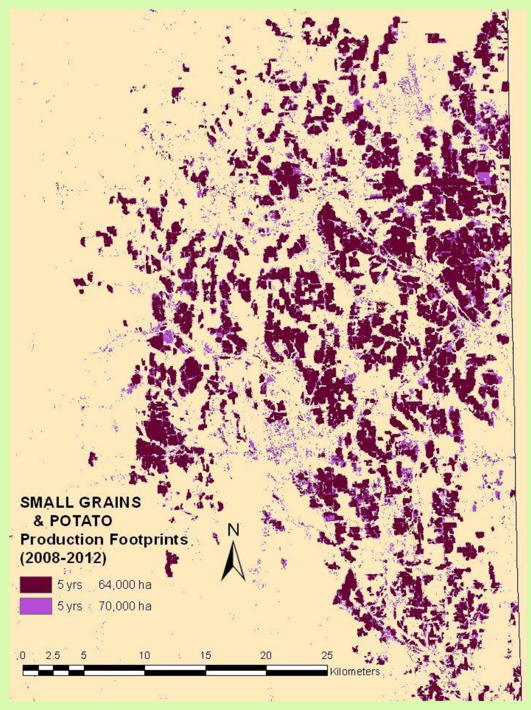


Figure 8. Five-year production footprints for potato and small grains (CDL raw data shown) for Aroostook County display an exceptionally high degree of spatial interdependency.

RESULTS Geospatial integration of classified imagery, soils and CLUs revealed a 5-year potato systems footprint estimated at 63,000 ha; 87% of production soils were considered potentially highly erodible or highly erodible land. Close to 95% of Maine potato production occurs in 3 counties; potato-small grain sequences dominate Aroostook, whereas tightly-coupled potato-corn rotations characterize Penobscot and Oxford counties. Potato varied from 23,000-24,000 ha detected per annum. Other crops generating positive net farm income (NFI) included broccoli (15% of potato land base), soybean, alfalfa, corn silage and canola (Table 1). Crop intensities for potato, corn and broccoli as well as their spatial interdependencies are summarized by county (Figs 5-16). Select outcomes for crop sequences detected on small, medium and large farms of Oxford County are summarized here in the form of a profitability map (Fig 17).

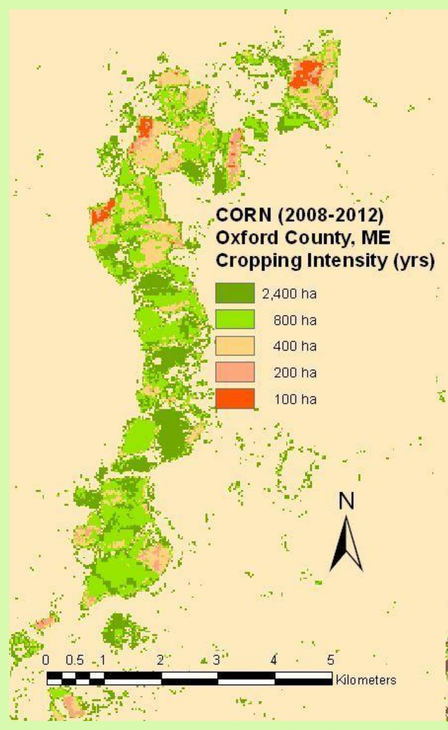


Fig. 9. Five-year production footprint for corn (CDL raw data) geoprocessed to reveal crop intensity.

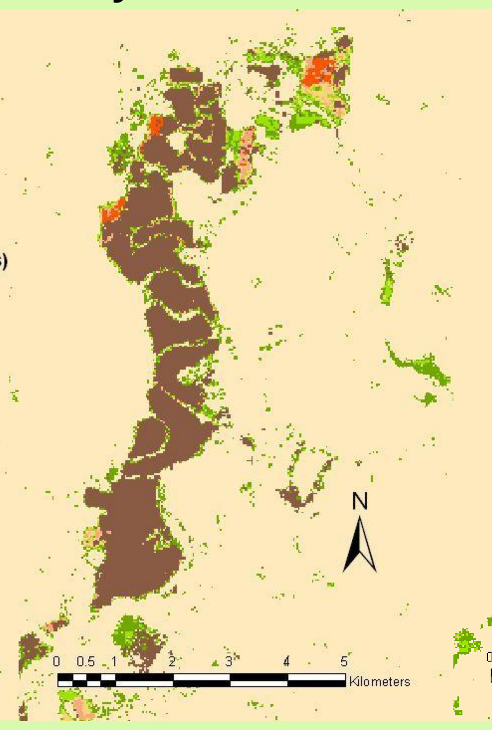


Fig. 10. Five-year production footprint for potato (CDL raw data) overlain on corn revealing spatial interdependencies.

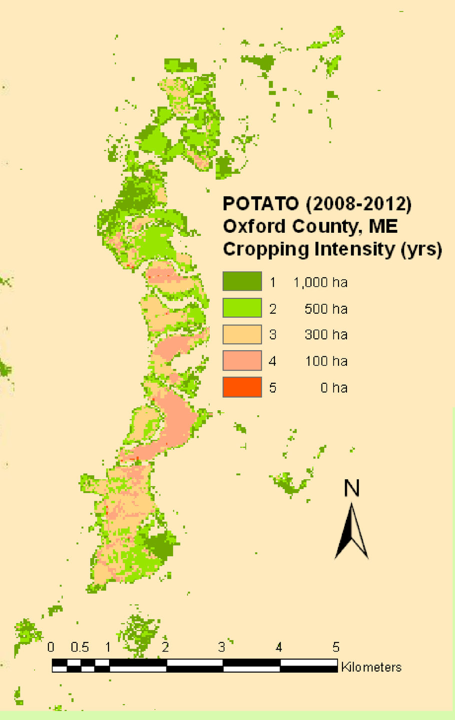
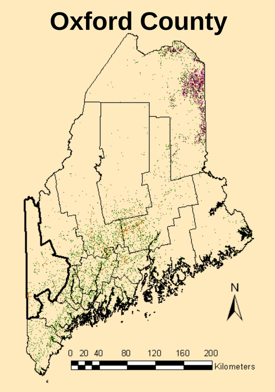


Fig. 11. Five-year production footprint for potato (CDL raw data) geoprocessed to reveal crop intensity.



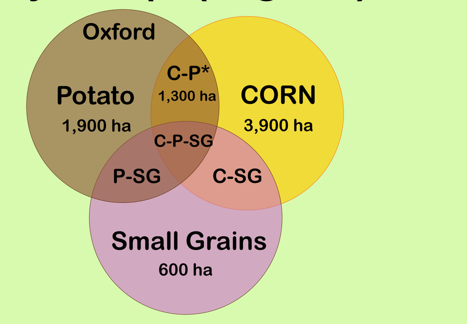
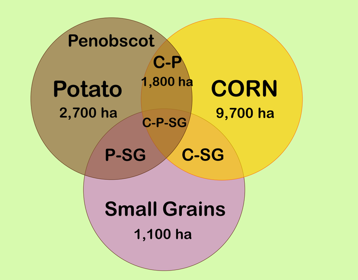


Fig. 12. Spatial interdependencies for key crops in Oxford County. CDL raw values rounded to the nearest 100 ha.



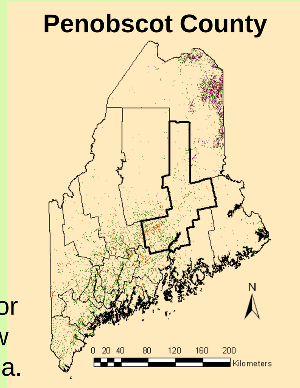


Fig. 13. Spatial interdependencies for key crops in Penobscot Co. CDL raw values rounded to the nearest 100 ha.

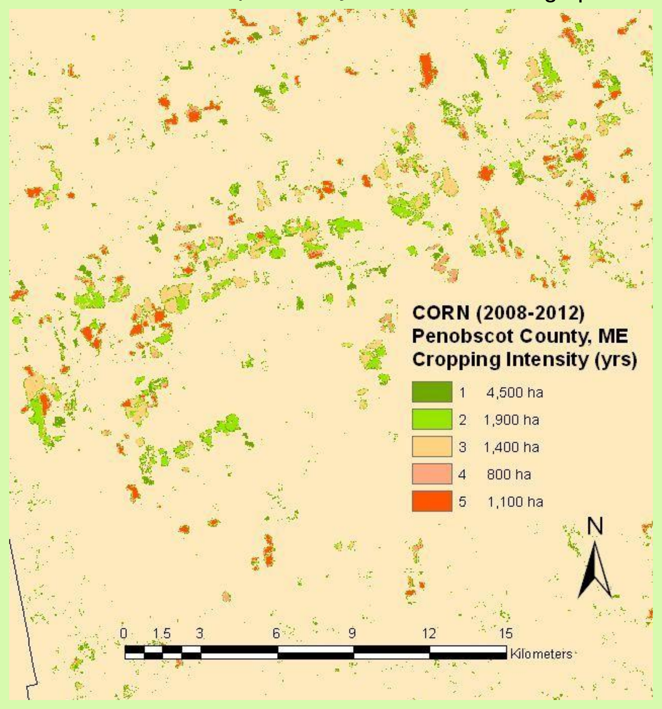


Figure 14. Five-year production footprint for corn (CDL – raw data shown) geoprocessed to reveal crop intensity.

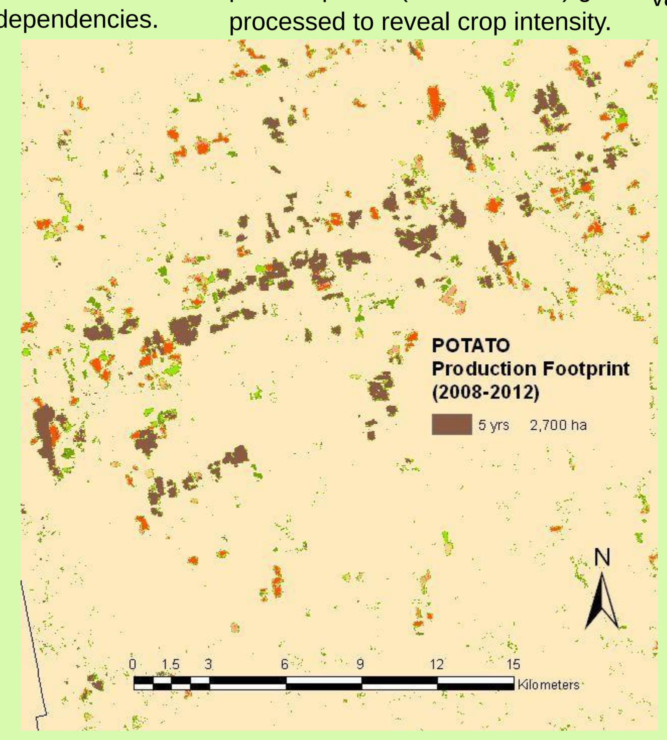


Figure 15. Five-year production footprint for potato (CDL raw data) overlain on corn revealing interdependencies.

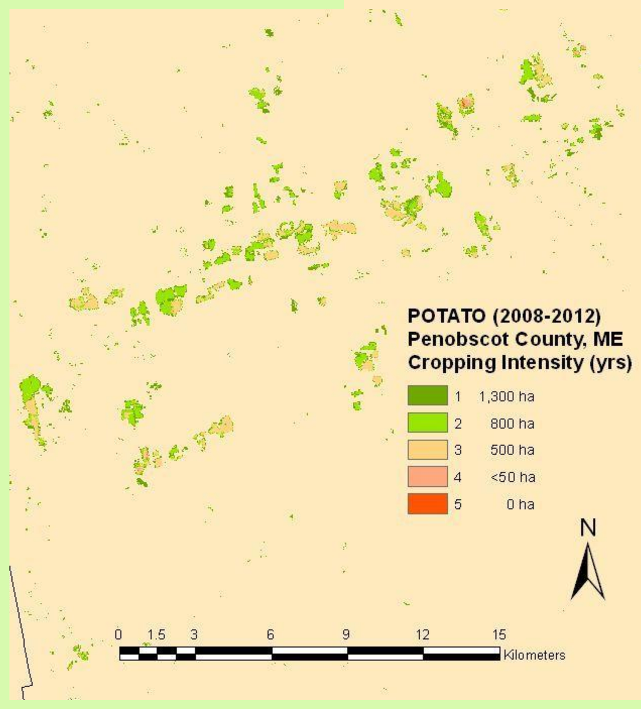


Figure 16. Five-year production footprint for potato (CDL raw data shown) geoprocessed to reveal crop intensity.

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

			------------- NFI -------------		
Crop	Yield (Mg ha^{-1})	Price ($ Mg^{-1})	324-ha ($ ha^{-1})	120-ha ($ ha^{-1})	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.

N.B.: NFIs for extra-small and extra-large farms are not shown in Table 1.

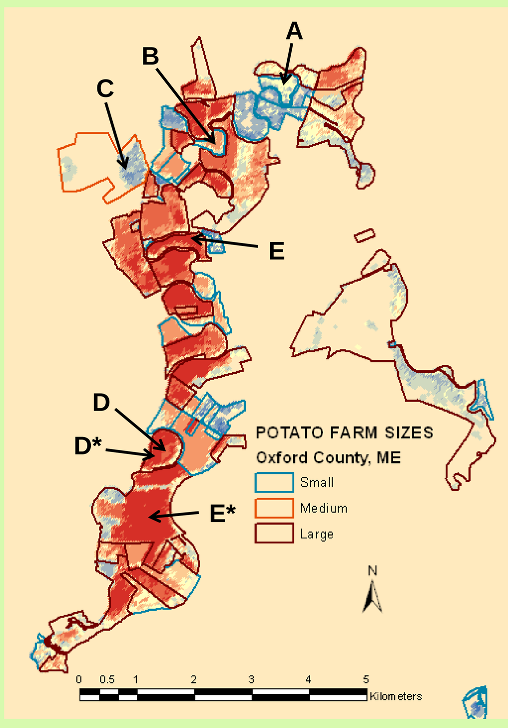


Figure 17. Profitability map for small (mean size = 65 ha), medium (mean size = 120 ha), and large farms (mean size =324 ha).

A – small farm
Sod-Sod-Corn-Fallow-Potato
$606 ha^{-1}
B – small farm
Potato-Potato-Potato-Corn-Potato
$1,850 ha^{-1}
C – medium farm
OtherHay-Hay-Potato-Hay-Hay
-$1,546 ha^{-1}
D – large farm
Potato-Corn-Potato-Pasture-Corn
$2,705 ha^{-1}
*Potato-Corn-Potato-Potato-Corn
$3,632 ha^{-1}
E – large farm
Potato-Potato-Corn-Corn-Potato
$3,632 ha^{-1}
*Potato-Potato-Potato-Corn-Potato
$4,134 ha^{-1}

CONCLUDING REMARKS Sustainable intensification of key cropping systems hinges on the identification of profitable rotation crops that result in yield optimization to improve financial outcomes for farms in Maine. Economic models for farms ≤ 120 ha are still being refined considering that many grow tablestock and seed potato rather than for processing; plus, these smaller farm-holders have expanded time horizons for equipment. Development of an interactive, user-friendly, web-based version of these geospatial agronomic-econometric models is also underway to further resolve farming communities, farm-guild associations, and their productive capacity throughout Maine.

REFERENCES

DeFauw SL, RP Larkin, PJ English, JM Halloran and AK Hoshide. 2012. Geospatial evaluations of potato production systems in Maine. *Am J Potato Res* DOI: 10.1007/s12230-012-9271-2 (6 October 2012)

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† SLD manages an agricultural consulting service in Mississippi.