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For the project entitled:

Description of the approach, data, and analytical methods used for the *Farms Under Threat: State of the States* project, version 2.0.

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Background

Farmers, land managers, and policy makers are greatly concerned over the loss of natural resources as land use change occurs (Brown et al. 2005). In this context, and although a number of national datasets on agriculture and land use have been developed over the past few decades (see Table 1), nationally consistent, high resolution spatial data on farmland location and change have been largely unavailable. The primary program to measure land cover and land uses change in the United States is the National Resources Inventory (NRI) administered by the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). The advent of the NRCS NRI program in 1977 made it possible to track the conditions and trends of soil, water, and related resources. NRCS conducts this statistical survey of natural resource conditions and trends on non-federal land on an annual basis with data publicly released at 5-year intervals years, and in cooperation with Iowa State University's Center for Survey Statistics and Methodology. Among other attributes, the NRI tracks changes in land cover/use, which provides critical information on how much agricultural land is developed (i.e., converted to urban land uses) and other trends affecting the nation's land and natural resources (McBride et al. 1997). The precision of NRI statistical estimates varies with the number of samples involved in a particular inventory activity. Although the NRI is based on a sample of roughly 800,000 survey points nationally, and summarized at national and state levels, data summaries at finer scales (e.g., counties or watersheds) may have relatively high estimates of uncertainty when associated with uncommon land cover/use classes. Consequently, it is most applicable for monitoring state and national levels of gross land conversion. The NRI currently releases state-level estimates to the public and is exploring ways to achieve more statistical reliability for publicly releasing county-level estimates (Schnepf and Flanagan, *pers. comm.*). These periodic inventories remain the primary source of information about changes in land cover/use in the US.

In addition to the NRI, the USGS National Land Cover Database (NLCD) maps general land cover/use derived from decadal Landsat satellite imagery, among other datasets. These datasets can be used to infer the extent of and change in agricultural lands within the continental U.S. between 2001 and 2016. The latest NLCD product (2016) was released in May 2019, using a consistent spatial modeling approach to mapping land cover/use over time (Yang et al. 2018). Another source of data on national-level agricultural lands is the USDA National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL), but it does not directly map rangeland or forested areas on farms or ranches, only provides data from 2008 to 2018, and is intended to map annual land cover rather than changes over time (Boryan et al. 2011, Lark et al. 2017). While both NLCD and CDL provide some spatial information on agricultural lands, neither are explicitly calibrated to NRI estimates, nor have been quantitatively compared or validated with NRI. Additionally, the USDA NASS Census of Agriculture (CoA) program provides information on the extent of agricultural lands, but is based on a survey of farm operators (USDA 2017), has varied definitions over time for several important classes that confound examining change in recent decades, and only provides data at the county scale. The USGS U.S. Conterminous Wall-to-Wall Anthropogenic Land Use Trends (NWALT) product maps anthropogenic land use at 60-meter resolution for five time periods between 1974 and 2012 (Falcone 2015). NWALT uses CoA county-level data to estimate agricultural land use change, but it does not incorporate NRI data and is only available to 2012.

Therefore, to address the ongoing need to improve understanding of agricultural land patterns and rates of change to inform land use planning at relevant scales, and to motivate decision makers regarding the importance of finite agricultural resources, American Farmland Trust and Conservation Science Partners worked together to release the “Farms Under Threat: The State of America’s Farmlands” (FUT) national report (Sorenson et al. 2018). The FUT program provides critical information to evaluate trends and patterns of agricultural lands in multiple ways by:

1) harmonizing NRI estimates of agricultural land with available spatial data;
2) mapping agricultural land use and conversion to development in a consistent way over time;
3) identifying agricultural lands based on their productivity, versatility and resiliency to support food and crop production;
4) accounting for effects of low-density residential development on agricultural lands;
5) including a new class of agricultural lands that estimates woodlands associated with farm enterprises;
6) mapping grazing on federal lands.

Building on the national FUT work, we have updated the FUT data products to version 2.0 to provide enhanced mapping capabilities at the state, county, and sub-county levels. FUT 2.0 incorporates updated source data information (2001 to 2016) and maps land cover at a 10-meter resolution, whereas the national FUT report used data from 1992 to 2012 at a 30-meter resolution. Here we provide the technical documentation to support the methods, results, and key data products developed for the FUT 2.0 effort.

Methods

We produced two principal products for the FUT project: (a) land cover/use, including historical, current, and change; and (b) agricultural land productivity, versatility, and resiliency (PVR). Here we describe our approach to mapping land cover/use for 2001 and 2016, as well as our approach to mapping PVR of agricultural lands.

Mapping land cover/use

The NRI uses the term land cover/use to identify categories that account for all the non-federal surface area of the United States. Land cover is the vegetation or other kind of material that covers the land surface. Land use is the purpose of human activity on the land and is usually, but not always, related to land cover (USDA 2015). For FUT, we mapped land cover/use by combining data from the NRI, the NLCD, the NRCS Soil Survey Geographic Database (SSURGO), and the Digital General Soil Map of the United States (STATSGO). The resulting FUT land cover/use dataset uses classes consistent with the NRI and introduces three additional land cover/use classes (see Table 2 for definitions). FUT classes that are consistent with NRI include: cropland, pastureland, rangeland and forest land. The FUT woodland class is a new land cover/use class, which is a subset of the NRI forest land class, and maps the area of forest associated with farms reported by operators during the CoA. FUT adds an additional developed land cover class to map low-density residential land use that is not explicitly represented in NRI. Within federal lands, FUT distinguishes between grazed versus non-grazed federal lands. Additionally, FUT 2.0 explicitly maps roads separately from other developed land cover as a new class representing transportation land cover/use.

To generate the land cover/use maps for 2001 and 2016, we used a mixed-method approach that combines the benefits of both suitability (probability) mapping and remotely sensed land cover products. The principal steps in our modeling process were to: (a) define desired land cover/use classes that were consistent with the NRI; (b) map and mask out non-agricultural land cover including urban areas, water, barren areas, and forest; (c) generate a suitability surface for cropland, pastureland, rangeland, and woodlands; (d) identify locations that maximized the suitability values of the land cover classes and assign pixels of each type to equal the acres of that agriculture class estimated in the NRI by county; (e) map federal lands including grazing allotments on US Forest Service (USFS) and Bureau of Land Management (BLM) lands; (f) map major roads; and (g) merge county-level data layers with state-level data into a national dataset. For step (d), county-level acreage estimates were calculated based on NRI by summing the acreage estimated by NRI for each county. Table 1 provides a list of input datasets, along with the dataset source, scale or resolution, and other relevant information.

Table 1. Name, source, and scale (extent or resolution) of the principal datasets used in the FUT 2.0 products.

Name	Source/URL	Scale	Notes
Land use/cover: NLCD 2001, 2016	DOI/USGS National Land Cover Database	Conterminous US (CONUS), 30 m	NLCD version released in May 2018 using updated methodology (Yang et al. 2018) Accuracy assessment is for NLCD 2011 (Wickham et al. 2017). No accuracy assessment is currently available for the NLCD 2018 release.
Land cover/use: NRI 2002, 2015	USDA/NRCS National Resources Inventory	CONUS, ~800,000 sample points	State summaries are available publicly. We obtained county-level summaries and sample point location coordinates through an agreement with NRCS.
Agricultural cover/use: 2014-2018	USDA/NASS Cropland Data Layer (CDL)	CONUS, 30 m	CDL data is available for 2008-2018 through the "CropScape" portal.
Farm size from Census of Agriculture 2017	USDA/NASS Census	US, county	We obtained 10th percentile farm size by county through a special data request.
Soils: SSURGO	USDA/NRCS Soil Survey Geographic Database	10 m	Gridded (gSSURGO) database was accessed December 2018.
Soils: STATSGO	USDA/NRCS Soil Survey	CONUS polygons, 1:250,000	STATSGO2 database was accessed in January 2019 and used where SSURGO was unavailable.
Water including lakes/reservoirs and wide streams/rivers: NHD	USGS National Hydrography Dataset (High Resolution)	CONUS, vector, 1:24,000	NHD water bodies include Lake/Pond (FCode = 390) and Reservoir (FCode = 436).

Name	Source/URL	Scale	Notes
Major land resource areas	USDA/NRCS MLRA	CONUS, vector, 1:250,000	V4.2 (2006) used as input data for frost free days.
Elevation	USGS National Elevation Dataset	10 m	
Protected areas for non-federal and federal lands	USGS Protected Areas Database (PAD-US v2.0 2018)		Included lands classified as "FED" in PAD-US v2.0, including all 4 levels of protection. Ownership and management attributes were used as the basis for mapping federal lands in FUT.
Housing density 2000, 2016	US Census Bureau, American Community Survey	Block-level (2000), Block Group-level (2016)	Housing density data were acquired from Geolytics.
Normalized Difference Vegetation Index (NDVI)	USGS Landsat 8, Copernicus Sentinel-2 satellite imagery 2015	30 m, 10 m	Imagery available through Google Earth Engine data catalog.
Woodland Acreage from Census of Agriculture 2017	USDA/NASS Census	County-level	Acquired woodland acreage data by county for 2002, 2012, and 2017.
TIGER roads	US Census Bureau TIGER/Line 2016	CONUS polyline	Major roads were selected from the TIGER roads data including Interstates, US highways, and State highways. Data used to map the Transportation land cover/use class. Also available through Google Earth Engine data library Table ID TIGER/2016/Roads.
BLM National Grazing Allotment Polygons for 2016	Bureau of Land Management	CONUS vector	
USFS Grazing Allotment Polygons for 2017	USFS Range Management Unit (RMU)	CONUS vector	Metadata link

Table 2. Land cover/use classes, definitions, and specific datasets/methods used to map each class. Definitions for cropland, pastureland, rangeland, and forestland are drawn from and consistent with NRI (USDA 2015). *Denotes new classes mapped by the FUT effort.

Cover/use class	FUT class	NRI	Definition
Cropland	1	Cultivated (1), Uncultivated (2)	Areas used for the production of adapted crops for harvest, including cultivated and non-cultivated. Cultivated cropland comprises land in row crops or close-grown crops and also other cultivated cropland, for example, hayland or pastureland that is in a rotation with row or close-grown crops. Non-cultivated cropland includes permanent hayland and horticultural cropland.
Pastureland	2	3	Areas managed primarily for the production of introduced forage plants for livestock grazing. Pastureland cover may consist of a single species in a pure stand, a grass mixture, or a grass-legume mixture, regardless of whether or not it is being grazed by livestock. Management usually consists of cultural treatments: fertilization, weed control, reseeding or renovation, and control of grazing.
Rangeland	3	4	Areas composed principally of native grasses, grass-like plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland.
Forestland	4	5	Areas that are at least 10% stocked by single-stemmed woody species of any size that will be at least 4 meters (13 feet) tall at maturity. The minimum area for classification as forest land is 1 acre, and the area must be at least 100 feet wide.
Woodland*	5	NA	Non-federal, natural or planted forested cover that is part of a functioning farm unit. Woodlands can include woodlots, timber tracts, wooded fence lines, windbreaks, grazed forests, and other primarily treed areas adjacent to cropland or pastureland (no further than 160 meters, or approximately 1/10 mile). Federally grazed forested lands are excluded from the woodland class and are included as a separate land cover/use class.
Urban and Highly Developed (formerly Urban/built up)	6	7	Occupied by urban, commercial, industrial, and high-density residential development. These locations are mapped directly from the urban/developed categories (21-24) from the USGS National Land Cover Database (https://www.mrlc.gov/). Typically, residential areas with less than 1 housing unit per 1-2 acres are NOT represented in this class. Note for FUT 2.0 transportation is now mapped as a separate class.

Cover/use class	FUT class	NRI	Definition
Water	7	9 & 10	Covered by freshwater (lakes, reservoirs, large rivers), and includes some near-shore ocean. From National Hydrography Dataset High Resolution waterbodies (ponds, lakes, reservoirs).
Federal	8	11	Lands in federal ownership or management. State, county, or tribal lands are not included.
Federal (grazed)*	9	NA	Lands in federal ownership or management where grazing is a permitted use within BLM or USFS grazing allotments. Land may or may not be actively grazed. Compiled from USFS (2017) and BLM (2016) allotment data.
Other	10	6 & 8	Locations that were not classed in other cover/use classes, typically occurring on or along rural roads, in barren areas with little vegetation cover, or on steeper slopes.
Low-density residential*	11	NA	Locations dominated by residential land use with low densities of houses, from 1 unit per ~2 acres and larger lots. Housing density is calculated from US Census block-level housing statistics, and the threshold between low-density residential and agricultural uses is determined for each county by finding the ~10th percentile of farm acreage.
Transportation*	12	NA	Land used for motor vehicle transportation with land cover dominated by paved major roads. Major roads are defined as TIGER/Line route types (RTTYP): Interstate, U.S. Highways, and State Highways. County roads and other road types were excluded from mapping.
CRP	NA	12	The extent of Conservation Reserve Program (CRP) locations were not available for FUT spatial modeling efforts. Thus, we did not map CRP lands as a separate agricultural land class. We suspect that most CRP lands are mapped as pastureland or rangeland in the FUT land cover/use model.

Pre-processing NLCD to remove roads

The 2016 NLCD provides a new data layer called the impervious surface descriptor layer that identifies roads for each impervious pixel. Notably, FUT products rely primarily on the NLCD as an input source for mapping land cover/use, which can lead to an overestimate of road features and result in analytical errors (Theobald 2013; Lark et al. 2017). To address this issue, prior to our analysis, we developed intermediate NLCD land cover datasets for 2001 and 2016, and replaced rural road pixels with the dominant (mode) non-urban cover class within an eight-pixel neighborhood at a 30-meter resolution (native NLCD resolution). We did this for two principal reasons: first, the NLCD land cover class represented by a 30 x 30-m pixel that overlaps a road typically has only a portion of its area occupied by a road, while the remaining area might have non-developed characteristics. This is especially the case for smaller, rural roads that are often < 10-m wide, and thus, are over-represented in land cover models (Lark et al. 2017). Second, the NLCD draws from a coarse vector map source to superimpose roads onto the final land cover dataset. Road pixels in areas dominated by urban land cover were classified as urban. The NLCD rural-roads-removed dataset was then exported at 10-meter resolution.

Generating suitability surfaces

For each cover class, *i*, of cropland, pastureland, and rangeland, we calculated the suitability of that class for each pixel across the landscape using a combination of factors thought to influence the spatial distribution of a given land cover/use class (Bonham-Carter 1994; Carr and Zwick 2007). Here we use the term ‘suitability’ to refer to the likelihood that a location is occupied by a specific cover class, not a more integrated analysis that includes soil productivity (as is described below). Note that we excluded from consideration those locations (pixels) that were identified as urban/developed from NLCD (including open space to high-intensity, classes 21-24), forest (NLCD forest classes 41-43 and woody wetlands 90), water (from the USGS National Hydrographic Dataset [NHD]), federal or military lands, or snow/ice.

For suitability, S_i, we assumed a resulting land cover/use class *i* (e.g., cropland, pastureland or rangeland) would occur preferentially at locations that have:

- Productive soils (*c*), where *c* is re-scaled from 0-1 from the reverse order of values from SSURGO non-irrigated land capability classification system (variable “niccdcd”);
- Evidence from NLCD that at a given location the target cover/use class was there, based on the probability that a given location is a given NLCD class (e.g., cropland, class = 82). That is, we used the 2011 NLCD national-level uncertainty assessment (Wickham et al. 2017; Table 3) to calculate the probability, *p,* that a pixel is in class *I;*
- Flatter slopes (*s*), where *s* is calculated as a gradient, max-normalized to a 45 degree slope and ranging in value between 0 and 1.
- Land only, found by excluding water as specified by the NHD high-resolution water bodies (*t*);
- Non-federal lands (*f; f = 1* for non-federal, 0 for federal);
- Higher Normalized Difference Vegetation Index (NDVI) values during the growing season (April to October), calculated as the median NDVI from 30-m Landsat satellite imagery averaged with

the 10-m NDVI derived using European Space Agency Sentinel imagery from 2015. Note: NDVI was added as a component of the suitability model in FUT v2.0 to better differentiate areas that are non-productive because of poor soils (e.g., rock outcropping, ditch, access road, etc.) and to make the mapped product more valuable for applications where more localized information is needed (e.g., siting of solar panels, etc.);

- Cropland (*d*) mapped in CDL for any of the years from 2014-2016 (only used in suitability for cropland cover/use class in 2016, CDL data for 2001 is not available). To fill gaps from NLCD impervious surface classes being burned into CDL, a ~60-m square kernel maximum value moving window was applied.

We calculated suitability of class *i* as:

$$S_i = c * p * s * t * f * NDVI * d. \qquad \text{Eq. 1}$$

We calculated *p* for each class *i* to explicitly incorporate the uncertainty of the NLCD land cover/use classification, which has an overall accuracy of 76%. Although the accuracy of the NLCD for cropland is 83%, it is only 48% for pastureland and 63% for all developed classes. We incorporated classification uncertainty into the calculation of suitability to include the error likelihood in a given pixel (Table 3). For example, a pixel that is classed as cropland is correct 80% of the time (see italicized value in column "Crop p" and row "82", NLCD class = cropland). However, a pixel classed as pastureland has a 19% chance that it is actually cropland, and the other rows provide the probability that that cover class is actually cropland. So, for each of the three agricultural cover classes, a data layer is generated where land cover classes are replaced with the chance (probability) that pixel *i* is actually class *c*. We applied these 2011 probabilities to the 2001 and 2016 suitability surface because an accuracy assessment for the newly released 2016 NLCD product does not yet exist.

Table 3. Listing of National Land Cover Database (NLCD) class classes used for FUT v2.0 and associated class membership probabilities. Note that the probability, *p*, of an NLCD class was calculated using the 2011 NLCD accuracy assessment (Wickham et al. 2017). For cropland, pastureland, and rangeland covers, a data layer is generated where land cover classes are replaced with the chance (probability) that pixel *i* is actually class *c*. Woodland is not included in the table because woodlands are mapped directly from NLCD forestland cover where they are in proximity to cropland and pastureland.

NLCD class #	NLCD class type	Crop *p*	Pasture *p*	Range *p*
11	Water	0.0071	0.0049	0.0045
12	Ice/snow	0.0	0.0	0.0002
21	Developed, open-space	0.0952	0.0986	0.0857
22	Developed, low-intensity	0.0173	0.0170	0.0132
23	Developed, medium-intensity	0.0006	0.0	0.0003
24	Developed, high-intensity	0.0	0.0103	0.0
31	Barren	0.0059	0.0038	0.4358
41	Forest - coniferous	0.0163	0.0042	0.0347
42	Forest - deciduous	0.0012	0.0021	0.1443
43	Forest - mixed	0.0	0.0055	0.0513
52	Shrubland	0.0038	0.0133	*0.8444*
71	Grassland	0.0401	0.1127	*0.7638*
81	Pastureland	0.1946	*0.5636*	0.0670
82	Cropland	*0.8006*	0.1003	0.0281
90	Wetland - woody	0.0082	0.0033	0.0584
95	Wetland - herbaceous	0.0101	0.0474	0.1331

Harmonizing agricultural lands to NRI estimate

We harmonized acreage estimates from NRI broad land cover/use classes including cropland (cultivated and non-cultivated), pastureland, and rangeland for 2002 and 2015. We adjusted a county shapefile to be in concordance with the county frame used by the NRI dataset, which excludes counties created since 2010 (e.g., Broomfield, Colorado), and combines other small counties into adjacent units (e.g., towns in Virginia) to match the aggregation units used by the NRI. The NRI acreage estimates for cropland, pastureland, and rangeland where then used along with the agricultural suitability surfaces in a harmonization process to spatially allocate pixels of a given agricultural land cover class within a county. Suitability values are sorted from smallest to largest to obtain the distribution of suitability values within a county. We then identify the suitability value for the point along the distribution that most closely matches the NRI acreage estimates.

We allocated the county area of cropland defined by NRI to the pixels most suited for cropland. Figure 1 depicts the plotting of the cropland suitability distribution for an example county. Suitability values are plotted on the y-axis and the percentage of a county available for cover class *i* is plotted on the x-axis. The point on the plotted distribution where the percent of the county area matches the area estimated in the NRI dataset for that county defines the suitability threshold (horizontal line in figure 1) on the y-axis. All pixels with suitability values equal to or greater than this suitability value are then mapped as the relevant cover class.

We mapped the locations of cropland cover/use class for each county, and then excluded cropland cells in the next step when harmonizing for the pastureland cover/use class, following the economic assumption of highest best use (e.g., von Thunen/Alonso Rent Theory; Alonso 1964). We progressed incrementally, where both cropland and pastureland were excluded from harmonizing rangeland.

Mapping woodlands

Since NRI does not include woodlands associated with farms as a land cover/use class, the woodland class was harmonized to the USDA CoA estimate of woodland acres for each county. To calculate the woodland cover/use class (classified as forest cover but proximal to crop and/or pasture lands, as part of a functioning farm unit), we obtained the estimated area of woodland acres from the CoA for 2002, 2012, and 2017 at the county level. We found considerable variability in woodland acreage estimates from year to year and CoA woodland estimates were not always in line with NRI forest acreage estimates. In an effort to more consistently map woodlands through time, and to have better alignment with NRI forest estimates, we used the median woodland acreage from CoA years 2002, 2012, and 2017. We then calculated the ratio of median woodland from CoA to NRI forestland acres for each time period (2001 and 2016). The woodland suitability surface was calculated using cost-distance, taking into account both proximity to crop/pasturelands and slope. Higher woodland suitability favors flatter forested lands connected to crop and pasture lands. The harmonization process was applied to forestlands until the target number of CoA woodland to NRI forest ratio for each county was obtained.

We then applied a distance of 160 meters (approximately 1/10th of a mile) to constrain woodland mapping to more closely reflect the CoA estimates of woodlands for each county.

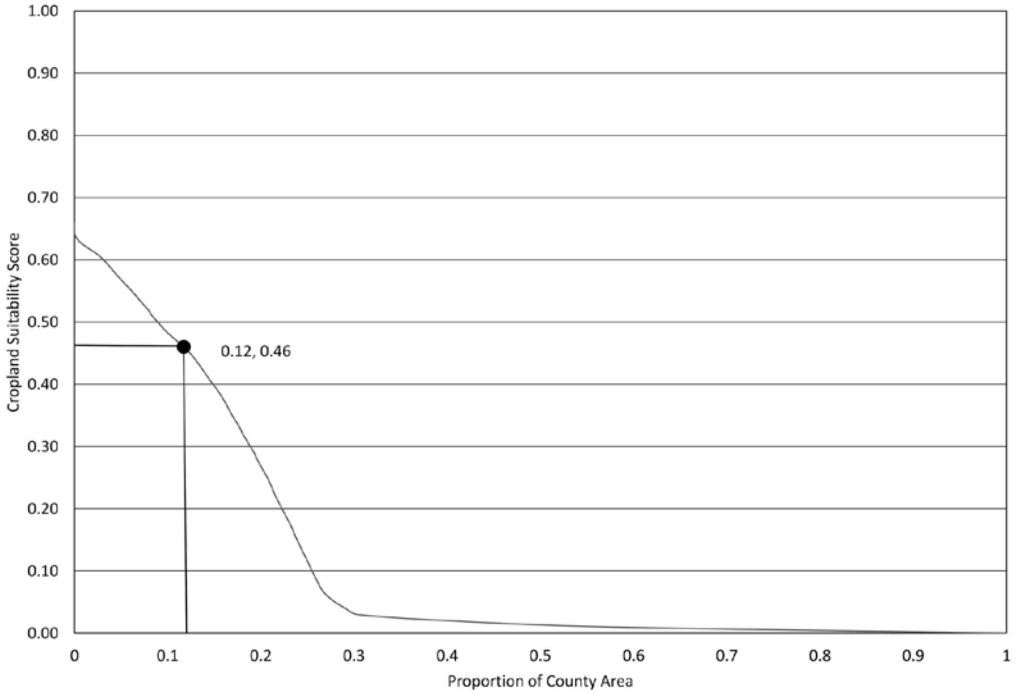

Figure 1. A graph of the cumulative distribution of cropland suitability values for Larimer County, Colorado. The y-axis shows the suitability score, which ranges potentially from 0.0 to 1.0 (up to ~0.65 in this example), where higher values indicate higher suitability. The x-axis shows the cumulative area associated with declining suitability values, in terms of the proportion of non-federal land area in the county. The algorithm identifies the suitability threshold value that generates the proportion of area specified by the NRI county estimate (here, 0.117 or 11.7%). The pixel locations that have suitability values of at least 0.46 are then re-classed as cropland. These steps are then applied to all counties in the US.

Post-processing to correct agricultural land misclassification

There is some error in NLCD classification of harvested timber land, which can inflate the amount of agricultural land identified in some counties. This was particularly evident in the state of Maine. We applied a fix to address this issue by locating areas across the conterminous US that had undergone deforestation or reforestation between 2001 and 2016 and had been classified as agricultural land. We reclassified cropland, pastureland, and rangeland parcels that were classified by NLCD as shrubland in 2001 and forest in 2016 *or* forest in 2001 and shrubland in 2016 to ‘other’ lands. In addition, we reclassified cropland and pastureland areas that were labeled as grass or shrub in both 2001 and 2016 to ’other.’ This last adjustment was only applied in the state of Maine.

Mapping low-density residential

Typically, NLCD pixels classified as developed under-represent suburban and exurban residential land use beyond the urban fringe (Theobald 2001; Irwin and Bockstael 2007). To identify a meaningful housing density threshold to distinguish low-density residential development as distinct from similar housing densities associated with agricultural uses, we evaluated the farm size at the county level from the CoA. This process helped refine region-wide assumptions about the threshold at which farms and ranches are too small to provide an efficient production capacity (these are often called "subsidized farms" or "hobby farms"). Using county level farm size data for defining low-density residential land use takes into account the range in median farm size as it varies across the continental US, with larger farms in the Midwest (>160 acres) and smaller farms on the east and west coasts (roughly 10 acres). We consider this to be an improvement over simply assuming this threshold was at 40 acres in the West and 10 acres in the East (e.g., Sorensen et al. 1997, Bierwagen et al. 2010). To further refine this threshold because the distribution of farm sizes typically is skewed to smaller farms, we obtained percentiles of county farm size from the CoA for 2017 (USDA 2017). We then estimated, through discussions and visual evaluation of the thresholds viewed on top of high-resolution aerial photography by regional experts across the country, that low-density residential land would occur at approximately the 10th percentile of the farm size distribution for each county (Figure 2). The 10th percentile farm size threshold represents the low-end of the tail of the distribution of farm size, below which we considered agricultural lands (cropland, pastureland, and rangeland) to be heavily influenced by surrounding housing such that the options for use of the remaining farmland might be increasingly limited due to its proximity to residential areas. In these low-density residential areas, we assume that farmland that remains is under threat. The options for agricultural production may be increasingly limited due to its proximity to residential areas (Sorensen et al. 1997) or it could be further developed unless restrictive zoning or permanent protection is in place to protect it. Figure 3 plots the distribution of farm size thresholds for all counties in the lower 48.

To identify low-density residential land use we applied this farm size threshold to a housing density layer generated from US Census blocks. To map housing density for 2000, we used Census housing unit data at the census block level. Housing density was estimated at the block group (which are composed of census blocks), for 2016 by the US Census Bureau as part of the American Community Survey (ACS) for 2016. The housing unit data for 2016 was collected by the US Census ACS. The housing units at the block group level for 2016 were divided by block group housing units for 2010 to get a change ratio at the block group level. Within each block group, this change ratio was then multiplied by the block-level housing units from 2010 to estimate housing unit density at the census block level for 2016.

To better understand the impacts of LDR land use on agriculture, we evaluated the fate of agricultural land that was in LDR areas in 2001. To do so, we calculated an "LDR Multiplier" by dividing the rate of conversion to UHD from 2001-2016 for agricultural land within LDR areas by that for all other agricultural lands. Values above 1 indicate that agricultural land in LDR areas was more likely to be converted to UHD than other agricultural land.

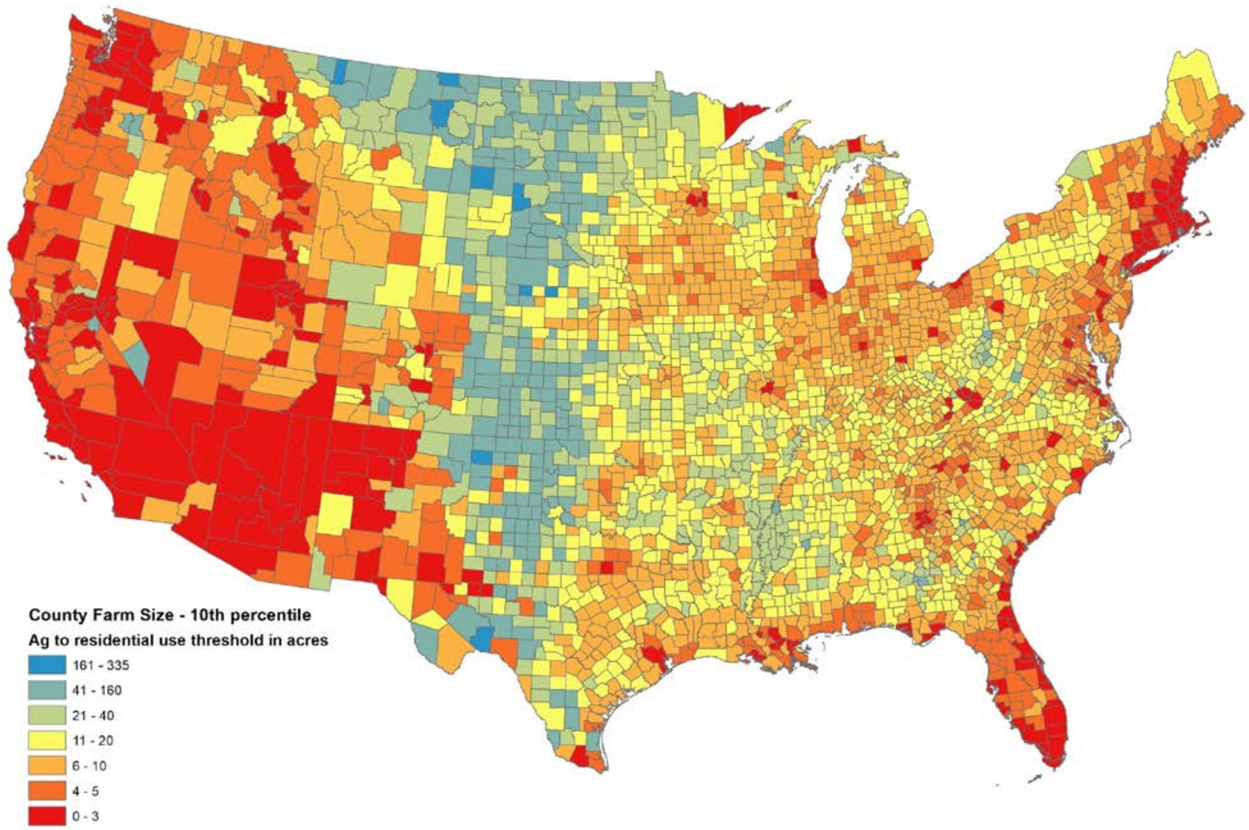

Figure 2. The spatial distribution of the 10th percentile of farm size (acres) from the 2017 USDA Census of Agriculture for all CONUS counties. The 10th percentile was found independently for each county and was used to define the threshold between low-density residential and agricultural land use.

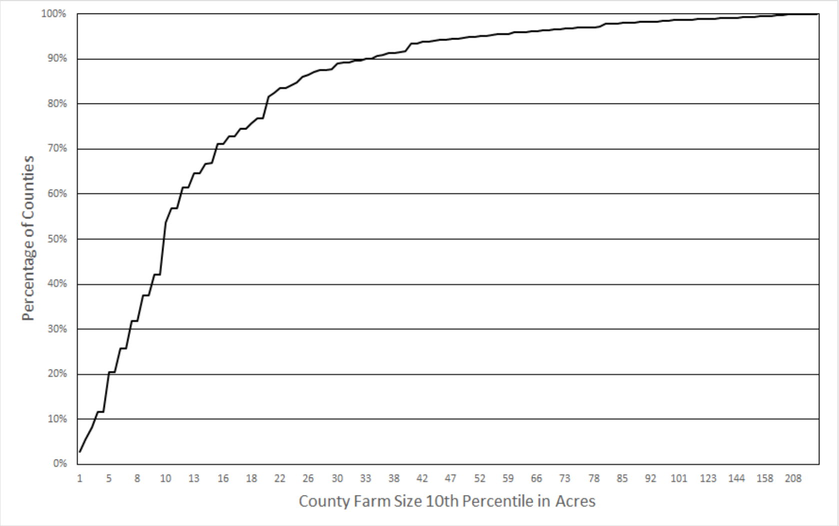

Figure 3. The cumulative distribution of the 10th percentile of farm size for each county for 2017, which was used as the threshold between low-density residential and agricultural land use (in acres).

Mapping Productive, versatile, and resilient agricultural lands

We generated a spatial dataset that represents the land's agricultural potential based on its productivity, versatility and resiliency (PVR), circa 2001 and 2016. Although this is a snapshot in time, the PVR affects the long-term sustainability of keeping the land in cultivation or in other agricultural uses. *Productivity* is defined typically as output per unit of input (often measured as crop yield per acre). The highest productivity occurs where climate and soil conditions are most conducive to plant growth, particularly in warmer locations where multiple crop cycles are supported. In addition, certain factors favor production of perishable food crops that are highly nutritious and difficult to replace in human diets (e.g., fruits, vegetables, dairy), such as special microclimates, location near urban centers, and irrigation. *Versatility* is the ability of land to support production and management of a wide range of crops. It is mainly assessed in terms of soil and land physical characteristics (Bloomer 2011). *Resiliency* is the ability of land to maintain its potential to provide ecosystem services and depends on the same factors that determine potential productivity (topography, relatively static soil properties, and climate; Herrick et al. 2016). The PVR analysis considered soils, their limitations, climate, type of production, and whether the land is capable of producing commonly cultivated crops and pasture plants without deterioration over a long period of time.

To identify the characteristics, the indicators, and weighting amongst these factors, we used a formal expert-elicitation process using established methods (Speirs-Bridge et al. 2010; McBride et al. 2012) and gathered parameters and estimates from 33 agricultural experts with a variety of experience and from across the country. We generated the PVR values using three factors (f): 1) soil productivity, 2) land cover/use, and 3) food production for direct human consumption. The experts participated in a structured process based on decision analysis theory (following Saaty 2008; Roszkowska 2013) to identify the relative importance or weight (w) of a PVR factor by assigning a numerical weight to each component within each PVR factor. The resulting PVR map assigned a 0 to 1.0 value based on its potential, where:

$$PVR = f_1w_1 + f_2w_2 + f_3w_3 . \qquad \text{Eq. 2}$$

Modeling soil productivity

To generate the soil productivity factor, we used data on important farmland designations and land capability classes from the SSURGO and STATSGO databases. The soil productivity factor measures the capacity of soils to support agricultural production, but also provides information about the soil versatility and capacity to sustain production with varying weather conditions (e.g., precipitation, temperature regimes). Using the attribute "farmland class" from SSURGO, we distinguished *prime farmland*, *prime farmland with limitations*, *unique farmland*, *farmland of statewide importance*, and *farmland of statewide importance with limitations*. Appendix Table 2-A contains the SSURGO farmland class reclassification table used for mapping soil productivity. Based on discussions with our advisory group and state soil scientists, we reclassified locally important soils in all states as not prime, except Michigan and Ohio, because states inconsistently define their locally important soils and most states identify fewer than 1,000 acres as locally important. In Michigan, we reclassified locally important soils in counties adjacent to Lake Michigan as unique (since these areas support fruit trees or vineyards) and reclassified the locally important soils in remaining counties as statewide important. In Ohio, we reclassified locally important soils as statewide important. Based on the input from experts, we applied the following order of importance to the soil classes: prime, unique, prime with limitations, state important and state important with limitations. As a final step, and because a small extent (~2%) of non-federal lands have not been mapped in the SSURGO dataset, we filled no-data areas in SSURGO using the coarser resolution STATSGO soils data.

To strengthen the soil productivity analysis, we included a secondary factor based on production limitations documented within USDA NRCS Land Capability Classes (LCC) (USDA SCS 1961; M. Robotham, *pers. comm*.). The USDA developed this classification to group soils primarily on the basis of their capability to produce commonly cultivated crops and pasture plants without deteriorating over a long period. The LCC system takes into account numerous management hazards (e.g., erosion and runoff, excess water, root zone limitations and climatic limitations) and identifies whether soils are best suited to cultivated crops, pasture, range, woodland, and/or wildlife food and cover. While agricultural production can occur in nearly all LCCs (with the exception of LCC 8), the investments needed to mitigate hazards increase as class values increase.

Advisory group rankings for all land capability classes were used to determine the within-weight values for soil productivity (Table 4). Ranks were converted to weights using the square root of the rank sum weight (Roszkowska 2013) for both farmland class and LCC. The resulting weights were then multiplied together for each combination of farmland class and LCC to calculate the final within-weights.

Table 4. Within-weights calculated as the product of the farmland class and Land Capability Class. Weights were generated from ranks elicited from experts. Within-weights were calculated by using the square root of the rank-sum weight (Roszkowska 2013).

		Land Capability Classes							
		Suited to cultivation				Not suited to cultivation without significant investment to mitigate hazard			
		1	2	3	4	5	6	7	8
Farmland Class (rank)		Slight limitations	Moderate limitations	Severe limitations	Very severe limitations	Moderate limitations	Severe limitations	Very severe limitations	Not suitable for ag
	Within-weights	1.00	0.87	0.71	0.50	0.87	0.71	0.50	0.50
Prime (1)	1.00	1.00	0.87	0.71	0.50	0.87	0.71	0.50	0.50
Unique (2)	0.72	0.72	0.62	0.51	0.36	0.62	0.51	0.36	0.36
Prime lim (3)	0.55	0.55	0.48	0.39	0.28	0.48	0.39	0.28	0.28
State (4)	0.50	0.50	0.44	0.36	0.25	0.44	0.36	0.25	0.25
State lim (5)	0.30	0.30	0.26	0.21	0.15	0.26	0.21	0.15	0.15

Modeling land cover/use

For each of the FUT agricultural classes, the advisory panel estimated the ranks, which we then converted as rank sum weight (*f2*; Table 5; Roszkowska 2013). The experts ranked cropland as the most important cover/use class within the PVR model. This reflects the assumption that cropland has relatively fewer environmental limitations and/or more infrastructure, such as center pivot irrigation systems, when compared with other cover/use classes.

Table 5. Within-weight values (f_2) associated with FUT classes estimated for the land cover/use factor of the PVR analysis. Weights were generated from ranks elicited from experts in response to how important cover/use classes were in identifying valuable agricultural land. These values were made relative to cropland (the highest absolute value).

FUT Class	Within-weight
Cropland	1.00
Pastureland	0.54
Rangeland	0.318
Forestland	0.123
Woodland	0.246
Urban	0.0
Water	0.0
Federal	0.123
Federal (grazed)	0.318
Other	0.123
Transportation	0.0

Modeling food production

The food production factor characterizes the versatility and uniqueness of a location. Versatility can be deduced from the type of crop being grown as well as the length of the growing season. We grouped the crop types listed in the CDL, assigned annually from 2014 to 2018, into five classes: fruit and nut trees; fruits and vegetables grown as row crops; staple food crops (e.g. wheat, rice, barley, oats, dry beans, potatoes); feed grains, forages and crops grown for livestock feed and processed foods (corn and soybean; hay and alfalfa; oilseeds; and sugar beets and sugarcane); and non-food crops (i.e., crops used for energy production, excluding corn, plus fiber, tobacco and nursery/greenhouse). To calculate the within-weights for this factor, we elicited rankings of these five classes from our advisory group and then converted them to weights using rank sum weight (Roszkowska 2013). After calculating the within-weights and after inspecting the resulting maps, we applied a squared transform to accentuate the differences between the weights of the high and low ranked classes (Table 6). To account for the interannual variability of crop types, we calculated the average class rank over five years for each pixel. Pixels with no record in the CDL were assigned a within-weight value for food production (f_3) equal to zero.

We also included information about growing season length to account for regional differences in production value that varies because of climate (e.g., multiple rotations per year in California and Florida vs. short summer season in Maine). To do this, we adjusted the within-weight values of food production using a rough surrogate for the length of the growing season. That is, we multiplied the food production weights by the proportion of freeze-free days in a year, for each major land resource area (MLRA). We then normalized the overall food production value by the 90th percentile value (0.17) to max-normalize the within-weight values (f_3) to 0 to 1.0.

Overall PVR calculation

We calculated the overall PVR values for each 10m pixel for CONUS to align with the spatial scale for other FUT products. We calculated PVR values using Eq. 2 (above), where w values were the between-weights estimated by the advisory group that summed to a value of 1.0 (w_1=0.541; w_2=0.196; w_3=0.314).

Agricultural lands with lower PVR values have progressively greater limitations and usually require more inputs, although farmers can and do farm these lands by adapting crops and practices. Conversely, areas with higher PVR values are extremely valuable because they have few current and long-term limitations to agricultural production. To identify the most important agricultural land, we calculated the PVR value of land that could support *intensive production of food and other crops*, typically associated with increased management intensity and high-value crops. We used this PVR value as a threshold to identify the best land across the U.S., calling all land with PVR values above the threshold as “nationally significant.” This threshold was identified by finding the minimum values of each of the three factors that were sufficient to meet the assumption for each of the 3 factors. That is, we included: soil productivity types of prime and prime with limitations (> 0.423); land cover/use cropland and pastureland classs (> 0.538); and food production (> 0.299). Then, we calculated the overall threshold value by using the factor weighting:

$$(0.423 * 0.540) + (0.538 * 0.196) + (0.299 * 0.314) = 0.429 \qquad \text{Eq. 3}$$

Table 6. Listing of the within-weight values associated with food production classes estimated by the advisory group. Weights were generated from ranks elicited from experts in response to the importance of each class in identifying valuable agricultural land.

Food production class	Final within-weight
Fruit & nut trees	1.00
Fruits and vegetables	0.959
Staple	0.635
Feed	0.325
Non-food	0.093

Each state's best agricultural lands

The principal purpose of FUT 2.0 was to provide information about each state's agricultural lands. To identify the highest potential lands in each state—which we term "each state's best land"—we mapped the lands with PVR values greater than the approximate median PVR value for a state's agricultural lands. For states with a significant amount of rangeland, the "best land" may include rangelands with relatively low PVR values. This does not imply that rangelands are appropriate for crop production, but rather that these rangelands are among the most valuable agricultural lands in the state, and should be protected from conversion to urban development. Median PVR values for agricultural lands for each state are provided in Table A-1.

Results

Land cover/use patterns and statistics

We found that of the major land cover/use classs, agriculture dominates the continental US landscape (Table 7). In 2016, agricultural lands occurred on over 914-M acres of non-federal land, with an additional 216-M acres of grazing on federal lands, for a total of over 1,130-M acres. The largest proportion of the agricultural land in 2016 was rangeland (35%, with an additional 19% for grazing on federal land), followed by cropland (32%), pastureland (10%), and woodland (5%). We also found that urban, low-density residential, and major road transportation land cover/uses had a combined 116-M acres (6% of the US). For 2001, we found that agriculture occupied more land -- over 920-M acres (1,136-M acres including federal grazing lands).

Table 7. FUT land cover/use acreage estimates for CONUS in 2001 and 2016, including agricultural lands and federal lands used for livestock grazing for the continental US. Non-federal agriculture land cover/use class includes cropland, pastureland, rangeland, and woodland.

	2001		2016	
Land cover/use class	**Acres (thousands)**	**% of the US**	**Acres (thousands)**	**% of the US**
Cropland	359,831	18.7	356,361	18.5
Pastureland	103,073	5.3	107,735	5.6
Rangeland	399,401	20.7	395,478	20.5
Forest	362,240	18.8	352,152	18.3
Woodland	57,889	3.0	54,196	2.8
Urban and Highly Developed	45,020	2.3	51,323	2.7
Water	38,165	2.0	37,564	1.9
Federal	170,643	8.9	170,505	8.8
Federal (grazed)	216,049	11.2	216,029	11.2
Other	116,429	6.0	116,775	6.1
Low-density res.	45,065	2.3	55,399	2.9
Transportation	9,968	0.5	9,693	0.5
Total				
Non-federal agriculture	920,194	47.8	913,769	47.4
Agriculture (non-fed and federal grazed)	1,136,243	59.0	1,129,798	58.6
All federal lands	386,692	20.1	386,534	20.1
Developed (urban, low-density, transportation)	100,052	5.2	116,415	6.0

Land cover/use change and conversion of agricultural lands

We show in Table 8 the conversion of agricultural lands to urban or low-density residential land use.

Table 8. Conversion by land cover/use classes to urban and high density (UHD) and low-density residential (LDR) development, from 2001 to 2016. The percentage of land (including federal grazed land) converted for each land cover/use class is given in the "% of all land" column. The percentage of total agricultural land (including federal grazed lands, but not forestland) converted for each land cover/use class is given in the "% of ag land" column.

Land cover/use		Converted to UHD			Converted to LDR			Total (UHD and LDR) converted		
Class	% of ag land	Acres (thousands)	% of all land	% of ag land	Acres (thousands)	% of all land	% of ag land	Acres (thousands)	% of all land	% of ag land
Cropland	31.5	1,390	25.19	33.59	2,343	19.56	34.48	3,733	21.33	34.14
Pastureland	9.5	1,167	21.15	28.20	2,064	17.23	30.38	3,231	18.46	29.55
Rangeland	35.0	1,225	22.20	29.60	859	7.17	12.65	2,085	11.91	19.07
Woodland	4.8	357	6.46	8.61	1,528	12.75	22.49	1,884	10.77	17.23
Total Ag		**4,140**	**74.99**	**100.0**	**6,794**	**56.71**	**100.0**	**10,933**	**62.48**	**100.0**
Forestland*		1,381	25.01		5,186	43.29		6,567	37.52	
Total (w/ Forestland)		**5,520**	**100.0**		**11,980**	**100.0**		**17,500**	**100.0**	

* Forestlands are not included in the total agricultural land acreage.

Comparison and validation of FUT land cover/use maps

Although the FUT land cover/use dataset we developed differs from the NRI dataset because of substantial methodological differences (i.e., spatially explicit mapping vs. point-based estimates and different non-agricultural land cover classes), we believe it is useful to provide some general comparisons of overall estimates. In general, we observed very similar estimates of the areal extent of land cover/use classes to those estimated by the NRI (Table 9). Although we calibrated our land cover model to NRI acreage estimates, limitations in mapping and statistical precision as well as uncertainty around NRI estimates prevented our model outputs from fully converging with NRI estimates. We found 87% spatial agreement between FUT and NRI land cover/use classification at the NRI point level for combined agricultural land classes (cropland, pasture, rangeland; Table 10).

Table 9. A comparison of the estimated area of land cover/use classes between our results (FUT) for 2016 and the NRI for 2015 in millions of acres.

Land cover/use	FUT area	NRI area	FUT as % of NRI
Cropland*	356.4	363.8	98
Pastureland	107.7	120.3	89.5
Rangeland	395.5	399.3	99
Woodland**	54.2	74.4	72.9
Forest***	406.3	410.7	98.9
Urban	51.3	51.1	100.5

* FUT cropland acreage estimate combines NRI broad land cover/use classes for cultivated and uncultivated cropland. FUT does not include Conservation Reserve Program acres in cropland, pasture, or rangeland classes.

** Woodland acreage estimates are derived from the Census of Agriculture, not NRI.

*** We included forest and woodland from FUT in comparison to NRI forest.

Table 10. Confusion matrix showing percent agreement between land cover/use acres estimate by Farms Under Threat (FUT) for 2016 and NRI for 2015. Note that for FUT, cropland includes both cultivated and uncultivated cropland that is reported separately in NRI. Woodland is not reported by NRI and thus would fall into NRI Forest land class.

	Farms Under Threat Land Cover Class 2016					
NRI Broad Land Use Class 2015	**Cropland**	**Pastureland**	**Rangeland**	**Forest**	**Woodland**	**Urban**
Cultivated cropland	74.5%	8.0%	2.1%	0.6%	8.6%	4.0%
Uncultivated cropland	7.9%	7.9%	1.2%	0.4%	4.3%	1.5%
Pastureland	6.5%	43.9%	4.0%	2.5%	15.9%	4.6%
Rangeland	2.6%	16.0%	82.8%	5.3%	2.4%	3.0%
Forest land	1.7%	10.2%	3.4%	83.5%	56.2%	6.2%
Other rural land	2.0%	3.3%	1.7%	1.8%	2.9%	4.3%
Urban and highly developed land	1.5%	4.1%	0.9%	2.8%	4.7%	67.6%
Rural transportation	1.8%	1.9%	0.9%	1.3%	1.9%	2.2%
Small water areas	0.5%	1.0%	0.3%	0.9%	1.3%	1.2%
Census water	0.0%	0.1%	0.1%	0.1%	0.4%	0.6%
Federal land	0.1%	0.2%	0.7%	0.7%	0.3%	4.8%
Conservation Reserve Program (CRP)	1.0%	3.3%	2.0%	0.2%	0.9%	0.1%

We also compared the trends of conversion from 2001 to 2016 of agricultural lands defined in NRI as crop, pasture, and range to “developed land” and in FUT as crop, pasture, range, or woodland to urban. Making a direct comparison of FUT and NRI agricultural land conversion estimates is challenging due to methodological and land cover/use classification differences. Table 11 presents the most direct comparison of FUT and NRI agricultural land conversion to urban development. The lower conversion estimates in FUT are to be expected because our classification of urban land (derived from NLCD) is less expansive than the NRI definition of developed land, and because FUT does not account for conversion to roads.

Table 11. Comparison of the estimated area of agricultural land conversion to urban development between 2001 and 2016 from FUT compared to NRI in thousands of acres.

Land cover/use	FUT to Urban	NRI to Urban	% FUT of NRI
Cropland*	1,390	2,417	58
Pastureland	1,167	1,525	77
Rangeland	1,225	1,591	77
Total Ag	3,783	5,533	68
Forest	1,737	4,120	42
Total including Forest	5,520	9,653	57

* Cropland for NRI includes both Cultivated and Uncultivated cropland.

** Forest for FUT include both forestland and woodlands since NRI does not distinguish woodlands separate from forestland.

Discussion

We believe that the FUT datasets and related products provide valuable insight into the patterns and trends of conversion that are of importance to the agricultural community. Our results are consistent with existing national inventories of agricultural lands (NRI) and add value in multiple ways. Specifically, our results: (a) show the spatial patterns of agricultural land uses and conversion in a consistent way over time; (b) include a spatially explicit mapping of low-density residential development; (c) include maps of grazing allotments on federal lands; (d) map woodlands associated with farms; and (e) identify agricultural lands based on their productivity, versatility and resiliency to support intensive food and crop production (i.e., their PVR values). Moreover, we explicitly include uncertainty in the NLCD database in the suitability models that were used to build the FUT land cover/use maps.

We primarily explored the gross loss of agricultural lands, with a focus on conversion to urbanized and low-density residential land uses. We acknowledge that there are some lands that were put into agricultural productions since 2001 (Lark et al. 2015), however, this is challenging to map and was not the intent of FUT. We speculate that these recently cultivated lands, while potentially ecologically important, are likely less productive with low PVR values. We recommend that this aspect be further explored in subsequent analyses.

Some of the key outcomes of our FUT 2.0 effort include the following:

- More detailed mapping (with a mix of 10- and 30-meter inputs), allowing state, county, and sub-county level analyses and applications;
- Inclusion of low-density residential growth into agricultural lands;
- Summary statistics of land cover area and agricultural land conversion for states and counties;
- Mapping of PVR for all lands within the conterminous US, including federal lands and non-agricultural land cover classes (i.e., forest).

Intended data uses and limitations

From the outset of the FUT project, we recognized that the NRI provides critical information about the extent and trends of agricultural lands nationally. FUT is grounded on the platform of the NRI by driving the spatial patterns using NRI county-level estimates of agricultural land cover/uses. FUT extends the NRI by creating spatial maps of those data, using detailed land use/cover maps (NLCD). We note that there is some uncertainty in the FUT and NRI land cover/use estimates. It is important to remember this when comparing our results to NRI, especially with regards to the evaluation of conversion of agricultural lands to developed land uses.

We believe that FUT provides the best available spatial map of agricultural land cover/use and agricultural land conversion as a nationally consistent data product. However, as with any spatial analysis and mapping of this complexity, detail, and extent, improvements in the datasets remain. To this end, we identified two main sources of uncertainty. First, while we acknowledge the uncertainty surrounding NRI estimates of land cover, we do not explicitly incorporate into the FUT model margins of error of the NRI estimates. Second, the NLCD dataset is fundamental to the FUT product and thus the accuracy of NLCD is directly tied to how well we map land cover in FUT. At the time of this report no accuracy assessment for the 2016 NLCD products had been released. Third, low-density residential land that encroaches on agricultural production is challenging to map, especially from satellite imagery used by the NLCD. Residential areas occur across a gradient of densities, typically declining in density away from the urban fringe. Our mapping of low-density residential is an explicit attempt to map the areas that are not high enough in housing and impervious surface density to be mapped as urban areas, but where agricultural production may face increasing limitations due to adjacent residential land use. However, our method inevitably captures some viable agricultural fields within LDR areas. This is because the best spatial data for housing density is only available at the census block level. The variability in size and shape of census blocks presents challenges when mapping low-density residential land use. For this reason, in FUT 2.0 we map low-density residential land use as a separate layer, while maintaining the underlying land cover for more detailed analysis.

Although we produced the FUT 2.0 products at resolutions of 100 m^2 (or ~ 0.025 acre), we consider a reasonable minimum mapping unit to be between 100 and 200 acres, largely based on characteristics of the NLCD data. While the FUT datasets can be visualized at their native resolution, we caution the use of these data below our recommended minimum mapping unit, for example, in calculating summary statistics such as land cover acreage or average PVR values. We recognize that there will be utility in applying the data to relatively fine-scale applications, but urge caution when interpreting or comparing analytical results, particularly when applying the data to site-specific planning activities. Calculating landscape change is particularly challenging, and we suggest using FUT data to quantify robust measures of change at county, state, and national scales. Fine-scale analyses should proceed under the advisement of the data developers on a case-by-case basis.

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Appendix A

Table 1-A. State median values for Productivity, Versatility, and Resilience (PVR) for agricultural lands. Median values for all agricultural lands include cropland, pastureland, woodlands, and rangelands. Each state's best land is defined as lands with PVR values greater than the agricultural median for each state. Farmland median PVR is calculated for just cropland, pastureland, and woodlands.

State FIPS	State abbreviation	Agricultural land median PVR	Farmland median PVR
1	AL	0.34	0.34
4	AZ	0.12	0.45
5	AR	0.51	0.51
6	CA	0.13	0.43
8	CO	0.16	0.45
9	CT	0.45	0.45
10	DE	0.58	0.58
11	DC	0.19	0.19
12	FL	0.26	0.26
13	GA	0.45	0.45
16	ID	0.21	0.42
17	IL	0.56	0.56
18	IN	0.56	0.56
19	IA	0.56	0.56
20	KS	0.53	0.62
21	KY	0.39	0.39
22	LA	0.61	0.61
23	ME	0.34	0.34
24	MD	0.53	0.53
25	MA	0.34	0.34
26	MI	0.52	0.52
27	MN	0.56	0.56
28	MS	0.48	0.48

State FIPS	State abbreviation	All agricultural land median PVR	Farmland median PVR
29	MO	0.35	0.35
30	MT	0.13	0.42
31	NE	0.27	0.56
32	NV	0.12	0.35
33	NH	0.24	0.24
34	NJ	0.51	0.51
35	NM	0.12	0.37
36	NY	0.46	0.46
37	NC	0.48	0.48
38	ND	0.49	0.58
39	OH	0.56	0.56
40	OK	0.39	0.52
41	OR	0.27	0.42
42	PA	0.45	0.45
44	RI	0.39	0.39
45	SC	0.40	0.40
46	SD	0.33	0.53
47	TN	0.26	0.26
48	TX	0.15	0.46
49	UT	0.12	0.33
50	VT	0.33	0.33
51	VA	0.33	0.33
53	WA	0.31	0.49
54	WV	0.22	0.22
55	WI	0.50	0.50
56	WY	0.12	0.29

Table 2-A. SSURGO farmland class reclassification used to map soil productivity into the major classes used in the Productivity, Versatility, and Resilience (PVR) model. The map unit frequency column shows the number of SSURGO map units classified as a given Farm Class for the conterminous US.

SSURGO Farm Class Code	Farm Class	PVR remap for Code	PVR remap Class	Map unit Frequency
0	All areas are prime farmland	1	Prime farmland	47941
1	Farmland of local importance	6	Farmland of local importance	5158
2	Farmland of statewide importance	4	Farmland of statewide importance	42235
3	Farmland of statewide importance, if drained	5	Farmland of statewide importance with limitations	289
4	Farmland of statewide importance, if drained and either protected from flooding or not frequently flooded during the growing season	5	Farmland of statewide importance with limitations	23
5	Farmland of statewide importance, if irrigated	5	Farmland of statewide importance with limitations	975
6	Farmland of statewide importance, if irrigated and drained	5	Farmland of statewide importance with limitations	40
7	Farmland of statewide importance, if irrigated and either protected from flooding or not frequently flooded during the growing season	5	Farmland of statewide importance with limitations	17
8	Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium	5	Farmland of statewide importance with limitations	52
9	Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60	5	Farmland of statewide importance with limitations	1
10	Farmland of statewide importance, if protected from flooding or not frequently flooded during the growing season	5	Farmland of statewide importance with limitations	6

SSURGO Farm Class Code	Farm Class	PVR remap for Code	PVR remap Class	Map unit Frequency
11	Farmland of statewide importance, if warm enough	5	Farmland of statewide importance with limitations	2
12	Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season	5	Farmland of statewide importance with limitations	1
13	Farmland of unique importance	3	Unique farmland	996
14	No Digital Data Available	0	No Data	154
15	Not prime farmland	7	Not prime farmland	176123
16	Prime farmland if drained	2	Prime farmland with limitations	15131
17	Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season	2	Prime farmland with limitations	1735
18	Prime farmland if irrigated	2	Prime farmland with limitations	9711
19	Prime farmland if irrigated and drained	2	Prime farmland with limitations	484
20	Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season	2	Prime farmland with limitations	383
21	Prime farmland if irrigated and reclaimed of excess salts and sodium	2	Prime farmland with limitations	6490
22	Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60	2	Prime farmland with limitations	161
23	Prime farmland if protected from flooding or not frequently flooded during the growing season	2	Prime farmland with limitations	1521
24	Prime farmland if subsoiled, completely removing the root inhibiting soil layer	2	Prime farmland with limitations	2
25	Unknown	0	No Data	3216
26	Water	0	No Data	116