PRIMER REPORT

ENHANCING THE INFRASTRUCTURE TO IMPROVE LAND USE CHANGE ANALYSIS AND ASSESSMENT

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GOALS

The purpose of the Land Use Change Assessment Workshop is to convene a multi-stakeholder group focused on the state of the science and key gaps in land use change (LUC) assessment, data, and methodologies. The intent is to:

- Establish shared definitions of key terminology and criteria for ideal LUC frameworks;
- Create a shared vision for a LUC quantification framework that meets the needs of all relevant stakeholders; and
- Develop an action plan for achieving the shared vision and form work groups to begin implementing that action plan.

This document serves as background information on issues associated with estimating land use change to support the two Land Use Change Assessment Workshop sessions planned for April, 2023.

These workshops are part of a broader initiative to provide the scientific, social, and peer-reviewed publications to build common ground and improve accuracy in assessment, access to consensus-derived methodologies and needed dialogue that will enhance understanding in land use change quantification.

WORKSHOP SESSION 1: SETTING THE STAGE

Thursday, April 13 / Noon–3:30 pm (eastern time)

Participants will build a shared understanding of the current state of land use change quantification and the benefits and limitations of existing frameworks.

WORKSHOP SESSION 2: FROM VISION TO ACTION

Thursday, April 27 / Noon–3:30 pm (eastern time)

Participants will build on the shared understanding established in workshop Session One to develop a shared vision for how to evolve and enhance LUC quantification. For those who want to continue to build momentum and lend their expertise, work groups will be formed to begin implementing that vision.

THE PROJECT IS WORKING TO COMPLETE THE FOLLOWING DELIVERABLES TO BUILD CONSENSUS ON THESE CRITICAL ISSUES:

✓ **Convene a multi-stakeholder workshop** focused on the state of the science and key gaps in assessment methodologies to build dialogue and consensus.

✓ **Establish diverse, methodology advancement** working groups to continue building momentum from the workshop.

✓ **Publish peer-reviewed scientific journal issue(s)** dedicated to the topic of land use classification and land use conversion assessment.

✓ **Deliver a public report and communications campaign** to help build awareness and understanding across many audiences.

CRITICAL ISSUE:

Broad consensus on how to best quantify direct land use change (LUC) and land use classification for United States row crops is lacking. Different data sources and methods of calculation are used, resulting in a considerable range of LUC estimates. LUC estimates are instrumental to resource management decision-making and policy development, directly impacting farmer and rancher livelihoods, biodiversity, water security, food security, energy security, and other critical ecosystem services. Therefore, developing a consistent LUC and classification quantification framework that meets stakeholder needs is critical to reduce risk of impairment of natural and managed ecosystems and support resiliency moving forward.

BARRIERS:

Key barriers to developing consensus on LUC assessment methodologies include fluid and inconsistent definitions of foundational terms, varying accuracy of data sets over time and location, variation in analytical timeframes, methods for reporting results (e.g., net vs gross LUC) and previous land use baselines (managed vs unmanaged), lack of access to protected information, models that are expensive and under continual revisions, difficulties with remote sensing in differentiating between lightly managed lands, minimal independent validation of reported accuracies, and a failure to consider the social aspects of rural communities.

OPPORTUNITIES:

Gaps remain in land use classification and conversion quantification – consistent and accurate methodologies are lacking to assess conversion between major land cover categories such as native grassland, intermittent pasture, forest, and row crops, as well as associated subcategories. The use of inconsistent or inaccurate digital information has created debates over changes in land classifications and uses over time. These debates have introduced confusion into natural resource management decision-making and policy development. Precision laboratory techniques, agricultural technology, satellite imagery and computer analysis suites have provided tools to improve understanding of influences on land use across the United States, but consensus on quantification approaches has not been met. Technological advances in aerial imagery, computational resources and data connectivity across sources and sectors present opportunities for enhanced accuracy in assessment and harmonization of methods. Developing consensus for a LUC quantification framework can enhance retrospective LUC lookbacks and improve forward looking projections, and thereby support farmer and rancher livelihoods, biodiversity, water security, food security, energy security, and other critical ecosystem services.

BENEFITS OF ADDRESSING LAND USE CHANGE:

Individuals and societies have used land use change to address critical issues facing societies today, including climate change, plant and animal biodiversity loss and extinctions, water quality and quantity, ecosystem resilience, and food and energy security. How land is used has a direct impact on these issues. The failure to understand land use conversion can exacerbate these issues.

HISTORY

Land cover is the biophysical state of the earth's surface and immediate subsurface (Turner et al. 1995). In other words, land cover describes the physical state of the land surface: as in cropland, mountains, or forests. "Land use involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation – the purpose for which the land is used" (Turner et al. 1995).

The primary approaches to developing data sources that are used for calculating LUC have included producer surveys, remote sensing, models, and visual observation and measurement (Table 1). Each such approach has different strengths and weaknesses and can produce different results (Table 2). Land use/cover data are developed for a variety of purposes, and published LUC studies often represent some combination of them. Further complicating direct comparison is the estimation of LUC over different time periods and geographies.

Table 1. Data Sets Commonly Used to Estimate Land Use Change.

Data Set	Acronym	Agency	Spatial Resolution	Temporal Resolution	Description/Purpose
Cropland Data Layer	CDL	USDA	30 m	Annual	Crop-specific land cover data set
National Land Cover Data	NLCD	USGS	30 m	5 years	Produce nationally consistent land cover data based on Landsat imagery
National Agriculture Imagery Program	NAIP	USDA	1 m	3 - 5 years	Digital orthophotography reflecting land use agricultural growing season
Census of Agriculture	Ag Census	USDA	NA	5 years	Complete count of US farms, ranches and people
Land Change Monitoring Assessment & Projection	LCMAP	USGS	30 m	Annual	New generation of land cover mapping and change monitoring with finer spatio-temporal resolution.
National Resource Inventory	NRI	USDA	15 m	5 years	Statistical survey of natural resource conditions and trends
Corn Soybean Data Layer	CSDL	Open Source	30 m	Annual	Fill data gaps in CDL and validate classified data

[1] The same 20 crops are included as individual classes in the CDL allowing for direct comparison (Copenhaver et al., 2021).

Land use involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation—the purpose for which the land is used.

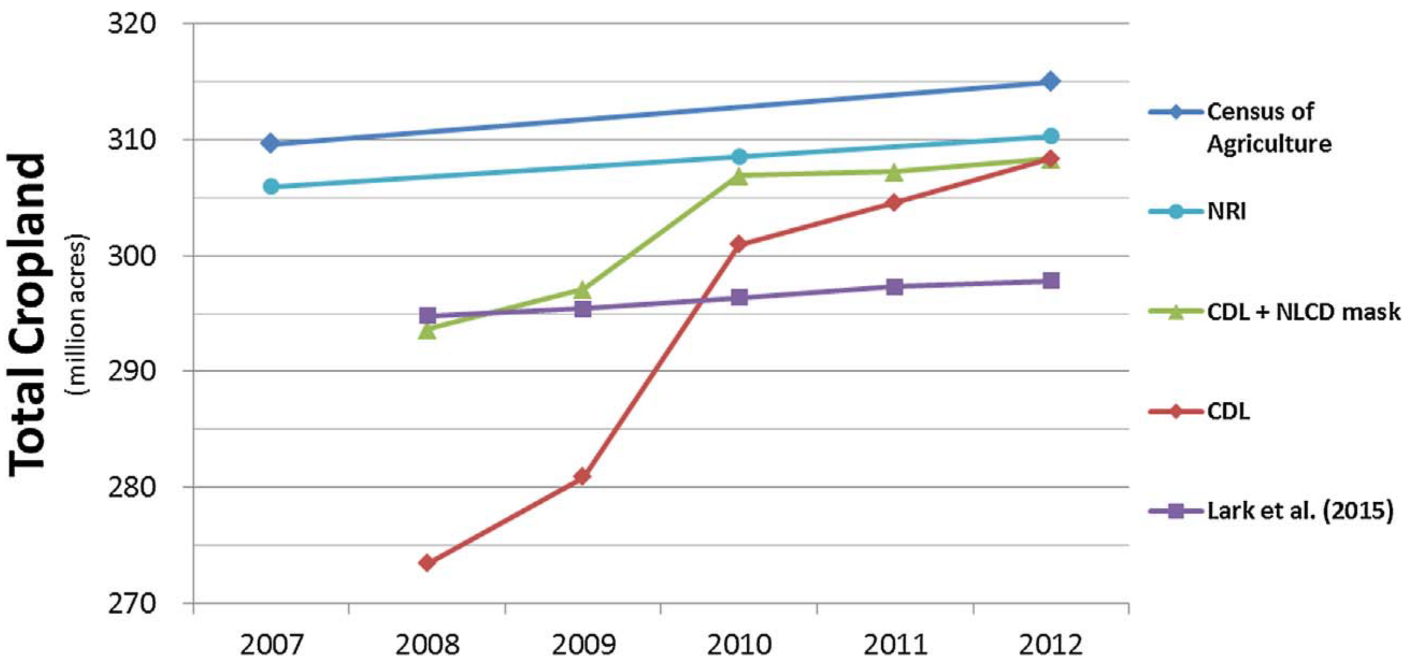
(TURNER ET AL. 1995)

Table 2. High-level Comparison of Aggregate Land Use Change, 2008 – 2017.

Land Use Change Category	LCMAP V1.1, 2021	Lark *et al.*, 2020	NRI, 2020	Potapov *et al.*, 2022
Cropland abandonment	3,152	3,519	6,784	3,922
Cropland expansion	8,335	10,096	10,650	7,890
Net expansion	5,183	6,577	3,866	3,968
Intermittent	5	17,983	--	--
Stable cropland	462,736	286,826	353,362	364,097
Stable non-cropland	1,450,446	1,606,248	1,566,920	1,560,796
Total	1,924,673	1,924,673	1,937,716	1,936,706

Source: Martin et al. (in preparation).

Figure 1. Total Cropland Over Time



Source: Lark et al., 2017.

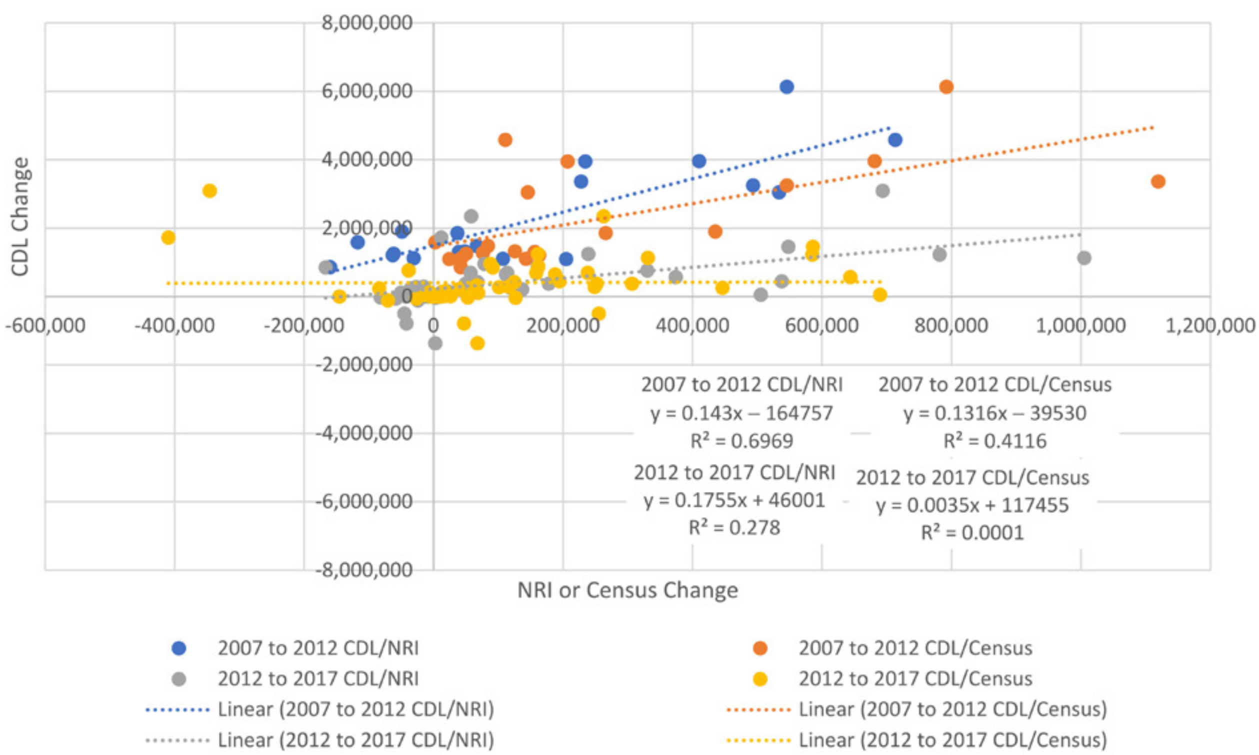
Total cropland over time based on uncorrected cropland data layer (CDL) compared to the United States Department of Agriculture's (USDA) Census of Agriculture and National Resource Inventory (NRI), the CDL with a mask from the United States Geological Survey's National Land Cover Data (NLCD) and a combination of the CDL, NLCD and Land Cover Trends Dataset (Soulard et al., 2000) analyzed by Lark et al. (2015).

HISTORY

Figure 1 illustrates that the CDL predicts a greater rate of LUC compared to other commonly used datasets that employ different ground-truthing methods. In a similar analysis using CDL data from 2008 to 2011 Lark et al. (2015) suggested that up to 1.9 million acres of new corn plantings and 1.5 million acres of new soy plantings could be ineligible as renewable biomass for agricultural and biofuel policies. Reitsma et al. (2016) showed that the CDL variability was location-dependent, and that producer accuracies[1] for grasslands in 2012 within the South Dakota CDL were 38.9% in the southeast National Agricultural Statistics Service (NASS) region and 95.2 % in the northwest NASS region.

Another issue with using the CDL is that decreasing classification error with time creates implicit bias in land use change calculations (Figure 1). Lark et al. (2017) suggested that this error can be reduced by calibrating the CDL with external data, such as USDA Census of Agriculture, (NASS, 2014), USDA NASS survey data (NASS, 2016), the National Land Cover Database (Homer et al., 2015), and NRCS National Resource Inventory (USDA, 2015). Others, including Copenhaver et al. (2021) (Figure 2), and Wang et al. (2020) have also investigated methods to use additional data sources to improve the accuracy of the CDL. Different databases, however, do not necessarily provide similar estimates of land cover (Laingen, 2017), nor agreement on the amount of cropland in production at a given point in time (Lark et al., 2017), potentially further complicating efforts to calibrate datasets such as the CDL. Using surrounding pixels within the CDL, as well as historical CDL data, and a decision tree approach, Lin et al. (2022) avoided calibrating the CDL using different data sources, and reduced the classification noise inherent in the CDL (Figure 3).

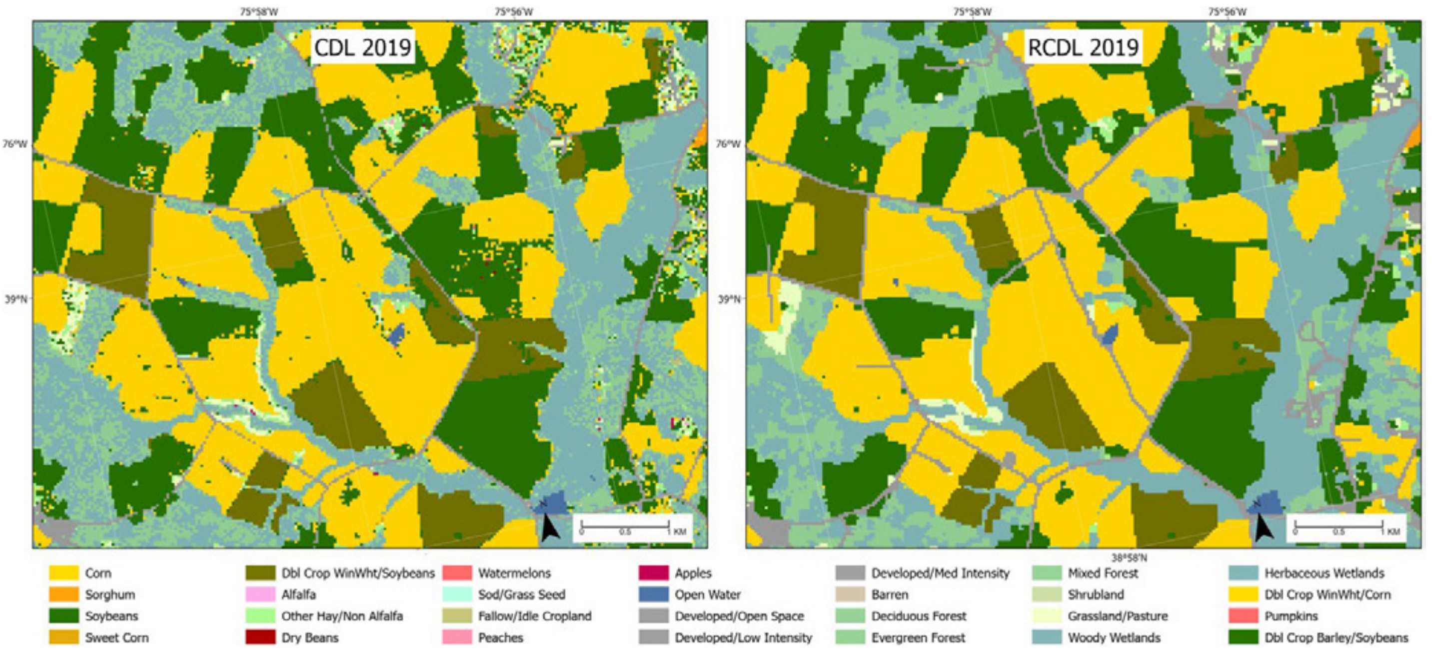
Figure 2. Comparison of change in cropland between the CDL, the NRI and the Census for 2007–2012 and 2012–2017.



Source: Copenhaver et al., 2021.

[1] % false positive = 100-producer accuracy

Figure 3. Comparison of imagery classification results for Queen Anne's County, Maryland, 2019, from the Cropland Data Layer (CDL) (left) and the CDL refined using decision tree approaches.

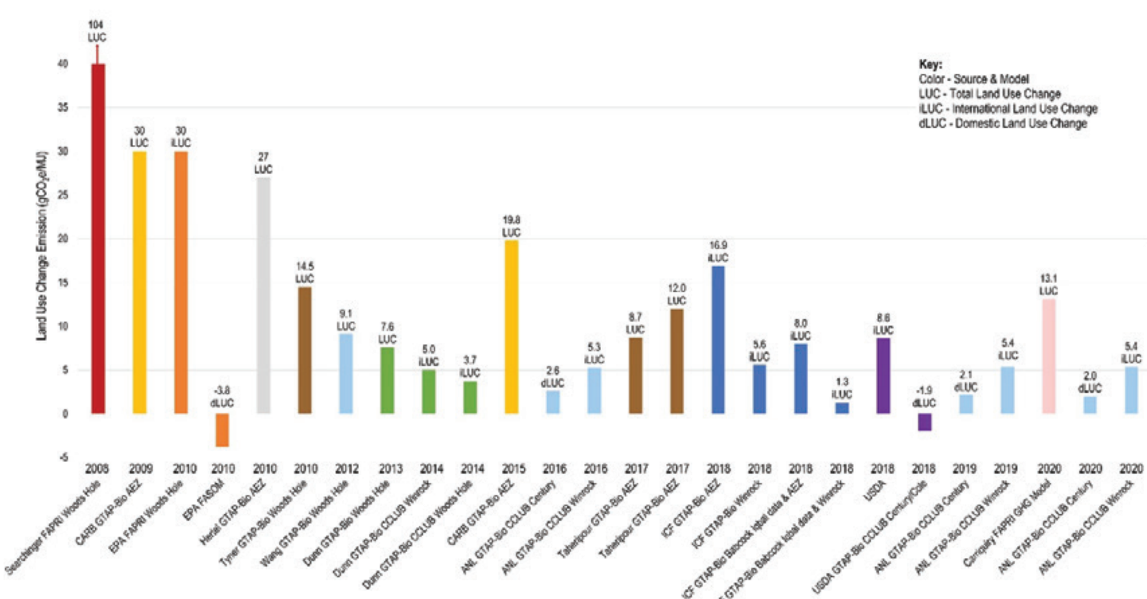


Source: Lin et al., 2022

Uncertainty in LUC estimates can lead to uncertainty in subsequent calculations based on those estimates. For example, Figure 4 illustrates how land use data variability contributes to LUC assessment variability, presented here in terms of estimates of greenhouse gas emissions associated with corn ethanol production. Four major elements contribute to the illustrated LUC emission estimates: the agro-economic model, economic data year, yield price elasticity, and land intensification. Land intensification[2] refers to the practice of using existing cropland more efficiently and relates directly to LUC.

[2] Examples include yield improvement, multiple cropping, reduction of agricultural land in fallow, conversion of other unused cropland to crop production, and reduction in temporary or mowed pasture.

Figure 4. Estimates of greenhouse gas emissions associated with corn-related land use change.



Source: Scully et al., 2021.

DEFINITIONS

FLEXIBLE DEFINITIONS CONFUSE DISCUSSION

Definitions are critical in land use classification and conversion quantification. For example, what does marginal land mean and over what timeframe? To support classification of land use suitability the USDA-NRCS (Soil Conservation Service, 1961) defined land use capability classes (LCC) based largely on the risk of erosion, indicating that conservation practices like no-tillage, cover crops, and conservation tillage should be used on soils with LCC values of 3 and 4 (Table 3). Lark et al (2015) reported that land with a LCC value of 1 had no limitations for land use and that land with a LCC value of 2 had slight limitations, whereas land with LCC values of 3 and 4 were considered marginal and had severe to very severe limitations. Wright and Wimberley (2013) similarly reported that land with LCC values of 3 and 4 had severe to very severe limitations. Others, however, have defined marginal lands primarily as unprofitable (Popp et al., 2018; Sawyer et al., 2018).

Since the creation of the LCC classification cropping system management has changed (Soil Conservation Service, 1961; Wimberly et al., 2017). For example, results from USDA Economic Research Service data suggest United States soybean farmers increased adoption of no-till (35% in 2002 to 39% in 2018) and mulch till (from 28% in 2002 to 35% in 2018) in recent years (Claasen et al., 2018). These management changes were not considered in Wright and Wimberly (2013) and Lark et al.'s (2015) discussions of marginal lands, illustrating the importance of accurate definitions of key terms influencing LUC.

Table 3. Land Use Capability Classes (LCC), Features and Recommended Uses

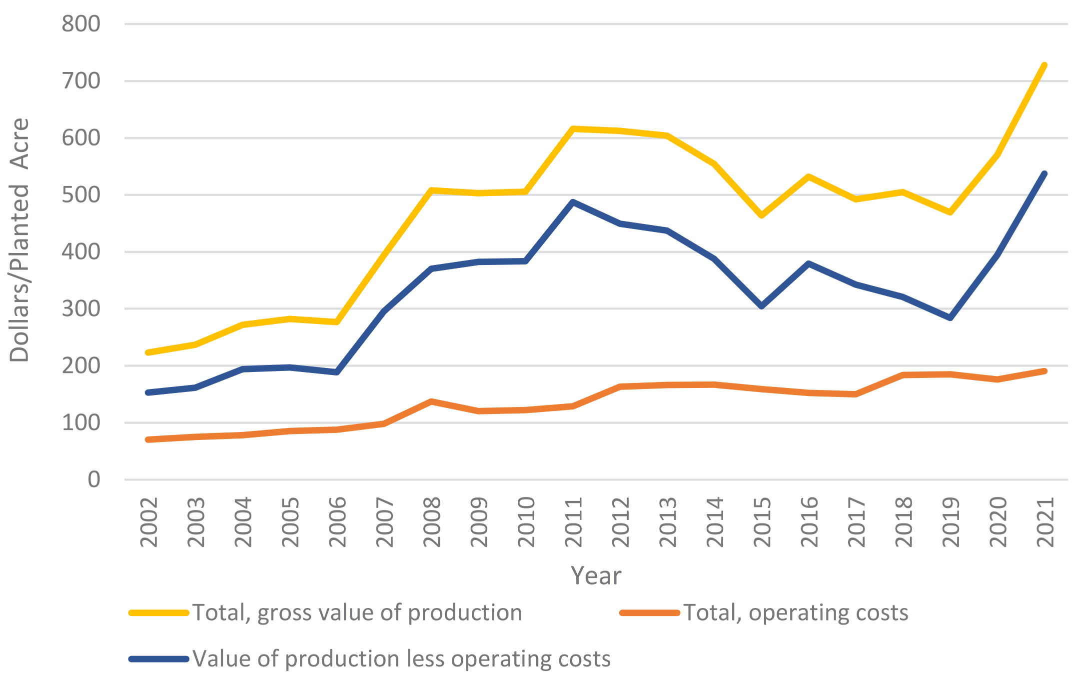
LCC†	Features	Use and Recommendation
1	No topographic and climatic limitation	Are considered suitable for cultivated crops
2	Few limitations	Generally suitable for most cultivated crops or require moderate conservation practices
3	Restrictions in amount of clean cultivation (no residue left on soil surface)	Requires careful conservation practices like no- tillage, cover crops and conservation tillage
4	Severe limitations that restrict the choice of plants and cultivation approaches	Require proper management and conservation practices like no- tillage, cover crops and conservation tillage
5	Wet most of time	Not recommended for annual crops
6	Several limitations due to steep slope	Unsuited for crop cultivation and mainly used for pasture, range and forestland
7	Very severe limitation due to steep slope	No crop cultivation and primarily used for grazing, forestland or wildlife
8	Even more severe limitation	Restricted for recreation, wildlife, water supply or aesthetic purpose

Source: Soil Conservation Service, 1961

PROJECTING FUTURE RISKS

Based on short-term economic gains, relatively simple models can be used to project risks. For example, rates of return on cropland can be based on commodity costs and returns published by the USDA Economic Research Service (Figure 5). Simplistic commodity models, however, miss a key point: for many farmers, decision-making is grounded in diversification, which is a more complex strategy (Wang et al., 2021; Adhikari et al., 2021). On many farms, income is derived from the sale of multiple products including grains, forages, eggs, livestock, and indirectly from ethanol (Bourlion et al., 2013; Davis et al., 2016; Dunn et al., 2005). Prices for these products vary annually and this impacts land use and conversion as well as crop-planting decisions. For example, for a farmer the conversion of grasslands to croplands may mean that there will be a decrease in the income from livestock with an associated increase from crops. Because diversification protects farmers from market swings most managers do not make these changes lightly (Gasson, 1973; Barbieri and Mahoney, 2009). Further, marginal lands are defined several ways depending on the publication, but many include terms such as low productivity and lower quality soils (Milbrandt et. al., 2014). Conversion of low productivity land and lower quality soils to agricultural production can be costly and net very little return on investment for farmers. Primary interview data from farmer leaders suggests farmers consider land conversion decisions seriously due to lower productivity and uncertain return on investment (Farmer panel interview data, 2023). The transcript data move further to explain that conversion of marginal lands to crop production is high risk and that this is widely understood in the farming community.

Figure 5. Production costs and returns per planted acre of soybeans in the Midwest Heartland[3] Region 2002 – 2021 (USDA-ERS, 2023).



Source: USDA-ERS, 2023

This graph based on USDA-ERS Historical Costs and Returns: Soybeans Report - accessed here: www.ers.usda.gov/data-products/commodity-costs-and-returns/commodity-costs-and-returns/

Source data provided as an Excel Pivot Table. Figure 5 represents a simple line graph of the following three rows of data for the Heartland Region (no editing or other analysis of these data was conducted): *Total, gross value of production *Total, operating costs *Value of production less operating costs.

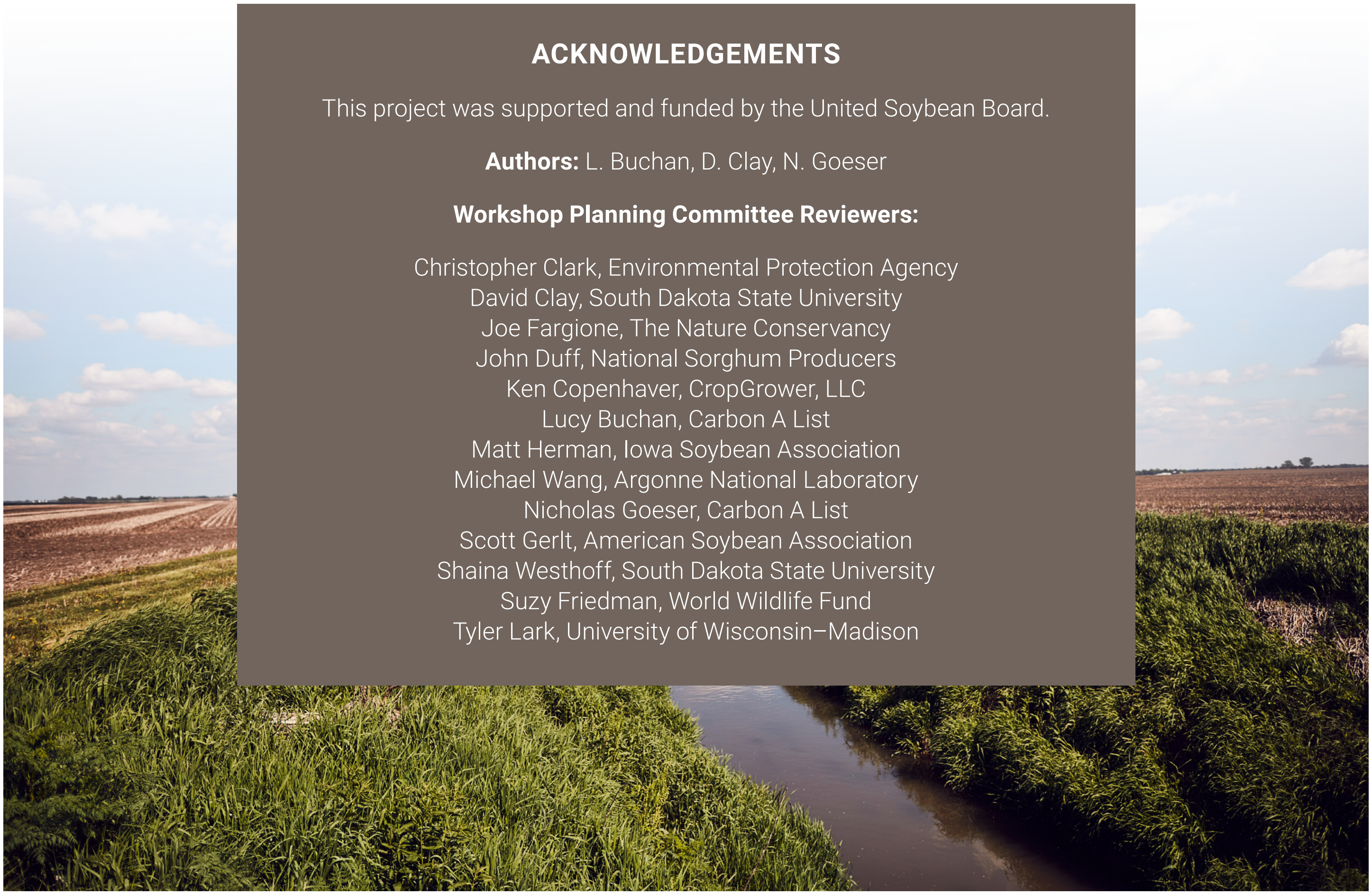
[3] Includes Iowa, Illinois, and Indiana, and parts of Minnesota, South Dakota, Nebraska, Missouri, Kentucky, and Ohio

SUMMARY & CONCLUSION

Considering ecological, economic, and environmental aspects of managed and wild lands simultaneously in decision-making and program development provides the potential to enhance ecosystem resiliency. The failure to address these issues in land classification and land use conversion quantification can have cascading consequences across agricultural supply chains and ecosystem functions. The first step in managing complex land use conversion problems is to ensure consistent land use classification terminology is utilized, and then quantify the magnitude and extent of land use change in a spatially explicit manner with a high degree of accuracy. This step, however, is confounded by the multitude of data sources and approaches employed in LUC assessments, which produce different results that are difficult to independently validate. The goal of this Workshop is to address this gap.

The conversion of grasslands or forests to croplands has the potential to increase erosion, degrade water quality, decrease wildlife and pollinator habitat, lead to wildlife habitat fragmentation, decrease income diversity, and contribute to greenhouse gas emissions (Lark et al., 2020). The degradation of ecosystem services depends on where the land is converted and how the land is managed following the conversion. For example, whether conservation practices are adopted or if the land is put under low or intense grazing intensity will impact flood mitigation and result in changes to wildlife and pollinator habitat. To lead to meaningful dialogue about land use we must agree on the definitions and approaches used to quantify land use and land use changes.

It is important to remember that many farmers manage land for the long term, value soil health, like to diversify their income streams, are resistant to change or inertia, value their local communities, and would like to pass the land onto their children (Wang et al., 2020). Accurately quantifying land use change will have important ramifications for farmers and for building climate resiliency. Solidifying this work and building consensus amongst subject matter experts in land use change is of paramount importance to generating useful, impactful, and trusted dialogue with those outside academia.



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