DRAFT
Summary of Background Research on Additionality for Cropland Management Project Protocol

April 1, 2011

Table of Contents

1 Introduction

1.1 Purpose

The Climate Action Reserve (Reserve) is developing a Cropland Management Project Protocol (CMPP) to quantify greenhouse gas (GHG) offsets from implementation of agricultural practices on U.S. croplands that increase carbon sequestration in soil. A key criterion for offset projects is that they be truly additional, meaning they would not have happened absent the carbon market.

This paper provides background information to support development of the CMPP, focusing primarily on additionality. However, first the paper provides a basic definition of the intended scope for the protocol to help organize and frame the rest of the paper. Further below in the Introduction, basic concepts of and the Reserve's general approach to additionality are reviewed, drawing largely from an issue brief published by the Reserve in October 2010 titled, "Options for Determining Additionality of Agriculture Projects." The rest of the paper is dedicated to summarizing and evaluating available data relevant to additionality of projects falling under the scope of the CMPP. It ends with a summary of the key findings.

This paper is being published as a draft document to inform the next meeting of the Cropland Management Project Protocol workgroup scheduled on April 7, 2011. The Reserve anticipates refining and elaborating on the data presented here and other relevant trends with further internal research and information provided from the workgroup.

1.2 General Definition of Cropland Management Projects

The Cropland Management Project Protocol (CMPP) will focus on projects that reduce CO_2 emissions or enhance CO_2 removals by increasing organic matter (carbon) in mineral soils. This happens by minimizing soil disturbances and/or maximizing organic matter inputs. A number of changes in cropland management (e.g., using no-till, reducing summer fallow, planting winter cover crops, etc) can impact disturbance and inputs and, as a result, cause GHG reductions. Setting aside cropland that is otherwise capable of producing food and converting it into a permanent non-tree vegetative cover, such as pasture or natural grasslands, can substantially increase soil carbon sequestration as a result of eliminating soil disturbance, increasing permanent belowground biomass in roots and shoots, and possibly increasing overall organic matter inputs from permanent vegetation compared to a cultivated system.

There are two somewhat distinct categories of project activities that may be covered by the CMPP: (1) those that affect the way cropland is managed, but do not affect the essential use of the land and (2) those that represent a significant change in land use. While different considerations arise in evaluating these two general project types, for example, in developing performance standards and evaluating leakage risks, the general approach to quantifying GHG emissions and sequestration will likely be the same for both categories.

The two project categories likely to be encompassed by the CMPP are further defined as follows:

- **Change in management on existing croplands ("Management Change")**: a change in cropland management on existing productive croplands that does not require changing the primary service provided by the cropland. This would include adopting activities that do not affect crop rotations at all or that modify rotations but provide a consistent level of primary goods and services produced from the production system.

Wholesale changes from one annual crop system to a different annual crop system (or from one perennial to another perennial system) may occur in some circumstances as a result of normal operations and a need to be responsive to market demands, but such changes would not represent or be affected by the offset project activity. It will be important to consider how to incorporate flexibility that allows such changes while ensuring minimal leakage impacts.

Potential activities falling within this category are:

- Change from conventional to conservation till
- Change from conventional to no-till
- Eliminate summer fallow
- Use winter cover crops
- Diversify annual crop rotations
- Include perennial crops in rotations
- Organic soil amendments
- Switch from dry land to irrigated
- Irrigation improvements

- **Conversion of existing croplands to a new use ("Cropland Conversion")**: a change in cropland management where the defined change fundamentally converts the production system to providing different goods and services, specifically a complete shift from annual to perennial production or converting annual cropland to natural or grazed grasslands.

  Potential activities falling within this category are:

  - Change from annual to perennial crops
  - Cropland conversion to pasture
  - Cropland conversion to uncultivated use

Projects that avoid CO_2 emissions by preventing conversion of non-cropland into actively cultivated cropland will not be included in the CMPP protocol at this time. Such projects have an inherently different baseline scenario than the project types under consideration for the CMPP. Histosol or organic soils will also not be considered in the scope of this protocol due to substantially different methodological considerations, compared to mineral soils, in terms of processes leading to emissions and sequestration, impacts on other GHG impacts (specifically CH_4), and quantification of soil carbon impacts.

1.3 Overview of Additionality

Carbon offsets allow the emitters of greenhouse gases (GHGs) to forego achieving their own emission reductions by paying another party to achieve reductions instead. Because the effects of GHG emissions on climate do not depend on geography, the atmosphere should be indifferent between reducing CO_2 emissions at a smokestack and increasing carbon sequestration in an agricultural field. The risk, however, is that an emitter might pay for a reduction that another party was going to undertake anyway. In that case, the atmosphere would have been better off without the transaction; total emissions will be the same as if the emitter had taken no action. For carbon offsets to be effective at mitigating climate change they must therefore be "additional" to what would have occurred anyway. In formal terms, this means that GHG reductions used as offsets must be those that would not have occurred in the absence of a market of buyers willing to pay for them.

Although the logic behind "additionality" is relatively straightforward, designing rules to effectively test whether offsets are additional can be quite challenging. There are numerous possible approaches, but the Reserve is committed to using standardized methods. This means projects are evaluated according to explicit and objectively verifiable criteria rather than subjective methods that try to assess a project's individual circumstances. Standardized criteria are established separately for each project type, and are designed to exclude non-additional (or "business as usual") projects from eligibility. Standardized additionality tests have several distinct advantages:

- They avoid the administrative costs and delays associated with subjective, case-by-case evaluation of a project's circumstances.
- They are administratively easier to apply and improve consistency in how additionality determinations are made.
- They alleviate uncertainties for project developers and investors about which projects will be eligible.

In Reserve protocols, additionality tests generally have two components: a Legal Requirement Test and a Performance Standard Test. The Reserve also places restrictions on the earliest eligible start date for projects.

Projects are likely to be non-additional if their implementation is required by law. However, projects that are not legally required may still be non-additional if they would have been implemented for other reasons, e.g., because they are economically attractive even without carbon offset revenues. This paper focuses on developing performance standard tests to screen out this potential set of projects in the context of the CMPP. Specific provisions of a legal requirements test will also be developed for the CMPP, but that is beyond the scope of this particular paper.

In developing performance standards, the Reserve considers financial, economic, social, and technological drivers that may affect decisions to undertake a particular project activity. Standards are specified such that the large majority of projects that meet the standard are unlikely to have been implemented because of these other drivers. Performance standards will often reflect "common practice" within a particular economic sector, so that only projects that "go beyond" common practice are eligible.

The Reserve, in close consultation with a workgroup, develops a performance standard for each type of project covered by a protocol. Performance standards can be specified in several ways:

- Practice- or technology-based thresholds. Performance standards may be specified in terms of a specific practice or technology that is rarely or never implemented in the absence of a carbon offset market. Such standards are generally based on surveys of the market penetration rates of candidate practices or technologies. Projects employing a qualifying technology or practice are automatically considered additional.
- Emission or sequestration rate thresholds. For some project types, a performance standard may be specified in terms of a rate of GHG emissions or sequestration (usually per unit of production of some product or service, e.g., tonnes of CO_2 per megawatt-hour). Generally, the threshold rate would be based on a level of performance that is significantly better than average for the industry or sector. Projects that have lower emission rates (or higher sequestration rates) than the threshold, for example, would be considered additional.

- Other qualifying conditions or criteria. Performance standards may also incorporate, or be based on, other specific qualifying conditions that a project must meet in order to be considered eligible. Conditions may include characteristics related to the project site, specifications for a particular eligible technology or practice, or other contextual factors.

Several specifications may be combined in a single Performance Standard Test. For example, a protocol may define a performance standard in terms of a specific type of technology that has an emission rate below a certain threshold and is implemented at an eligible project location.

The Reserve has no predefined threshold for determining an acceptable performance standard. Rather, establishing performance standards involves balancing the need to restrict eligibility for non-additional projects with the goal of allowing a majority of additional (and otherwise eligible) projects to participate. Setting a threshold always involves making tradeoffs between these two goals.

The starting point for developing performance standards is the analysis of available data on industry trends. The remainder of this paper summarizes the Reserve's performance standard research to date for the CMPP.

2 Additionality of Tillage Practices

This section reviews available data on additionality of projects under the category of Management Change, focusing specifically on the project activity of conversion from conventional tillage to conservation till or no-till. While other practice changes may fall under this broad category, as noted above, at this time the best available data on current and future trends in cropland management practice changes that affect soil carbon sequestration are on tillage management.

Conversion from conventional till to no-till (referred to as "no-till adoption" throughout this paper) is perhaps the most well studied practice change of all those listed above in terms of its GHG mitigation potential and trends in use; and, other existing soil carbon offset methodologies in the U.S. and Canada are specifically designed to quantify GHG reductions from tillage management.

While this section focuses on tillage management, some information is reported at the end on trends in the use of cover crops to provide an indication of trends in other potentially relevant cropland management practice changes.

2.1 National Trends in Tillage Practices

In November 2010, the U.S. Department of Agriculture (USDA) released the most comprehensive report available to date on U.S. tillage practices.[1] The report, "'No-till' Farming is a Growing Practice," estimates that by 2009, no-till was being used on 35.5% (or 88 million acres) of major U.S. cropland, with increasing adoption rates of roughly 1.5 percent per year (%/yr). Previously reported no-till adoption data suggested 7% and 17% of total U.S. cropland acres were under no-till and conservation tillage (respectively) by 1997, but did not provide any

[1] J. Horwitz, Ebel, R., and Ueda, K. "No-till" Farming is a Growing Practice. USDA ERS, Economic Information Bulletin Number 70 (November 2010), Available at: http://www.ers.usda.gov/Publications/EIB70/

indication of the annual rates of increasing adoption of these practices.[2] While adoption levels were previously known to be 50% or higher in some Midwestern regions,[3] the most recent data reported by USDA suggest extensive levels of no-till adoption at the national level. The most recent USDA data were released soon after the Reserve kicked-off the CMPP protocol development process with formal scoping meetings in October 2010. This section summarizes the no-till adoption trends from the USDA report.

The USDA analysis is based on data from the Agricultural Resource Management Survey (ARMS) covering eight major crops (barley, corn, cotton, oats, rice, sorghum, soybeans, wheat) that comprise 94% of total planted U.S. acreage (approximately 239.8 million acres). Notably, all U.S. fruits, vegetables, nuts, and other specialty crops are grown on the other 6% of U.S. acreage (approximately 15.3 million acres) and are not covered in the report.

The survey data evaluated a range of tillage practices, including conventional till, no-till,[4] conservation tillage and reduced tillage as well as information on residue retention. In addition to national no-till estimates for 2009, USDA also provided more detailed data on the acreage under each type of tillage practice noted above, by state and crop for each ARMS survey year for that crop (survey dates for each crop occurred sometime during 2000-2007, but not all crops are surveyed each year; two survey dates were available for four of the eight crops).

Based on longitudinal data for four crops, the ARMS data show the adoption of no-till growing at a national average rate of 1.5% per year. The actual rates vary for the four crops, but all show positive growth:

- 1.08%/yr for rice (survey years 2000-2006);
- 1.37%/yr for cotton (2003-2007);
- 1.86%/yr for corn (2001-2005); and
- 2.59%/yr for soybeans (2002-2006).

To estimate the current extent of no-till adoption from the various survey years of available data, USDA projected forward no-till adoption rates for each of the major crops from their most recent survey date using the national average no-till adoption rate of 1.5%/yr. The projections were done by crop type and show no-till was likely used on at least 16% or more of the acres planted in each of the eight major crops in 2009 (Table 1). No-till adoption is widespread in soybeans, with nearly 50% of cultivated acres using no-till. The lowest levels of no-till adoption are in rice (16%) and oats (20%) (Table 1). The data in Table 1 are directly from the USDA report, except for the last column, which was calculated by the Reserve using the crop-specific no-till adoption rates reported above.

[2] USDA Greenhouse Gas Inventory 2009 (http://www.usda.gov/oce/climate_change/AFGGInventory1990_2005.htm)
[3] Conservation Technology Information Center 2006 Data Analysis; voluntarily reported county-level data. Available at: http://ctic.org/crm
[4] USDA defines no-till as "a tillage system in which crop residue is left on the soil and the soil is left undisturbed from prior harvest to no-till planting except for nutrient injection." Using the ARMS data, a field was assumed to have had no tillage operations if none of the following machinery categories were used on the field between the harvest of the previous crop and the current year's planting: plows and disks (including moldboard plow, offset disk, and tandem disk), cultivators, harrows, bedder-shapers, packers, and other tillage equipment (e.g., Land-all, Do-all, Mix-n-till, mulch treader, rototiller, soil finisher, or stalk puller).

Table 1. USDA Estimates of No-Till Operations for Eight U.S. Crops in 2009
(Adapted from Table 1 of USDA report; last column calculated by the Reserve)

Crop	No-tillage operations (most recent crop survey year)	No-tillage operations, 2009 (estimate)[1]	Total planted acres, 2009	BAU annual increase in no-till acres[2]
	Percent of crop acres		Million acres	Acres / yr
Barley	27.6 (2003)	36.6	3.6	54,000
Corn	23.5 (2005)	29.5	86.5	1,608,900
Cotton	20.7 (2007)	23.7	9.1	124,670
Oats	13.8 (2005)	19.8	3.4	51,000
Rice	11.8 (2006)	16.3	3.1	33,480
Sorghum	25.0 (2003)	34.0	6.6	99,000
Soybeans	45.3 (2006)	49.8	77.4	2,004,660
Wheat	21.9 (2004)	29.4	59.1	886,500
Total (all eight crops)		35.5[2]	248.9	4,862,210

[1]Assuming 1.5 percentage-point growth per year.
[2]Calculated by the Reserve, assuming crop-specific no-till adoption rates reported above.
Source: Horowitz, John, et al., "'No-Till' Farming Is a Growing Practice," USDA, Economic Research Service analysis of Agricultural Resource Management Survey data.

Overall, the national estimates show high market penetration of no-till (16-50% depending on crop type) with significantly positive rates of no-till adoption. Based on these data, it can be assumed that each year, no-till is newly adopted on roughly 4.8 million acres of cropland. Much of this trend is driven by high annual adoption rates for corn, soybeans, wheat and cotton and extensive cropland area dedicated to cultivating these crops. These trends suggest underlying non-carbon market incentives (e.g., reduced soil erosion, reduced fuel costs, increases in crop productivity) are driving a modest to high uptake of no-till practices already. However, recognizing potentially significant variation regionally, the Reserve took a closer look at the state- and crop-specific data to identify possible situations where no-till adoption trends deviate from the national average.

First, the Reserve screened the data for instances where the latest ARMS survey showed no-till was used on 10% or fewer acres of a given crop in the most recent survey year, and found that, as summarized in (Table 2):

- All of the 8 major crops had instances where no-till was used on 10% or fewer acres in at least one state; and
- These instances occurred in sixteen different states;
- California, Minnesota, Texas, and Utah each had instances where no-till use was zero, for at least one crop.

Then, for each of the state-crop combinations identified in Table 2, the Reserve projected the trends forward to 2012, the year in which the CMPP is expected to take effect, using the crop-specific no-till adoption rates noted above for rice, cotton, corn, and soybean, and the national average for all other crops. It was assumed that if no-till adoption was zero at the last ARMS survey that it would remain zero into the future.

Table 2. States and Crops Where No-Till Was Used On 10% or Fewer Acres During 2003-2007.

State	Crop	Last Survey Year	Annual No-till Adoption Rate (% per year)	% No-till at Last Survey Year	Projected % No-till by 2012	Year When No-till is Projected to Exceed 50% of Acres
Arkansas	Cotton	2007	1.37	9.4	16.25	2037
California	Barley	2003	1.50	0	0	--
	Cotton	2007	1.37	0	0	--
	Rice	2006	na	0	0	--
Illinois	Oats	2005	1.50	10	20.5	2032
Iowa	Oats	2005	1.50	6.4	16.9	2035
Kansas	Wheat	2004	1.50	8.7	20.7	2032
Louisiana	Cotton	2007	1.37	4.6	11.45	2041
Michigan	Oats	2005	1.50	1	11.5	2038
Minnesota	Barley	2003	1.50	0	0	--
	Oats	2005	1.50	0	0	--
Missouri	Rice	2006	1.08	5.8	12.28	2047
North Dakota	Soybean	2006	2.59	9.2	24.74	2022
New York	Corn	2005	1.86	2.4	15.42	2031
	Oats	2005	1.50	1	11.5	2038
Pennsylvania	Barley	2003	1.50	6.7	20.2	2032
Texas	Corn	2005	1.86	9.5	22.52	2027
	Cotton	2007	1.37	9.8	16.65	2037
	Oats	2005	1.50	0.5	11	2038
	Rice	2006	na	0	0	--
	Sorghum	2003	1.50	2.8	16.3	2035
Utah	Barley	2003	1.50	0	0	--
Washington	Wheat	2004	1.50	5.6	17.6	2034
Wyoming	Barley	2003	1.50	1.4	14.9	2036

Taking into account the positive growth rate in no-till adoption, by 2012 there are expected to be no cases where no-till would still be practiced on 10% or fewer cropland acres, except in the seven state-crop combinations where no-till adoption was initially zero (California barley, cotton, and rice; Minnesota barley and oats; Texas rice; and Utah oats). In other words, even in cases where no-till adoption appears low enough to suggest that it is not currently “common practice,” eventually it will become common practice under current trends. The last column in Table 2 indicates the year in which no-till adoption is expected to exceed 50% of acres, assuming a constant positive rate of no-till adoption. The earliest year the data predicts this occurring is 2022, ten years after the CMPP is scheduled to take effect.

2.2 Continuous versus Intermittent No-till

The ARMS data report on tillage practice over single-year periods. Therefore, the trends above do not necessarily indicate continuous use of no-till, which reportedly has more significant long-term carbon sequestration impacts than intermittent use of no-till. The Chicago Climate Exchange Continuous Conservation Tillage protocol indicates a 5-10% adoption of continuous no-till based on expert opinion.[5] The USDA report also includes some limited survey data on trends of no-till use over multiple years. The data are not as comprehensive in geographic scope and are derived from a different survey instrument than the ARMS data summarized above. Even so, they provide possibly the only available quantitative assessment of multi-year no-till adoption trends.

Based on data collected in the Upper Mississippi River Basin as part of the Natural Resources Inventory Conservation Effects Assessment Project (NRI-CEAP), the USDA assembled a picture of continuous no-till trends for that region during 2002-2006. The predominant crops in the Upper Mississippi River Basin are corn and soybeans (making up 89% of the cropland in roughly equal proportions).

The NRI-CEAP data indicate that:

- No-till was used on approximately 13% of all cropland in the Upper Mississippi River Basin for at least three years in a row during the period of 2003-2006.
- This trend was roughly consistent between corn and soybean operations; however, soybeans showed a slightly higher rate of 3-yr no-till adoption (14% of acres compared to 12% for corn).
- In a separate analysis of the same survey data, USDA found that for acres that were in no-till at least once during 2002-2004, close to 50% remained in no-till for three consecutive years.

The USDA report also provides information to help interpret the representativeness of this region to the nation as a whole. Mainly, the USDA notes that in the four predominant states of the Upper Mississippi River Basin, no-till adoption for corn is lower than the national average (15% compared to 23.5%, according to ARMS data). This suggests that, in a general sense, no-till adoption trends from this region likely under-represent no-till adoption trends nationally.

2.3 California Trends

This section takes a closer look at tillage management trends in California, for two reasons: California no-till adoption is notably lower than most of the country for the crops covered by the ARMS data; and the ARMS survey does not cover many of the crops grown in California. The ARMS data cover only about 25% of cropland in California (1.5 out of about 6 million total acres of cropland). While California agriculture alone does not account for the entire 15.3 million acres of cropland not covered by the ARMS survey, most of the crops missing from the ARMs survey are grown in California. Therefore, California can be considered representative of at least some of the gap in the ARMS survey data.

---

[5] Chicago Climate Exchange, "Continuous Conservation Tillage and Conversion to Grassland Soil Carbon Sequestration Offset Project Protocol," 30 September 2009, Available at: http://theccx.com/docs/offsets/CCX_Conservation_Tillage_and_Grassland_Conversion_Protocol_Final.pdf

2.3.1 Conservation Tillage and No-till Adoption Rates

Data on a continuum of tillage management practices are provided in the USDA report of the ARMS survey. These detailed data for California are shown in Table 3. Tillage use trends shown in Table 3 indicate conventional till is predominant for cotton and rice, with very little and potentially statistically negligible use of other tillage management practices for rice. But, reduced till is most prevalent for barley (with some conservation till and very little conventional till).

Table 3. California Tillage Management Trends for Barley, Cotton, and Rice

Crop	Survey Year	Acres Planted	% with No-till	% with Residues >30% (Conservation Till)	% with Residues > 30% and No-Till	% with 15-30% Residues (Reduced Till)	% with Residues <15% (Conventional Till)
Barley	2003	1,743,659	0	4.2	0	90.1	5.7
Cotton	2003	693,613	0	0	0	0	100.0
Cotton	2007	455,116	0	0	0	0	100.0
Rice	2000	3,915,672	0	0	0	*	94.3
Rice	2006	3,725,074	0	*	0	2**	96.1

*Number of observations too small to be reported
**Coefficient of variation between 0.5 and 0.75 (unmarked data have coefficient of variation below 0.25)

Data are also available from California's Conservation Tillage and Cropping Systems Workgroup on adoption of conservation tillage practices for cotton and other crops grown in California (Table 4).[6] There are essentially four types of reduced tillage practiced in California, referred to collectively as Conservation Till (CT): no-till, ridge-till, strip-till and mulch-till. The most frequent type of reduced tillage practice used in California is strip-till, which is defined as "a wide range in production practices that deliberately reduce primary, intercrop tillage operations such as ploughing, disking, ripping and chiseling."[7] The Conservation Tillage Workgroup also surveyed minimum tillage practices, which by their definition reduce the overall number of tillage passes by at least 40% relative to what was done in the year 2000.

The data show the highest use of conservation till for growing corn and small grains (associated with dairy feed). Conservation till is less common in cotton, tomatoes, and melons. The same survey used to compile the data in Table 4 indicates an increase from 3% to 10% of surveyed acres under conventional till from 2006 to 2008. County-specific data are also available but are not shown here. These data do not fully represent, however, the wide diversity of crops grown in California.

[6] Conservation Tillage and Cropping Systems Workgroup, "2008 Tillage Survey Fact Sheet," Available at: http://ucanr.org/sites/ct/files/44135.pdf
[7] "Understanding the key elements necessary to develop a new protocol to claim emissions reductions arising from reduced fuel consumption linked to conservation tillage", prepared for Sustainable Conservation by EcoRessources Carbone, 29 October 2010.

Table 4. Tomato, Cotton, Bean, Corn and Small Grain Acreage under Conventional, Minimum, and Conservation Tillage in 2008 in Nine-County Central Valley Region.
(Table 2 in the original publication)

Crop	Total	Conventional Tillage	Minimum Tillage	Conservation Tillage	% of Total Acreage Under Conservation Tillage
Acreage					
Tomatoes	257,698	249,295	157,482	8,403	3.3
Cotton	262,525	256,295	28,930	6,230	2.4
Edible dry beans	19,734	19,734	1,450	0	0
Silage corn	562,530	468,876	79,444	97,654	17.4
Grain corn	135,698	130,332	33,200	5,466	4.0
Small grains for grain	401,521	349,954	38,403	51,567	12.8
Small grains for hay or ensiled	533,274	475,564	76,926	57,710	10.8
Melons	37,292	36,525	200	767	2.1

Source: California's Conservation Tillage and Cropping Systems Workgroup 2008 Tillage Survey Summary

California's Mediterranean climate allows for its extensive agricultural diversity but also necessitates its characteristically intensive agricultural management practices, such as intensive fertilization, irrigation, and tillage practices. Though seven of the eight major row crops are grown in California for a total of 1.6 million acres,[8] the majority of California farmland is cultivated with the state's many specialty crops, each of which have different management needs. The combination of the warm, dry climate and agricultural heterogeneity makes it difficult to extrapolate GHG mitigation potentials from studies performed on other crops outside of California to California agriculture. The warm climate and history of intensive agricultural management practices have resulted in carbon-poor California soils relative to comparable Midwest soils, which may indicate a greater potential for total carbon sequestration in California soils over the long term.[9] Information on the GHG mitigation potentials for conservation tillage in California is provided in Appendix A.

It is important to note, however, that the conservation tillage systems implemented in California are not equivalent to no-till and conservation till practiced elsewhere, in terms of the level to which soil disturbance is reduced. In general, conservation tillage in California is still somewhat intensive compared to no-till.

2.3.2 Technical Feasibility of No-till Adoption in California

Technical feasibility has limited the adoption of conservation till in California's specialty crops. Technical barriers include irrigation systems, increased susceptibility to weeds and pests, and the need for particularly clean seedbeds for certain crops. Though this section focuses on how these technical barriers have limited conservation till adoption in California, many of these barriers could be relevant outside the California-context, as well.

[8] Soybeans are the only major row crop not grown in California in significant quantities, though a very small amount of the crop are grown in California.
[9] Horwath, W.R. et al. "Tillage and Crop Management Effects on Air, Water, and Soil Quality in California." University of California, Division of Agriculture and Natural Resources. September 2008. ANR Publication 8331. Available at: http://anrcatalog.ucdavis.edu

Intensive tillage in irrigated systems helps maintain furrows that also convey irrigation water. With conservation tillage, accumulation of crop residue can prevent water in gravity/surface irrigation systems from reaching the necessary root depth. As 95% of harvested cropland in California is irrigated, traditional irrigation systems present a significant barrier to conservation till adoption. Innovative irrigation techniques, such as subsurface drip irrigation (SDI), do allow for conservation tillage in irrigated systems and have been successfully implemented by some California farmers practicing conservation till, yet this practice change necessitates a significant investment in the necessary SDI equipment.

Increased weeds and the need for increased application of herbicides is a challenge for all conservation tillage systems, as tillage has long been a commonly-used tool for combating weed growth. However, it is a challenge that is potentially easier to overcome with major row crops than with specialty crops, as the major row crops are typically available in genetically modified herbicide-resistant varieties (e.g. Roundup-Ready), while specialty crops are not. The fact that California's specialty crops under conservation tillage will be typically more susceptible to weeds likely has inhibited the adoption of conservation tillage in California somewhat. However, studies show that combining conservation tillage with cover crops can help to reduce the weed challenges, in addition to providing greater GHG benefits.

Certain crops simply cannot be grown under complete no-till management for technical and/or legal reasons. Cotton grown in California, for example, is particularly susceptible to the pink bollworm pest, which has historically cost the U.S. cotton industry billions of dollars. As part of an effective 30-year integrated pest management program, California's cotton growers are legally required to shred cotton stalks, dislodge or undercut the cotton plant roots, and mix plant residues with the surface soil prior to the annual 3-month "host free period" from mid December to mid-March, during which no living cotton plants remain to host the pest.[10] Recent innovations in cotton-specific tillage equipment (e.g., "pass combination" minimum tillage implements; root cutters with angled disk blades that reduce soil disturbance) could lessen the technical barrier for conservation till in cotton. However, these new tillage methods are still being closely monitored by the California Department of Food and Agriculture and the Conservation Tillage Workgroup for their effectiveness in preventing pink bollworm. Even if these methods are highly effective, it is unlikely that tillage intensity can be reduced enough to make full conversion to no-till technically feasible for cotton.[11]

Other crops, particularly specialty crops like tomatoes, require a clean, smooth seedbed for optimal cultivation, making a shift to complete no-till highly unlikely. However, innovative California tomato farmers have been using strip till techniques, which in the case of tomatoes, typically implements a second "smoothing" pass of the seedbeds, as well as establishing transplanted tomato plants.[12]

---

[10] CDFA Integrated Pest Management Program, Available at: http://www.cdfa.ca.gov/phpps/ipc/pinkbollworm/pbw_hp.htm

[11] Mitchell, J.P. et al, "Conservation Tillage Systems for California Cotton: A Review of Research Findings." Pre-print research report available on University of California, Conservation Tillage and Cropping Systems Workgroup Website, January 2011, http://ucanr.org/sites/ct/files/67445.pdf

[12] Mitchell, J. et al. "Conservation Tillage Tomato Production in California's San Joaquin Valley." University of California, Division of Agriculture and Natural Resources. Publication 8330. January 2009.

2.4 Use of Cover Crops in the U.S. Corn Belt

A relatively recent paper published results of a mail survey of 3,500 farmers in the U.S. Corn Belt region that asked farmers detailed questions about their use of cover crops.[13] While somewhat limited in scope, the main findings of that survey are reported here to give an indication of current trends in the use of cover crops in U.S. agriculture. However, a more complete review of the literature is necessary before strong conclusions can be drawn.

Survey results suggest that about 18% of farmers in the Corn Belt region have tried cover crops in the past. Of those farmers who tried cover crops, they reported planting them on about 6% of their total acreage. Cover crop use varied somewhat by state, with average use on about 16% of acres in Indiana and Illinois, 10% in Minnesota, and 6% in Iowa. Use of cover crops was positively correlated to crop diversity, meaning the number of different types of crops grown is an indication of a farmer’s likelihood to try cover crops at some point. Farmers also reported on what kind of incentives would be necessary for them to consider using cover crops. More than half (56%) say that with cost share payments they would plant cover crops, if the payment were on the order of about $23/acre.

This limited data suggest there is a modest baseline use of cover crops in the Corn Belt, but that use is still limited to small portions of an operation and that it would take a significant financial incentive payment to induce farmers to increase their use of cover crops.

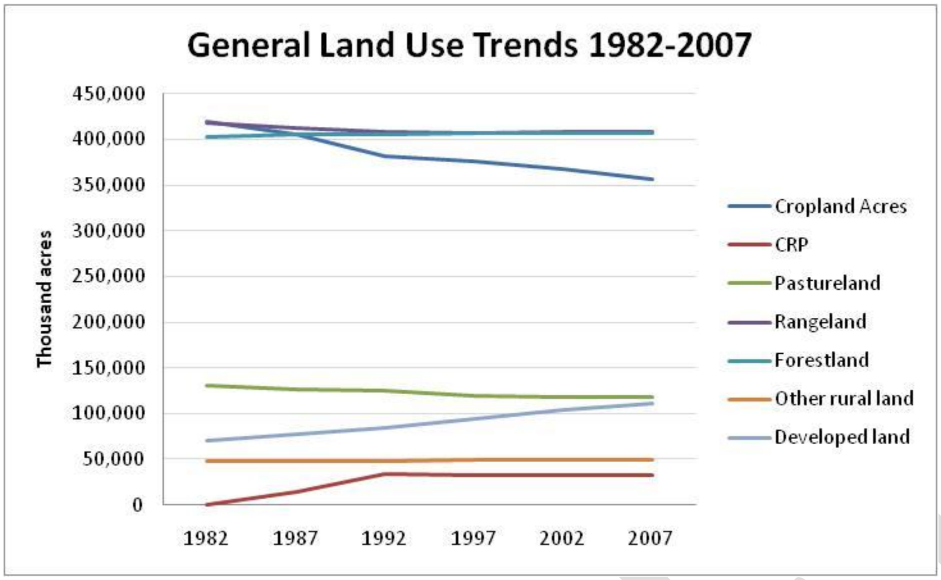
3 Additionality of Cropland Conversion

3.1 Historic Trends in U.S. Cropland Conversion

The USDA Natural Resources Inventory (NRI) has collected longitudinal data on land-use and land-use change trends at five year intervals since 1982. The most recently available survey data are from 2007, providing 25 years of historical data. Figure 1 below shows general land-use change trends over this 25 year period. About 15% of the original 420 million acres of cropland in 1982 was converted to some other use by 2007. Pasture and rangeland areas also decreased during this time by 9% and 2%, respectively. In contrast, developed land, forest land and rural land all increased during this time period. However, developed land has seen the most growth by far with an increase in area of 57% since 1982.

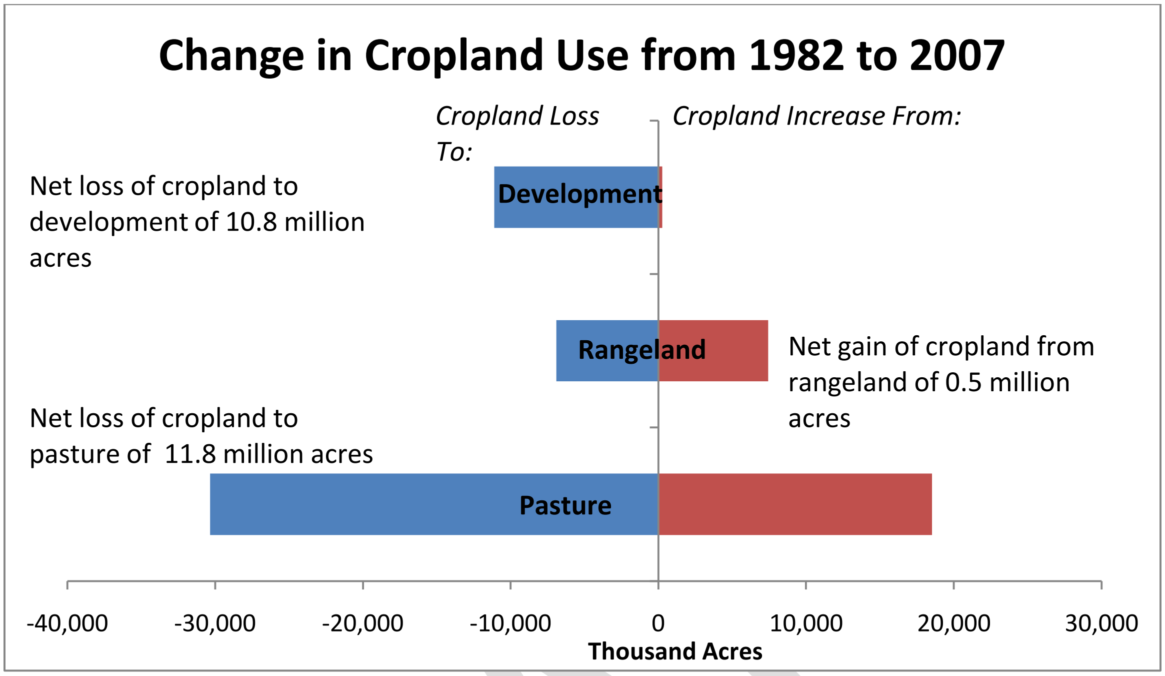
[13] J.W. Singer, Nusser, S.M., and Alf, C.J. “Are cover crops being used in the U.S. corn belt?” Journal of Soil and Water Conservation, volume 62, number 5, September/October 2007, p. 353.

Figure 1. Land Use Change Trends (NRI 2007)



Much of the decrease in cropland area from 1982 to 2007 can be attributed to expanding development of urban areas into land that was originally cropland as well as cropland conversion to pasture (Figure 2). Although there was a slight net gain in cropland as a result of rangeland conversion to cropland, more than 22 million acres of cropland were converted to development and pasture over the same period. Specifically, a net of 10.8 million acres of cropland was lost to development during this time, taking into account a small amount of development that was actually converted into cropland during that same time period. At the same time, there was a net loss of 11.8 million acres of cropland to pastureland, taking into account modest gains in cropland from converted pasture. Not shown in Figure 2, but discussed further below, is cropland enrollment in the Conservation Reserve Program (CRP), which also led to a decrease in total cropland acres during this time of about 30 million acres. For a complete matrix of land use changes during this time period, as well as NRI definitions of land use categories, see Appendix B.

Figure 2. Specific Changes in Area of Cropland to and from Developed Uses, Rangeland, and Pasture from 1982 to 2007.



NRI data for five-year intervals within the twenty-five year period shown in Figure 2 were used to evaluate the stability of land-use change trends. Overall, the direction of the net land-use change trends within each five-year interval was consistent with the overall twenty-five year trends. In nearly all cases, there were net losses of cropland to pasture and development, and net gains from rangeland to cropland. However, the rate of change fluctuates notably. For example, there was a net loss of 702,000 acres of cropland to pasture during 1982-1987, compared to a net loss of 4,999,000 acres during 2002-2007. With the exception of the period during 1992-1997, the rate of cropland conversion to pasture appears to have steadily increased over time. Another notable trend is the net 830,000 acre loss of cropland to rangeland during 2002-2007, representing a reverse trend of cropland area gain from rangelands during the four preceding time intervals.

Table 5. Specific Changes in Area of Cropland to and from Developed Uses, Rangeland, and Pasture from 1982 to 2007, and for intervening five-year intervals.

	25-year trend	Intervening 5 year trends				
	1982-2007	1982-1987	1987-1992	1992-1997	1997-2002	2002-2007
	Thousand acres					
Cropland to Pasture	-30,345	-9,943	-8,806	-9,727	-10,949	-7,974
Pasture to Cropland	18,527	9,242	6,331	8,728	8,319	2,975
Net change Cropland to Pasture	*-11,818*	*-702*	*-2,476*	*-1,000*	*-2,630*	*-4,999*
Cropland to Rangeland	-6,895	-1,143	-1,019	-1,513	-1,522	-1,280
Rangeland to Cropland	7,431	3,627	2,291	1,923	1,626	449
Net change Cropland to Rangeland	*535*	*2,484*	*1,272*	*411*	*104*	*-830*
Cropland to Development	-11,118	-1,751	-1,929	-2,794	-2,041	-1,657
Development to Cropland	264	93	81	27	46	59
Net change Cropland to Development	*-10,853*	*-1,659*	*-1,848*	*-2,767*	*-1,996*	*-1,599*

The most relevant trend to consider for the CMPP protocol category of Cropland Conversion is the amount of cropland being converted to uses such as grasslands/pasture and grazing lands. Using the most recent five-year time period of 2002-2007, national data indicate a baseline trend of cropland conversion to pasture[14] of approximately 0.27%/yr and cropland conversion to rangeland of 0.05%/yr. This small but consistent trend shows that some level of cropland conversion to pasture/grasslands/grazing lands is occurring under business as usual, outside of the CRP program each year. Also, if historical increasing rates of change are assumed to continue into the future, then the baseline rates noted here would also be expected to increase over time.

3.2 Conservation Reserve Program (CRP) Trends

3.2.1 CRP Enrollment

The CRP program was authorized by the 1985 Food Security Act to:

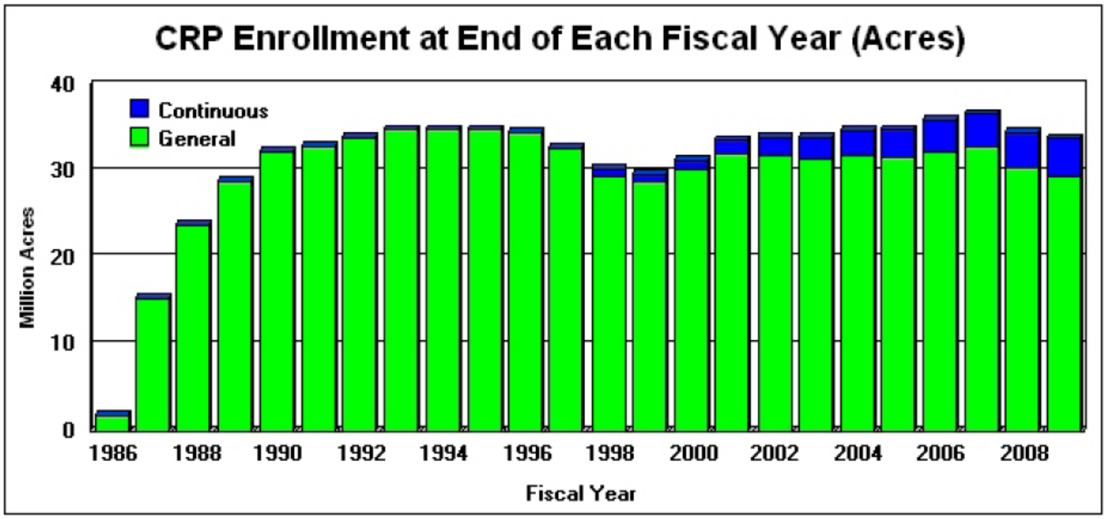
> "Assist owners and operators in conserving and improving soil, water, and wildlife resources on their farms and ranches by converting highly erodible and other environmentally sensitive cropland and marginal pasture to long-term resource conserving covers. In exchange for annual rental payments and cost-share assistance of up to 50 percent of cover establishment costs, agricultural landowners and operators agree to establish and maintain an approved permanent cover on enrolled acreage for 10 to 15 years."[15]

Cropland was first enrolled in CRP starting in 1986 with maximum cumulative enrollment levels set at 34.6 million acres. The program was rapidly adopted by the agricultural community and

[14] Note the NRI definition of Pastureland is provided in appendix B and indicates that Pastureland includes grazed and ungrazed grasslands
[15] Conservation Reserve Program, Annual Summary and Enrollment Statistics FY 2009. Farm Service Agency. USDA. Available at: http://www.fsa.usda.gov/Internet/FSA_File/fyannual2009.pdf

the enrollment cap was met within about 5 years. The latest Farm Bill ("Food, Energy, and Conservation Act of 2008") restrained the cap on CRP enrollment to 32 million acres and reauthorized the program until September 2012. Figure 3 is directly out of a report providing the latest (2009) CRP enrollment statistics. Acres are cumulative and represent enrollment levels, as opposed to acres entering and leaving the program each year.

Figure 3. Cumulative Acres Enrolled in CRP, 1986-2009.



*Continuous and General refer to two different opportunities for signing up for the CRP program.

While there is some amount of land entering and leaving the program as a result of new and expiring contracts during the time period shown above, once in the CRP program, land tends to stay there. Lands with expiring CRP contracts are explicitly eligible for and thus prioritized for re-enrollment. CRP projections reported in 2009 indicate that in 2010, 72% of CRP land with expiring contracts will either re-enroll for another 10-15 year contract or extend their contract for 2 to 5 more years (Table 6). The high rate of re-enrollment suggests that there are few alternative uses for CRP land that are as economically attractive as keeping land in CRP. From 2007 to 2010 there is a downward trend in re-enrollment and contract extensions, but this likely reflects structural changes in the CRP program (i.e., declining enrollment limits noted above) more than competing opportunities for use of the land.

Table 6. Projections for Expiring CRP Acres and Re-Enrollment Trends, 2007-2010 (Source: "CRP Annual Summary and Enrollment Statistics FY 2009 Report")

	2007	**2008**	**2009**	**2010**
Total expiring acres (1,000 acres)	15,685	5,893	4,141	2,055
% Extending contracts for:				
2 years	18.3%	16.4%	16.1%	16.7%
3 years	17.9%	15.5%	15.5%	13.6%
4 year	16.6%	21.4%	14.9%	14.2%
5 years	16.5%	12.2%	16.3%	13.7%
% Re-enrolled (for 10-15 yrs longer)	16.1%	15.9%	15.3%	14.2%
Total	85.4%	81.4%	78.1%	72.4%

3.2.2 CRP Eligibility and Allowable Conservation Practices

Only certain cropland areas are eligible for the CRP program, and eligibility criteria are designed to ensure the program meets its stated objected. Specifically, to be eligible for CRP, land must be either:

- Cropland (including field margins) that is planted or considered planted to an agricultural commodity 4 of the previous 6 crop years, and which is physically and legally capable of being planted in a normal manner to an agricultural commodity; or
- Certain marginal pastureland that is suitable for use as a riparian buffer or for similar water quality purposes.

and must:

- Have a weighted average erosion index of 8 or higher (i.e., be classified as highly erodible cropland or “HEL” by the USDA);[16]
- Be expiring CRP acreage; or
- Be located in a national or state CRP conservation priority area.[17]

Data from recent years show that the majority of cropland enrolled in CRP is designated as “highly erodible land” by the USDA (Table 7). Other types of land enrolled in the program include wetlands and riparian buffers, for example.

Table 7. Amount of HEL Land under CRP contract, 2005-2009
(Source: “CRP Annual Summary and Enrollment Statistics FY 2009 Report”)

	2005	**2006**	**2007**	**2008**	**2009**
	Million acres				
Cumulative Area Under CRP Contract	34.90	36.00	36.80	34.60	33.70
Area Highly Erodible Land	24.60	25.20	25.50	23.60	22.80
% in HEL	70%	70%	69%	68%	68%

While many kinds of resource conserving practices are eligible under CRP, and by 2009 thirty-eight different conservation practices were in use on CRP lands, grasslands are by far a predominant component of the CRP program. Table 8 shows the top practices that are adopted under CRP contracts; existing and new grass practices make up over 68% of CRP acres.

[16] From NRI 2007: Highly Erodible Land (HEL) has an Erodability Index (EI) of at least 8. Erosion equation factors are used to determine the EI for NRI sample sites. The EI indicates the potential of a soil to erode, considering climatic factors and the physical and chemical properties of the soil. The higher the index, “the greater is the investment needed to maintain the sustainability of the soil resource base if intensively cropped.”
[17] CRP website: http://www.apfo.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp

Table 8. Top Conservation Practices Employed on Land Enrolled in CRP (Source: "CRP Annual Summary and Enrollment Statistics FY 2009 Report")

Conservation Practice	Conservation Practice Number	Cumulative Acres in 2009	Percent of program
Existing Grass	10	13,395,729	39.7%
New Grass-Native	2	6,722,691	19.9%
New Grass-Introduced	1	2,858,565	8.5%
Wildlife Habitat	4D	2,326,446	6.9%
Wetland Restoration	23	1,409,330	4.2%
Rare and Declining Habitat	25	1,211,988	3.6%
Filter-Strips	21	1,040,755	3.1%
Existing Trees	11	1,033,229	3.1%

By and large, most of the cropland going into the CRP was originally designated as HEL and with cost-share support from the program has been converted to and maintained in grassland cover.

3.2.3 "Slippage" and CRP

Slippage refers to an observed trend where farmers ultimately cultivate alternative acreage to account for land taken out of production in the CRP program. Slippage in the CRP program has been a subject of some study and debate in the research literature, and findings suggest that slippage occurs at a rate of about 20%, which means for every 100 acres set aside in CRP, about 20 acres outside of the CRP program are put back into active cultivation.[18]

Slippage can lead to leakage[19] in the context of offsets projects. When uncultivated land is converted to cropland to meet market demands, this causes soil related CO_2 and other GHG emissions. Data on slippage have been used by some analysts as plausible leakage rates for Cropland Retirement offsets projects.[20] The inferred maximum leakage rate of 20% is low compared to some reported values for forestry projects, but still higher than the plausible leakage risk from no-till project types, which are reported to be 0-5%.[21]

CRP slippage rates are believed to be less than 100% because only marginal or low producing lands are allowed to enroll in CRP. When low producing lands are taken out of production, there is little measurable effect on markets because those lands were not contributing much to the supply of agricultural goods in the first place. Thus, leakage risks for Cropland Conversion projects could be minimized if they were undertaken exclusively on marginal or HEL cropland.

[18] Wu JJ (2000) Slippage effects of the conservation reserve program. Am J Agri Econ 82(4):979–992
[19] Leakage is an unintended increase in GHG emissions caused by the project.
[20] Murray, B. et al. 2007. "Economic consequences of consideration of permanence, leakage and additionality for soil carbon sequestration projects." Climatic Change. (2007) 80:127–143.
[21] ibid

3.3 Trends in U.S. Area of Highly Erodible Land

Since 1982, the total amount of HEL cropland decreased nationwide by 22% or 27.5 million acres (Table 9), corresponding to a nationwide trend of declining soil erosion rates detailed in an NRI data supplement.[22] Perhaps coincidentally, the reduction in area is almost the same amount as was enrolled in the CRP program during this time period (25.5 million acres in 2007) (Table 7). However, there is not information available to suggest that the declining HEL acres correspond exactly to those enrolled in the CRP program, as CRP acres may retain their HEL designation well into their contract period. Even so, a significant amount of the HEL land conversion is likely related to enrollment in the CRP program.

More information on the primary drivers for HEL acreage decreases and the extent to which the trend relates to enrollment in CRP or other non-CRP cropland conversion trends would enable a better understanding of baseline trends of HEL conversion to pasture or grasslands for the purposes of managing soil erosion and the extent to which this happens outside the CRP program and absent a carbon market.

Table 9. Amount of Highly Erodible Land (HEL cropland) in the U.S. 1982-2007 (NRI 2007)

	1982	1987	1992	1997	2002	2007
	Million acres					
Total HEL Cropland	125.3	117.7	106.0	104.6	101.2	97.8
Change in HEL area 1982-2007						-27.5

CRP enrollment caps are well below the total amount of available HEL land in the US, which appears to be about 98 million acres based on 2007 data (Table 9). This suggests a gap of nearly 72 million acres of HEL cropland that will never be enrolled in CRP and could possibly be targeted for conversion to grassland or pasture under an offsets protocol.

Regional data on HEL areas and CRP enrollment were compared to give a sense of the amount and distribution of HEL land not already enrolled in the CRP program (Table 10). This is not a perfect comparison, as not all land in the CRP program is HEL land. For example, the total CRP acreage in the Delta State region exceeds the amount of HEL land in that region presumably because much of the CRP land is wetlands and riparian areas, as well as HEL land. Still, by assuming all CRP acres are HEL land, these data provide a conservative approximation of how much HEL land exists that is not currently enrolled in CRP. The data show that for most regions the amount is quite high, on the order of 45% or higher. The trend is also relatively evenly distributed across regions, with the possible exception of the Delta States region.

[22] "2007 Annual National Resources Inventory: Soil Erosion on Cropland," Natural Resources Conservation Service. USDA. April 2010. Available at: http://www.nrcs.usda.gov/technical/NRI/2007/nri07erosion.html

Table 10. Amount of Highly Erodible Land, CRP Land, and Total Potential for Cropland Conversion Project Type, in absolute acres and as percentage, 2007
(Source: CRP FY 2009 Report, NRI 2007)

Region	Total HEL (in acres)	Total CRP (in acres)	Total Potential (HEL - CRP) (in acres)	Total Potential, as % of HEL
Appalachian	7,632,000	847,979	6,784,021	88.89%
Corn Belt	20,253,600	5,329,004	14,924,596	73.69%
Delta States	1,157,400	1,502,828	-345,428	-29.85%
Lake States	5,169,300	2,712,334	2,456,966	47.53%
Mountain	20,201,200	7,860,397	12,340,803	61.09%
Northeast	5,654,700	419,073	5,235,627	92.59%
Northern Plains	21,546,100	9,548,023	11,998,077	55.69%
Pacific	4,187,300	2,273,676	1,913,624	45.70%
Southeast	1,300,000	1,098,653	201,347	15.49%
Southern Plains	10,669,900	5,148,111	5,521,789	51.75%
U.S. TOTAL	97,771,500	36,740,078	61,031,422	62.42%

4 Summary

4.1 Change in Management on Existing Cropland

The USDA report provides the most comprehensive and detailed study of tillage use trends in the U.S. to date. Data from the report show that about 35.5% of U.S. croplands use no-till today, at least for most major crops. But, perhaps more importantly, the data show a significantly positive rate of no-till adoption, indicating its use is already increasing under business as usual in the U.S., regardless of carbon markets, at a rate of roughly 4.8 million acres per year. While our understanding of multi-year no-till (or “continuous no-till”) use is less complete, data indicate about 50% of no-till acres will be maintained under no-till practices for at least three years.

There are some select cases where no-till adoption appears unlikely in the future. Specifically, in seven state-crop combinations—California barley, cotton, and rice; Minnesota barley and oats; Texas rice; and Utah oats—the use of no-till is zero and there is little reason to suggest this will change in the future. The complete lack of no-till use in these cases indicates potential technical or legal barriers to no-till adoption. Such barriers are preliminarily explored above for California. Further analysis of barriers is necessary before strong conclusions can be drawn; however, the mere existence of these barriers indicates a high potential for additionality in the case of no-till. Without the added revenue of carbon markets, no-till use is unlikely in these cases. Some information is available on the use of conservation till in California, which show conservation tillage use on 0-17.4% of cropland for some specific crops.

The analysis above is focused almost exclusively on trends in tillage management. Therefore, it does not capture the potential interacting effects of using several GHG mitigating practices in combination, such as using cover crops in combination with conservation tillage, or adding perennials into rotation with annuals. This paper provides some preliminary information indicating that extensive use of cover crops (i.e., on an entire operation) is not only relatively uncommon, but would require significant cost-share incentives for farmers to adopt the practice.

There are several other potential practice changes proposed for a cropland management protocol and listed under the definition for Management Change in Section 1, that were not evaluated in terms of their additionality for this paper, namely:

- Eliminate summer fallow
- Diversify annual crop rotations
- Include perennial crops in rotations
- Organic soil amendments
- Switch from dry land to irrigated
- Irrigation improvements

The GHG mitigation impacts of these remaining practices are less well understood than tillage management practice changes. The scientific literature on GHG emissions from agricultural management changes, including all the practices considered under the scope of the CMPP, was recently reviewed by the Technical Working Group on Agricultural Greenhouse Gases (T-AGG) in an assessment paper, and the findings were also affirmed through an expert survey process administered by T-AGG. The T-AGG report provides the most current and comprehensive review of prospective project activities available to date, particularly in terms of their biophysical GHG mitigation potential (i.e., technical potential to impact GHG emissions if adopted, without regard to social and economic factors affecting adoption rates).

Based on the T-AGG review it appears as though many of the practices in the list immediately above have low or inconsistent average net GHG impacts, especially when taking into account effects on potential upstream and downstream processes in addition to impacts on soil carbon. The Reserve is developing a separate background paper that further considers these effects in the context of defining a GHG accounting boundary for the CMPP. Further research and analysis of the additionality of these practices may be undertaken pending the outcomes of the GHG boundary background paper, which will provide an indication of which practices will be retained within the scope of the CMPP.

4.2 Conversion of Existing Cropland to a New Use

There is a positive baseline trend of cropland conversion to pasture of approximately 0.27%/yr (amounting to almost 1 million acres per year) and of cropland conversion to rangeland of approximately 0.05%/yr (166 thousand acres per year). These baseline trends indicate a need to look for further criteria that screen out business as usual from additional cropland conversion projects. The widely popular Conservation Reserve Program has also driven substantial amounts of cropland conversion to grassland/pasture over the past 25 years, on top of the baseline trend noted above, indicating a need to screen out existing CRP land to ensure additionality.

While the option of restricting eligibility of land for Cropland Conversion projects to designated HEL land would have the benefit of helping manage the risks of leakage, there may be a significant baseline trend of this type of conversion already. Because it is a core eligibility requirement of the CRP program, it is not surprising that most land in the CRP is or was once designated as HEL land. Due to program enrollment limits, the CRP program does not reach a substantial amount of HEL cropland in the US, leaving as much as 72 million acres of HEL cropland available for offset projects. This suggests an extensive amount of HEL land could be available for offsets projects. However, there is also a consistent declining trend in HEL land area and more information on trends in HEL conversion to pasture and grassland outside the CRP program is needed.

Consideration of other potential future drivers for conversion of marginal land to other uses may be necessary during protocol development and after protocol adoption as well. For example, rising demand for biofuel feedstocks produced on marginal agricultural lands is plausible in the future given emerging biofuel market incentives and a desire to meet biofuel feedstock demand without affecting food production or competing with other land uses (e.g., forests).[23]

[23] Cai, et al. 2011, Land Availability for Biofuel Production, Environmental Science and Technology, volume 45, p. 334-339.

Appendix A: California Specific GHG Mitigation Potentials for Conservation Till

In an "Assessment of Greenhouse Gas Mitigation in California Agricultural Soils" commissioned by the California Energy Commission,[24] De Gryze et al. simulated emissions reductions in California using the DAYCENT model. The model suggests that changing from conventional to conservation tillage in California could yield an average emissions reduction of 0.19 – 0.23 tonnes CO_2e/acre/yr. The study also asserts that additional reductions would be possible with the inclusion of cover crops and/or switching to organic fertilizer from commercial mineral fertilizer. The model was run for a number of California's most important crops, both in terms of area cultivated and revenue generated, as well as for some of the less important crops which are commonly in rotation with these crops. The results are included in the table below. The crops included in the table represent approximately 60% of productive California agricultural land.

Table A-1. Comparison of California-Specific GHG Mitigation Potentials for Conservation Tillage for Selected Crops

		GHG Mitigation Potential in tonnes CO_2e/acre/yr (analogous to T-AGG's direct impacts category**)								
Location	**Cover Crop?**	**Alfalfa**	**Corn**	**Cotton**	**Melon**	**Rice**	**Saf-flower**	**Sun-flower**	**Tomato**	**Wheat**
Sacramento Valley	no	0.004	0.17	n/c	n/c	0.34	0.03	0.58	0.46	-0.04
Sacramento Valley	yes	-0.01	0.38	n/c	n/c	0.91	0.19	1.00	0.73	-0.06
San Joaquin Valley	no	0.02	0.37	0.26	0.12	0.45	n/c	n/c	0.24	0.06
San Joaquin Valley	yes	-0.02	0.41	0.85	0.10	1.53	n/c	n/c	0.50	0.04

* Positive values represents an emission reduction

** Similarly, to T-AGG's "direct impacts" category, emission reduction potentials from this study excluded potential emissions reductions due to reduced fuel use under conservation tillage. If included, reduced fuel use would account for an extra reduction in emissions of 0.1 - 0.2 tonnes/acre/yr

n/c - "Not considered." Crops noted as "n/c" were considered by the study in one region, but not the other. N/c denotes the region in which a given crop was "not considered."

Source: Adapted from De Gryze, Steven et al. "Assessment of Greenhouse Gas Mitigation in California Agricultural Soils." PIER Final Project Report. Prepared for the California Energy Commission. January 2009.

There is considerable range in mitigation potentials, depending on the crop type, and when conservation till is combined with a cover crop in most cases the mitigation potential is higher. Notable is the relatively high mitigation potential for cotton (0.85 tonsCO_2e/ac/yr) and tomatoes (0.73 tCO_2e/ac/yr in Sacramento Valley) when conservation till is combined with cover crops. Authors noted that due to limitations of the DAYCENT model, which is unable to model flooded conditions, the rice mitigation potentials should be taken as rough provisional estimates, which assume that CH_4 emissions from conventional tillage and conservation tillage are approximately equal.

[24] S. De Gryze, Catala R., Howitt, R. and Six J., "Assessment of Greenhouse Gas Mitigation in California Agricultural Soils" for the California Energy Commission PIER Program, California Climate Change Center Report Series Number 2008-004 (January 2009). Available at: http://www.energy.ca.gov/2008publications/CEC-500-2008-039/CEC-500-2008-039.PDF

Appendix B: NRI Land Use Category Definitions and 1982 to 2007 Land Use Change Matrix[25]

Pastureland. A Land cover/use category of land 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. Management usually consists of cultural treatments: fertilization, weed control, reseeding or renovation, and control of grazing. For the NRI, includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock.

Cropland. A *Land cover/use* category that includes areas used for the production of adapted crops for harvest. Two subcategories of cropland are recognized: cultivated and noncultivated. 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. Noncultivated cropland includes permanent *hayland* and *horticultural cropland*.

Conservation Reserve Program (CRP) land. A *Land cover/use* category that includes land under a CRP contract.

Pastureland. A *Land cover/use* category of land 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. Management usually consists of cultural treatments: fertilization, weed control, reseeding or renovation, and control of grazing. For the NRI, includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock.

Rangeland. A *Land cover/use* category on which the climax or potential plant cover is composed principally of native grasses, grasslike plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This would include areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied. Grasslands, savannas, many wetlands, some deserts, and tundra are considered to be rangeland. Certain communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also included as rangeland.

Forest land. A *Land cover/use* category that is at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters (13 feet) tall at maturity. Also included is land bearing evidence of natural regeneration of tree cover (cut over forest or abandoned farmland) and not currently developed for nonforest use. Ten percent stocked, when viewed from a vertical direction, equates to an areal canopy cover of leaves and branches of 25 percent or greater. The minimum area for classification as forest land is 1 acre, and the area must be at least 100 feet wide.

---

[25] U.S. Department of Agriculture. 2009. Summary Report: 2007 National Resources Inventory, Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa. 123 pages. Available at: http://www.nrcs.usda.gov/technical/NRI/2007/2007_NRI_Summary.pdf

Other rural land. A *Land cover/use* category that includes farmsteads and other farm structures, field windbreaks, *barren land*, and *marshland*.

Developed land. A combination of land cover/use categories, *Large urban and built-up areas, Small builtup areas*, and *Rural transportation land*.

Water areas. A *Land cover/use* category comprising water bodies and streams that are permanent open water.

Table B-1. Changes in Land Cover/Use, 1982-2007 (in thousands of acres, with margins of error)

	Land cover/use in 2007								
Land cover/use in 1982	**Cropland**	**CRP land**	**Pastureland**	**Rangeland**	**Forest land**	**Other rural land**	**Developed land**	**Water areas & Federal land**	**1982 total**
Cropland	326,196.4 ±2,675.3	30,168.6 –	30,344.7 ±1,148.8	6,895.4 ±1,025.2	8,922.7 ±617.8	4,136.4 ±428.5	11,117.5 ±403.8	1,765.2 –	419,546.9 ±2,441.3
CRP land	–	–	–	–	–	–	–	–	–
Pastureland	18,526.6 ±1,055.1	1,351.6 –	78,372.2 ±2,050.0	5,085.3 ±943.5	17,760.5 ±1,039.9	2,036.1 ±384.5	6,845.0 ±338.0	919.0 –	130,896.3 ±1,493.8
Rangeland	7,430.8 ±1,292.5	1,124.5 –	3,369.1 ±719.4	391,615.0 ±3,681.9	3,379.4 ±802.1	2,272.5 ±565.5	5,201.0 ±544.1	3,507.2 –	417,899.5 ±3,741.7
Forest land	2,121.7 ±328.4	144.4 –	4,847.6 ±841.7	2,175.6 ±970.1	371,660.4 ±2,942.2	2,229.1 ±464.3	17,083.5 ±417.1	3,117.3 –	403,379.6 ±2,731.8
Other rural land	1,685.2 ±231.3	56.4 –	1,159.0 ±265.6	915.5 ±422.1	3,310.2 ±372.2	38,734.9 ±1,262.4	1,077.8 ±110.2	304.1 –	47,243.1 ±1,308.6
Developed land	264.1 ±22.3	0.0 –	163.7 ±19.1	176.6 ±22.9	442.6 ±27.7	18.4 ±6.9	69,896.9 ±783.7	1.8 –	70,964.1 ±779.7
Water areas & Federal land	798.7 –	4.7 –	359.4 –	2,256.0 –	934.6 –	212.2 –	29.5 –	443,139.6 –	447,734.7 –
2007 total	357,023.5 ±2,688.7	32,850.2 –	118,615.7 ±2,347.0	409,119.4 ±3,992.9	406,410.4 ±3,065.4	49,639.6 ±1,359.1	111,251.2 ±1,499.4	452,754.2 –	1,937,664.2 ±163.8

Notes:
- Acreages for Conservation Reserve Program (CRP) Land and Water areas and Federal land are established through geospatial processes and administrative records; therefore, statistical margins of error are not applicable and shown as a dashed line (--). CRP was not implemented until 1985.
- Cropland includes cultivated and noncultivated cropland.
- When the estimate is 0.0, margins of error are not applicable and shown as a dashed line (--).

1982 land cover/use totals are listed in the right hand vertical column, titled 1982 total. 2007 land cover/use totals are listed in the bottom horizontal row, titled 2007 total. The number at the intersection of rows and columns with the same land cover/use designation represents acres that did not change from 1982 to 2007. Reading to the right or left of this number are the acres that were lost to another cover/use by 2007. Reading up or down from this number are the acres that were gained from another cover/use by 2007.