Dow AgroSciences Company Petition for Determination of Nonregulated Status of 2,4-D- and Glufosinate-Resistant DAS-81910-7 Cotton

OECD Unique Identifier:
DAS-8191Ø-7

Environmental Assessment

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Agency Contact
Sidney Abel
USDA, APHIS, BRS
4700 River Road
Riverdale, MD 20737
Fax: (301) 734-8669

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Acronyms and Abbreviations

2,4-D	2,4-dichlorophenoxyacetic acid
AAD-12 or *aad-12*	aryloxyalkanoate dioxygenase-12
ae	acid equivalent
a.i.	active ingredient
ALS	acetolactate synthase
APHIS	Animal and Plant Health Inspection Service (USDA)
ARS	Agricultural Research Service (USDA)
BMP	best management practices
BRS	Biotechnology Regulatory Services (USDA)
Bt	*Bacillus thuringiensis*
CP4 EPSPS	5-enolpyruvylshikimate-3-phosphate synthase
CFR	Code of Federal Regulations
DAS	Dow AgroSciences
DHT	Dow Herbicide Tolerant
DMA	dimethylamine
Dow	Dow AgroSciences
EA	environmental assessment
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ERS	Economic Research Service (USDA)
ESA	Endangered Species Act
EO	Executive Order
FDA	U.S. Food and Drug Administration
FEIS	Final Environmental Impact Statement
FFDCA	Federal Food, Drug, and Cosmetic Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FONSI	Finding of No Significant Impact
FQPA	Food Quality Protection Act
FR	Federal Register
GE	genetically engineered
GR	glyphosate-resistant
GHG	greenhouse gases
HR	herbicide-resistant
IPCC	Intergovernmental Panel on Climate Change
IPPC	International Plant Protection Convention
IPM	integrated pest management
IWM	integrated weed management
LMOs	living modified organisms
MCPA	(4-chloro-2-methylphenoxy) acetic acid
N	nitrogen
NASS	National Agricultural Statistics Service (USDA)
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NPS	nonpoint source pollution
NRCS	Natural Resources Conservation Service (USDA)
OECD	Organisation for Economic Co-operation and Development

Acronyms and Abbreviations

OPP	Office of Pesticide Programs (U.S. EPA)
PAT or *pat*	phosphinothricin acetyltransferase
PIP	plant-incorporated protectant
PM	particulate matter
$PM_{2.5}$	particulate matter with aerodynamic diameter of 2.5 micrometer or less
PM_{10}	particulate matter with aerodynamic diameter of 10 micrometer or less
POST	herbicides applied after crop emergence
PPA	Plant Protection Act of 2000
PRE	herbicides applied prior to planting the crop through planting of the crop, but before crop emergence
PPRA	Plant Pest Risk Assessment
RED	reregistration eligibility decision
TSCA	Toxic Substances Control Act
U.S.	United States
U.S.C.	United States Code
USDA	U.S. Department of Agriculture

1 Purpose and Need

1.1 Background

Dow AgroSciences (hereinafter referred to as “Dow”) of Indianapolis, Indiana, submitted a petition, APHIS Number13-262-01p, to the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) in November 2013. The purpose of the petition is to support a decision of nonregulated status for DAS-81910-7 cotton which is resistant[1] to the herbicides 2,4-dichlorophenoxyacetic acid (2,4-D) and glufosinate. The event DAS-81910-7 cotton is currently regulated under 7 CFR part 340. Interstate movements and field trials of DAS-81910-7 cotton have been conducted under permits issued or notifications acknowledged by APHIS since 2010. These field trials were conducted within 14 United States (U.S.) states (Arkansas, Alabama, California, Florida, Georgia, Indiana, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas) and Puerto Rico (DAS, 2013b). Data resulting from these field trials are described in the petition and analyzed for plant pest risk in the USDA-APHIS Plant Pest Risk Assessment (PPRA) (USDA-APHIS, 2014f).

The petition stated that APHIS should not regulate DAS-81910-7 cotton because it does not present a plant pest risk. If a determination of nonregulated status is made, it would include DAS-81910-7 cotton, any progeny derived from crosses between DAS-81910-7 cotton and conventional cotton, and crosses of DAS-81910-7 cotton with other biotechnology-derived cotton that are no longer subject to the regulatory requirements of 7 Code of Federal Regulations(CFR) part 340 under the authority of the Plant Protection Act of 2000 (PPA).

1.2 Purpose of Product

DAS-81910-7 cotton is a genetically engineered (GE) cotton line containing the aryloxyalkanoate dioxygenase-12 (*aad-12)* and phosphinothricin acetyltransferase *(pat)* genes, which confer resistance to the herbicides 2,4-D and glufosinate. DAS-81910-7 cotton was developed using *Agrobacterium*-mediated transformation to stably incorporate the *aad-12* gene and the *pat* gene into cotton. DAS-81910-7 cotton will enable additional choices of herbicides for the control of glyphosate-resistant (GR) and other economically important weeds. The herbicide application window for effective weed control can be lengthened because of the resistance to these two herbicides.

DAS-81910-7 cotton incorporates the *aad-12* gene, derived from the common soil bacterium derived from *Delftia acidovoran*. The *aad-12* gene in DAS-81910-7 cotton expresses the AAD-12 protein, which results in the metabolic inactivation of herbicides of the aryloxyalkanoate

[1] “Resistance” to herbicides is defined by the Herbicide Resistance Action Committee (HRAC) as the inherited ability of a plant population to survive and reproduce following repeated exposure to a dose of herbicide normally lethal to the wild type (HRAC. 2014. Glossary. Herbicide Resistance Action Committee http://www.hracglobal.com/Education/Glossary.aspx.) Several technologies are available that can be used to develop herbicide resistance in plants including classical breeding, tissue culture, mutagenesis and genetic engineering. “Tolerance” is distinguished from resistance and defined by HRAC (2013) as the inherent ability of a plant to survive and reproduce following exposure to an herbicide treatment. This implies that there was no selection or genetic manipulation to make the plant tolerant; it is naturally tolerant. Throughout this EA, USDA-APHIS has used the terms “resistance” and “tolerance” consistent with the definitions of the HRAC. It should be noted however, that different terms for the same concept may be used interchangeably in some instances. In its petition to USDA-APHIS, Dow referenced the subject as “glufosinate-tolerant soybean,” and used the term “herbicide tolerant” throughout its documentation to describe the cotton event. This terminology can be considered synonymous with “herbicide-resistant” (HR) used in this Environmental Assessment (EA).

family. The AAD-12 protein degrades 2,4-D into herbicidally inactive 2,4-dichlorophenol (DCP). Additionally, this same protein has been demonstrated to degrade other phenoxy carboxylic acid herbicides, including (4-chloro-2-methylphenoxy) acetic acid (MCPA) and 4-(2,4-dichlorophenoxy)butyric acid (2,4-DB), and pyridine carboxylic acids herbicides, such as triclopyr and fluroxypyr .

The *pat* gene, also inserted into DAS-81910-7 cotton, encodes the PAT protein that inactivates the herbicide glufosinate. The *pat* gene is derived from *Streptomyces viridochromogenes*, a gram-positive soil bacterium. Glufosinate resistance allows growers to employ this 'over-the-top' broad spectrum herbicide.

DAS has plans to cross DAS-81910-7 cotton with other deregulated herbicide-resistant (HR) cotton varieties, such as those varieties expressing glyphosate and insect resistance (DAS, 2013b). Dow plans to market DAS-81910-7 cotton including a glyphosate resistance trait under the name Enlist™ cotton.

1.3 Coordinated Regulatory Framework Review and Regulatory Review

Since 1986, the U.S. government has regulated GE organisms pursuant to Federal guidance published in the *Federal Register* (51 FR 23302; 57 FR 22984) (EOP-OSTP; US-FDA) entitled "The Coordinated Framework for the Regulation of Biotechnology" (henceforth referred to here as the Coordinated Framework). The Coordinated Framework, published by the Office of Science and Technology Policy, describes the comprehensive Federal regulatory policy for ensuring the safety of biotechnology research and products and explains how federal agencies will use existing Federal statutes in a manner to ensure public health and environmental safety while maintaining regulatory flexibility to avoid impeding the growth of the biotechnology industry. The Coordinated Framework is based on several important guiding principles: 1) agencies should define those transgenic organisms subject to review to the extent permitted by their respective statutory authorities; 2) agencies are required to focus on the characteristics and risks of the biotechnology product, not the process by which it is created; 3) agencies are required to exercise oversight of GE organisms only when there is evidence of "unreasonable" risk.

The Coordinated Framework explains the regulatory roles and authorities for the three major agencies involved in regulating GE organisms: USDA-APHIS, the U.S. Environmental Protection Agency (EPA), and the U.S. Food and Drug Administration (FDA). A summary of each role follows.

1.3.1.1 USDA-APHIS

USDA-APHIS regulations at 7 CFR part 340, which were promulgated pursuant to authority granted by the plant pest provisions of the PPA, as amended (7 United States Code (U.S.C.) 7701–7772), regulate the introduction (i.e., importation, interstate movement, or release into the environment) of certain GE organisms and products. A GE organism is no longer subject to the plant pest provisions of the PPA or to the regulatory requirements of 7 CFR part 340 when APHIS determines that it is unlikely to pose a plant pest risk. A GE organism is considered a regulated article if the donor organism, recipient organism, vector, or vector agent used in engineering the organism belongs to one of the taxa listed in the regulation (7 CFR 340.2) and is also considered a plant pest. A GE organism is also regulated under 7 CFR 340, when APHIS has reason to believe that the GE organism may be a plant pest or APHIS does not have information to determine if the GE organism is unlikely to pose a plant pest risk.

A person may petition the agency for a determination that a particular regulated article is unlikely to pose a plant pest risk, and, therefore, is no longer regulated under the plant pest provisions of the PPA or the regulations at 7 CFR 340. Under §340.6(c)(4), the petitioner must provide information related to plant pest risk that the agency can use to determine whether the regulated article is unlikely to present a greater plant pest risk than the unmodified organism. A GE organism is no longer subject to the regulatory requirements of 7 CFR part 340 or the plant pest provisions of the PPA when APHIS determines that it is unlikely to pose a plant pest risk.

1.3.1.2 Environmental Protection Agency

The EPA is responsible for regulating the sale, distribution, and use of pesticides, including pesticides that are produced by an organism through techniques of modern biotechnology. Such pesticides are regulated by the EPA as plant incorporated protectants[2] (PIPs) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (7 U.S.C. 136 *et seq.*). The EPA also regulates certain biological control organisms under the Toxic Substances Control Act (TSCA) (15 U.S.C. 53 *et seq.*).

Before planting a crop containing a PIP, a company must seek an experimental use permit from the EPA. Commercial production of crops containing PIPs for purposes of seed increases and sale requires a FIFRA Section 3 Registration with the EPA. When assessing the potential risks of genetically engineered PIPs, EPA requires extensive studies examining numerous factors, such as risks to human health, nontarget organisms and the environment, potential for gene flow, and the need for insect resistance management plans.

Under FIFRA (7 U.S.C. 136 *et seq.*), the EPA regulates the use of pesticides (which include herbicides and insecticides), and requires registration of all pesticide products for all specific uses prior to distribution or sale of a pesticide for a proposed use pattern. The EPA examines the ingredients of the pesticide; the particular site or crop on which it is to be used; the amount, frequency, and timing of its use; and storage and disposal practices. Prior to registration for a new use for a new or previously registered pesticide, the EPA must determine through submitted test results and modeling that the pesticide will not cause unreasonable adverse effects on humans, the environment, and non-target species when used in accordance with label instructions. The EPA must also approve the language used on the pesticide label in accordance with 40 CFR part 158.

Once registered, a pesticide may only be legally used in accordance with directions and restrictions on its label. The overall intent of the label is to provide clear directions for effective product performance, while minimizing risks to human health and the environment. The Food Quality Protection Act (FQPA) of 1996 amended FIFRA, enabling the EPA to implement periodic registration review of pesticides to ensure they are meeting current scientific and

[2] Plant-incorporated protectants are pesticidal substances produced by plants and the genetic material necessary for the plant to produce the substance.

regulatory standards of safety and continue to have no unreasonable adverse effects (US-EPA, 2011f).

The EPA also sets tolerances for residues of pesticides on and in food and animal feed, or establishes an exemption from the requirement for a tolerance, under the Federal Food, Drug, and Cosmetic Act (FFDCA). The EPA is required, before establishing pesticide tolerance, to reach a safety determination based on a finding of reasonable certainty of no harm under the FFDCA, as amended by the FQPA. The FDA enforces the pesticide tolerances set by the EPA.

1.3.1.3 Food and Drug Administration

FDA regulates GE organisms under the authority of the FFDCA (21 U.S.C. 301 et seq.). The FDA published its policy statement concerning regulation of products derived from new plant varieties, including those derived from genetic engineering, on May 29, 1992 (US-FDA, 1992). Under this policy, FDA implements a voluntary consultation process to ensure that human food and animal feed safety issues or other regulatory issues, such as labeling, are resolved before commercial distribution of bioengineered food. This voluntary consultation process provides a way for developers to receive assistance from FDA in complying with their obligations under Federal food safety laws prior to marketing.

In June 2006, FDA published recommendations in "Guidance for Industry: Recommendations for the Early Food Safety Evaluation of New Non-Pesticidal Proteins Produced by New Plant Varieties Intended for Food Use" (US-FDA, 2006). This establishes voluntary food safety evaluations for new non-pesticidal proteins produced by new plant varieties intended to be used as food, including bioengineered plants. Early food safety evaluations help make sure that potential food safety issues related to a new protein in a new plant variety are addressed early in development. These evaluations are not intended as a replacement for a biotechnology consultation with FDA, but the information may be used later in the biotechnology consultation.

1.4 Purpose and Need for USDA-APHIS Action

As noted in the previous section, any party can petition USDA-APHIS to seek a determination of nonregulated status for a GE organism that is regulated under 7 CFR 340. As required by 7 CFR 340.6, USDA-APHIS must respond to petitioners that request a determination of the regulated status of GE organisms, including GE plants such as DAS-81910-7 cotton. When a petition for nonregulated status is submitted, APHIS must determine if the GE organism poses a plant pest risk. The petitioner is required to provide information under § 340.6(c)(4) related to plant pest risk that the agency may use to compare the plant pest risk of the regulated article to that of the unmodified organism. A GE organism is no longer subject to the regulatory requirements of 7 CFR part 340 or the plant pest provisions of the PPA when APHIS determines that it is unlikely to pose a plant pest risk.

USDA-APHIS must respond to the petition from Dow requesting a determination of nonregulated status for DAS-81910-7 cotton. USDA-APHIS has prepared this Environmental Assessment (EA) to consider the potential environmental effects of an agency determination of nonregulated status consistent with Council of Environmental Quality's (CEQ) National Environmental Policy Act of 1969 (NEPA) regulations and the USDA and USDA-APHIS NEPA implementing regulations and procedures (40 CFR parts 1500-1508, 7 CFR Part 1b, and 7 CFR part 372). This EA has been prepared in order to specifically evaluate the effects on the quality of the human environment[3] that may result from a determination of nonregulated status for DAS-81910-7 cotton.

1.5 Public Involvement

APHIS routinely seeks public comment on EAs prepared in response to petitions seeking a determination of nonregulated status of a regulated GE organism. APHIS does this through a notice published in the Federal Register. On March 6, 2012, APHIS published a notice[4] in the *Federal Register* advising the public about changes to the way it solicits public comment when considering petitions for determinations of nonregulated status for GE organisms to allow for early public involvement in the process. As identified in this notice, APHIS publishes two separate notices in the *Federal Register* for petitions for which APHIS prepares an EA. The first notice announces the availability of the petition, and the second notice announces the availability of APHIS' decision making documents. Each of the two notices published in the *Federal Register* provide an opportunity for public involvement.

First Opportunity for Public Involvement

Once USDA-APHIS deems a petition complete, the petition is available for public comment for 60 days, providing the public an opportunity to raise issues regarding the petition itself and give input that the Agency considers as it develops its EA and PPRA. USDA-APHIS will publish a notice in the *Federal Register* to inform the public that USDA-APHIS accepts written comments regarding a petition for a determination of nonregulated status for a period of 60 days from the date of the notice. This availability of the petition for public comment is announced in a *Federal Register* notice.

Second Opportunity for Public Involvement

Assuming an EA is sufficient, the EA and PPRA are developed and a notice of their availability is published in a second *Federal Register* notice. This second notice follows one of two approaches for public participation based on whether or not APHIS decides the petition for a determination of nonregulated status is for a GE organism that raises substantive new issues:

<u>Approach 1. GE organisms that do not raise substantive new issues.</u>

This approach for public participation is used when APHIS decides, based on the review of the petition and our evaluation and analysis of comments received from the public during the 60-day comment period on the petition, that the petition involves a GE organism that *does not raise new biological, cultural, or ecological issues because of the nature of the modification or APHIS' familiarity with the recipient organism.* Agency criteria for this decision include a determination that the nature of the modification is not novel or that the Agency has a high degree of familiarity with the organism through previous regulatory actions, or both. After this determination is made,

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[3] Under NEPA regulations, the "human environment" includes "the natural and physical environment and the relationship of people with that environment" (40 CFR §1508.14).

[4] This notice can be accessed at: http://www.gpo.gov/fdsys/pkg/FR-2012-03-06/pdf/2012-5364.pdf

APHIS conducts the necessary analysis and prepares its PPRA, EA, and a Finding of No Significant Impact (FONSI). Once completed, APHIS publishes a notice in the *Federal Register* announcing its preliminary regulatory determination and the availability of the EA, FONSI, and PPRA for a 30-day public review period.

If APHIS determines that no substantive information has been received that would warrant an alteration of our preliminary regulatory determination or FONSI, substantially changing the proposed action identified in the EA, or substantially changing the analysis of impacts in the EA, APHIS' preliminary regulatory determination becomes final and effective upon public notification through an announcement on its website. No further *Federal Register* notice is published announcing the final regulatory determination.

<u>Approach 2. For GE organisms that raise substantive new issues not previously reviewed by APHIS.</u> A second approach for public participation is used when APHIS determines that the petition for a determination of nonregulated status is for a GE organism that raises substantive new issues. This could include petitions involving a recipient organism that has not previously been determined to have nonregulated status or when APHIS determines that gene modifications raise substantive biological, cultural, or ecological issues not previously analyzed. Substantive issues are identified based on our review of the petition and our evaluation of comments received from the public during the 60-day petition comment period on the petition.

APHIS solicits comments on its draft EA and draft PPRA for 30 days through the publication of a *Federal Register* notice. APHIS reviews and evaluates comments and other relevant information, then revises the PPRA as necessary and prepares a final EA. Following preparation of these documents, APHIS approves or denies the petition and announces its determination in the *Federal Register*. The announcement is accompanied by APHIS' final EA, PPRA, National Environmental Policy (NEPA) decision document (either a FONSI or NOI to prepare an EIS), and regulatory determination.

USDA-APHIS has decided this EA will follow Approach 1 because this is another EA prepared for cotton genetically engineered for resistance to glufosinate herbicides with the same *pat* gene as several other soybean varieties, and also for resistance to 2,4-D with the same genetic modification, addition of the *aad-12* gene, that had completed USDA review (see Section 1.6).

The Dow petition was published for public comment on March 18, 2014, with comments accepted until May 19, 2014. As of that date, the docket file contained a total of 193 public submissions.

Issues raised in these public comments on the petition were focused on the nature of agronomic inputs associated with this new trait, potential impacts to plants from off-target drift, management of HR weeds, human health considerations from exposure to herbicides, and domestic and international economic impacts associated with the development and marketing of a new HR product. Issues related to the use of herbicides, such as impacts on natural and physical resources are outside the scope of this EA.

1.6 Relationship to Other Environmental Documents

USDA-APHIS prepared a Final EIS (FEIS) for the nonregulated status of 2,4-D- and ACCase inhibitor-tolerant DAS-40278-9 corn; 2,4-D- and glufosinate-tolerant DAS-68416-4 soybean; and 2,4-D-, glufosinate- and glyphosate-tolerant DAS-44406-6 soybean (USDA-APHIS, 2014c). APHIS published a notice (79 FR 56555-56557) advising the public of the determinations of nonregulated status and availability of the Record of Decision (ROD) on September 22, 2014. This EA is tiered to that FEIS. Pertinent and current information available in the FEIS has been incorporated by reference into this EA.

This EA is also tiered to a second FEIS. USDA-APHIS prepared a Final EIS (FEIS) for the nonregulated status of dicamba resistant MON-87708 soybean; and dicamba resistant MON 87701-3 cotton (USDA-APHIS-2014d). APHIS published a notice (79 FR 73890) advising the public of the determinations of nonregulated status and availability of the Record of Decision (ROD) on December 12, 2014. This EA is tiered to that FEIS. Pertinent and current information available in the FEIS has been incorporated by reference into this EA.

1.7 Issues Considered

The list of resource areas considered in this draft EA were developed by USDA-APHIS through experience in considering public concerns and issues raised in public comments submitted for this petition and other EAs of GE organisms. The resource areas considered also address concerns raised in previous and unrelated lawsuits, as well as issues that have been raised by various stakeholders for this petition and in the past. The resource areas considered in this EA can be categorized as follows:

Agricultural Production

- Land Use for Cotton Production
- Acreage and Areas of Cotton Production
- Agronomic Cropping Practices
- Organic Cotton Production

Environmental Considerations

- Soil Quality
- Water Resources
- Air Quality
- Climate Change
- Animal Communities
- Plant Communities
- Soil Microorganisms
- Biological Diversity

Human Health

- Public Health
- Worker Safety

Livestock Health

- Animal Feed/Livestock Health

Socioeconomic

- Domestic Economics
- Trade Economics

2 AFFECTED ENVIRONMENT

The Affected Environment Section provides an overview of the use and biology of cotton, followed by a discussion of the current condition of those aspects of the human environment potentially affected by a determination of nonregulated status of DAS-81910-7 cotton. For this EA, those aspects of the human environment are: agricultural production of cotton; the physical environment; animal and plant communities; human health; animal feed; and socioeconomic issues.

Cotton (*Gossypium* spp.) is the world's most widely grown textile fiber crop, accounting for over 40% of fiber production in the world (Meyer et al., 2007). The major cotton by-products include an edible oil from seeds, as well as the use of chaff (hulls and linters), high-protein cake, and flour as livestock feed (OECD, 2008).

2.1 Areas and Acreage of Cotton Production

2.1.1 Land Use for Cotton Production

As of 2012, there were about 390 million acres of cropland in the United States, of which approximately 315 million acres were harvested (cultivated fallow not included) for crop production usda-nass. The remaining cropland was either idle or used for pasture. The cumulative land area in the United States planted to principal crops has remained relatively constant over the past 27 years (USDA-NASS, 2012a; USDA-NASS, 2013b). Land use in the eastern United States is dominated by forest, while the Mountain and Southern Plains regions have a majority of grassland, and the midsection of the country (Corn Belt, Lake States, and Northern Plains) has the highest percentage of land used for cropland. The Pacific Region has a mixture of uses with forest and grassland accounting for significant shares, and special uses (including urban) having a large share in California (USDA-ERS, 2011).

2.1.2 Conventional Cotton Production Areas and Acreage

Cotton (*Gossypium* spp.) is a warm-season perennial that is grown as an annual. Successful production of cotton requires a long frost-free period, plenty of sunshine and warm temperature, and moderate rainfall or irrigation, usually from 24 to 47 inches (60 to 120 centimeters) (Evett et al., 2011). It is geographically more limited than other major crops in the United States because its growth requires a minimum of 180 frost-free days per year (OECD, 2008; Rude, 1984; Smith and Cothren, 1999). Because it is a perennial, remaining cotton stalks can regrow following harvest, resulting in squares and bolls where boll weevils can feed and reproduce (Lemon et al., 2003).

According to USDA-NASS data, cotton was planted on approximately 11 million acres in the United States in 2014 (USDA-NASS, 2015b). Cotton is planted in 17 states across the southern United States, identified as the Cotton Belt. These states include Alabama, Arizona, Arkansas, California, Florida, Georgia, Kansas, Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia (USDA-NASS, 2015b). The five major cotton-producing states according to planted acreage are Texas (6.2 million acres), Georgia (1.4 million acres), North Carolina (0.47 million acres), Mississippi (0.43 million acres), and Alabama (0.35 million acres) (Table 1) (USDA-NASS, 2015b).

The most commonly cultivated species of cotton in the United States is Upland cotton (*G. hirsutum*), comprising 98 percent of the cotton crop planted (USDA-NASS, 2015b). Upland cotton is also known as short staple cotton, based on the relative length of the cotton fibers (Rude, 1984). All 17 cotton-producing states grow Upland cotton (USDA-NASS, 2015b). The remainder of cotton planted is Pima (extra-long staple [ELS] or Egyptian) cotton (*G. barbadense*) that is cultivated in Arizona, California, New Mexico, and Texas (USDA-NASS, 2015b). Figure 1 shows U.S. Upland cotton planted acres in 2013, while Figure 2 shows the planted Pima cotton acres in the United States in 2013 (USDA-NASS, 2013d; USDA-NASS, 2013e).

Table 1 presents the U.S. cotton acreage (Upland, Pima, and total) planted and harvest for the past three years (2012-2014) (USDA-NASS, 2015b). Upland cotton planted acreage for 2014, estimated at 10.8 million acres, increased by 6 percent from the previous year. The estimated harvested acreage for Upland cotton, 9.5 million acres, represents an increase of 30 percent from 2013 (USDA-NASS, 2015b). For 2014, Pima cotton planted acreage is estimated at 0.192 million acres, while harvested acreage is 0.189 million acres, representing decreases of 4 and 5 percent, respectively (USDA-NASS, 2015b). Overall, total cotton planted acreage increased 6 percent from 2013; however, this is 10 percent less than was planted in 2012 (USDA-NASS, 2015b). Total cotton harvested acreage, at 9.7 million acres, is a 29 percent increase from the previous year, 2013 (USDA-NASS, 2015b).

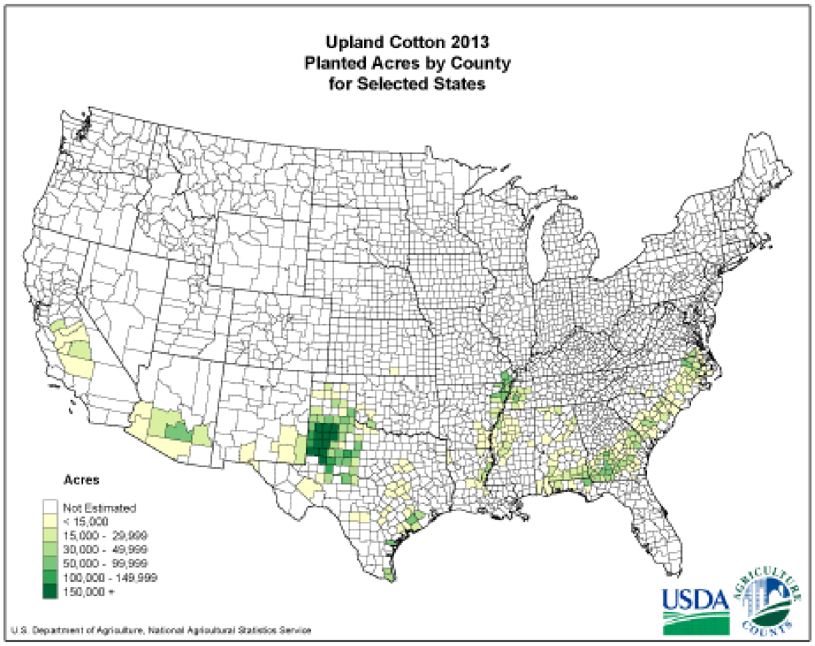
The total U.S. cotton acreage in the past 10 years has varied from approximately 9.15 to 15.77 million planted acres, with the lowest acreage recorded in 2009 and the highest in 2001 (see Figure 4) (USDA-NASS, 2015a). The variations observed in cotton planted acreage are driven by current market conditions, rather than agronomic considerations.

Table 1. Cotton Area Planted and Harvested: 2011-2013.

Type of Cotton and States where Grown	Acreage planted (1,000 acres)			Acreage Harvested (1,000 acres)		
	2012	2013	2014	2012	2013	2014
Upland Cotton						
Alabama	380	365	350	378	359	348
Arizona	200	160	150	197	159	148
Arkansas	595	310	335	585	305	330
California	142	93	57	141	92	56
Florida	108	131	107	107	127	105
Georgia	1,290	1,370	1,380	1,280	1,340	1370
Kansas	56	27	31	54	26	29
Louisiana	230	130	170	255	128	168
Mississippi	475	290	425	470	287	420
Missouri	350	255	250	330	246	245
New Mexico	45	39	43	38	31	35
North Carolina	585	465	465	580	460	460
Oklahoma	305	185	240	140	125	220
South Carolina	299	258	280	298	250	278
Tennessee	380	250	275	377	233	270
Texas	6,500	5,800	6,200	3,800	3,100	4,950
Virginia	86	78	87	85	77	86

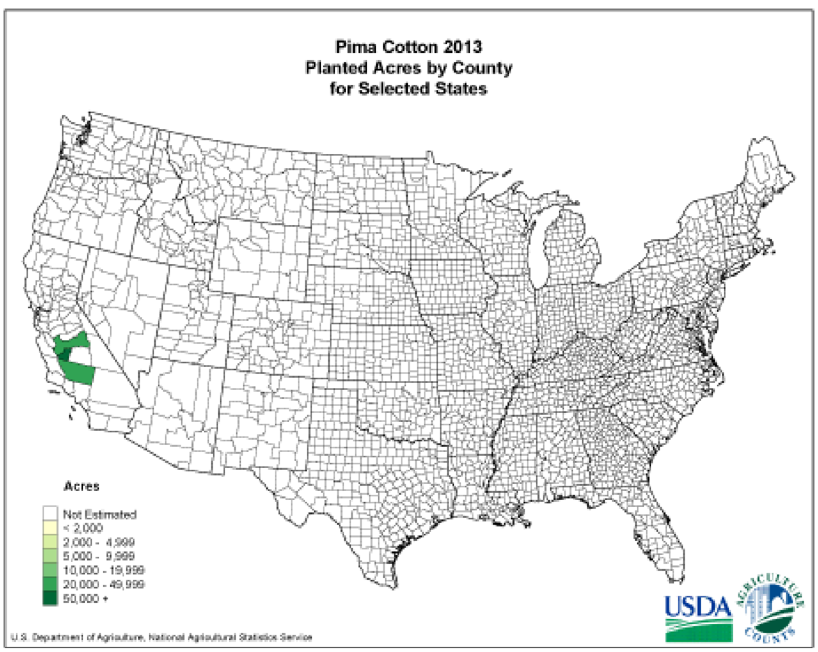
Type of Cotton and States where Grown	Acreage planted (1,000 acres)			Acreage Harvested (1,000 acres)		
	2012	**2013**	**2014**	**2012**	**2013**	**2014**
United States	**12,026**	**10,206**	**10,845**	**9,085**	**7,345**	**9,518**
Pima Cotton						
Arizona	3	1.5	15	3	1.5	14.5
California	255	187	155	224	186	154
New Mexico	2.4	3.5	5	2.3	3.4	4.9
Texas	8	9	17	7.5	8.5	16
United States	**238.4**	**201**	**192**	**236.8**	**199.9**	**189.4**
All Cotton						
Alabama	380	365	350	378	359	348
Arizona	203	161.5	165	200	160	162.5
Arkansas	595	310	335	585	305	330
California	367	280	212	365	278	210
Florida	108	131	107	107	127	105
Georgia	1,290	1,370	1,380	1,280	1,340	1,370
Kansas	56	27	31	54	26	29
Louisiana	230	130	170	225	128	168
Mississippi	475	290	425	470	287	420
Missouri	350	255	250	330	246	245
New Mexico	47.4	42.5	48	40.3	34.4	39.9
North Carolina	585	465	465	580	460	460
Oklahoma	305	185	240	140	125	220
South Carolina	299	258	280	298	250	278
Tennessee	380	250	275	377	233	270
Texas	6,508	5,809	6,217	3,808	3,109	4,966
Virginia	86	78	87	85	77	86
United States[3]	**12,264**	**10,407**	**11,037**	**9,322**	**7,544**	**9,707**

Source: (USDA-NASS, 2015b).



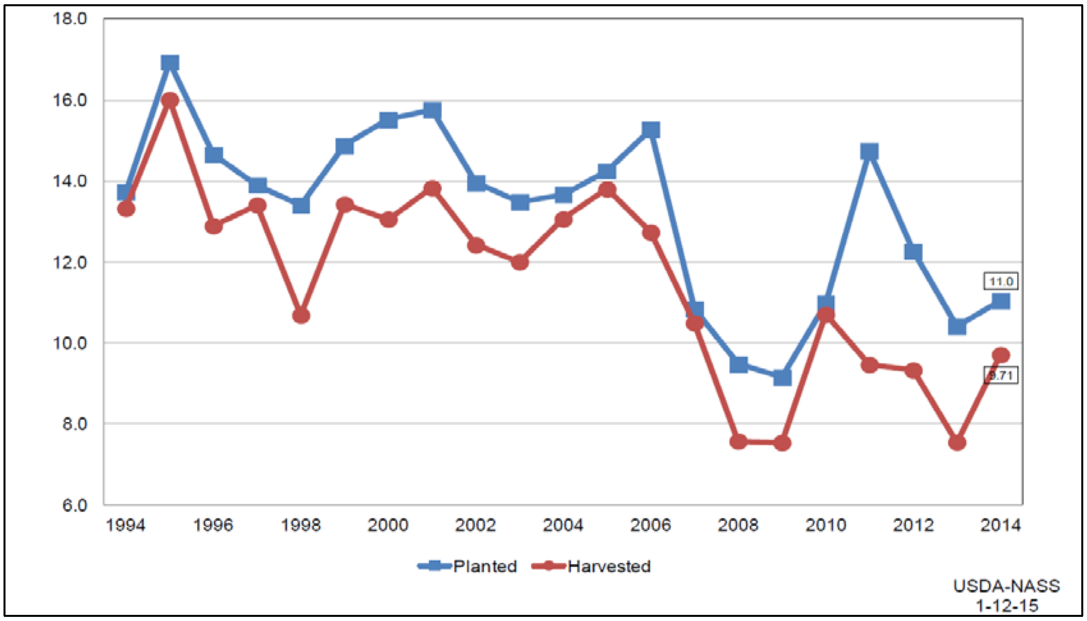
Source: (USDA-NASS, 2013e).

Figure 1. Upland Cotton Planted Acres in the United States in 2013.



Source: (USDA-NASS, 2013d)

Figure 2. Pima Cotton Planted Acres in the United States in 2013.



Source: (USDA-NASS, 2015a).

Figure 3. Acres of Cotton Planted and Harvested from 1993 to 2014.

2.1.3 GE Varieties of Cotton

GE-derived varieties of cotton, containing either herbicide resistance, insect resistance, or both traits, comprised 96 percent of all cotton acreage in 2014 (USDA-ERS, 2014a). Plantings of GE HR cotton expanded from about 10 percent of U.S. acreage in 1997 to 91 percent in 2014 (USDA-ERS, 2014b). Plantings of cotton with insect-resistant *Bacillus thuringiensis* (Bt) traits also expanded rapidly, from 15 percent of U.S. cotton acreage in 1997 to 84 percent in 2014 (USDA-ERS, 2014b). Adoption of cotton varieties stacked with both traits has accelerated in recent years. Adoption of GE cotton stacked with both HR and Bt traits reached 79 percent of cotton acreage in 2014 (USDA-ERS, 2014a). Table 2 lists the currently deregulated biotechnology-derived cotton products. There is no indication that the introduction and widespread adoption of GE-derived crops in general has resulted in a significant change to the total U.S. acreage devoted to agricultural production. The acreage planted with principle crops in the United States since the introduction of GE-derived crops in 1996 has remained relatively constant over the past 31 year (USDA-NASS, 2014c).

Table 2. Deregulated GE Cotton Events.

Phenotype	Event	Institution	Deregulation Effective Date
Glufosinate resistant, Lepidopteran resistant	T303-3XGHB119	Bayer CropScience	August 2012
Dicamba resistant, Glufosinate tolerant	MON 87701	Monsanto	January 2015

Phenotype	Event	Institution	Deregulation Effective Date
Glufosinate resistant, Lepidopteran resistant	T304-40XGHB119	Bayer CropScience	October 2011
Lepidopteran resistant	COT 67B	Syngenta	September 2011
Glyphosate tolerant	GHB614	Bayer CropScience	May 2009
Glyphosate tolerant	MON 88913	Monsanto	December 2004
Lepidopteran resistant	COT 102	Syngenta	July 2005
Lepidopteran resistant	281-24-236	Mycogen/Dow	July 2004
Lepidopteran resistant	3006-210-23	Mycogen/Dow	July 2004
Phosphinothricin tolerant	LLCotton25	Aventis	March 2003
Lepidopteran resistant	Cotton 15985	Monsanto	November 2002
Bromoxynil resistant and lepidopteran resistant	31807 and 31808	Calgene	April 1997
Sulfonylurea tolerant	19-51a	DuPont	January 1996
Glyphosate resistant	1445, 1698	Monsanto	July 1995
Lepidopteran resistant	531, 757, 1076	Monsanto	June 1995
Bromoxynil resistant	BXN	Calgene	February 1994

Source: (USDA-APHIS, 2014e)

2.2 Agronomic Practices in Cotton Production

Modern agriculture coordinates a wide variety of inputs to maximize crop yield and wisely use the land, vegetation, and environmental resources. Conventional farming covers a broad scope of farming practices, including the use synthetic fertilizers and pesticides. Conventional farming also includes the use of GE varieties that are no longer subject to the regulatory requirements of 7 CFR part 340 or the plant pest provisions of the PPA. Organic systems exclude certain production methods, such as synthetic agricultural inputs and GE crops. (Organic cotton production is discussed further in Section 2.3.)

Good cotton management practices allows the plant to produce a high yield at a reasonable cost by channeling energy into harvestable seed cotton within the limitations imposed by soil, length of season, and production cost (Rude, 1984). Particularly in upland varieties, boll maturation is dominant over vegetative growth and formation of new flower buds (called “squares”), once the plant begins to set bolls. If too few of the ovules are fertilized, the fruit drops within 10 days of flowering. During the post-harvest ginning process, longer cotton lint fibers are separated from the harvested seed cotton. Unfertilized ovules within a fruit that fully develops remain as contaminants or “motes” within the lint. Shorter fuzz fibers (called linters) remain attached to the seed after ginning (Boyd et al., 2004; Rude, 1984).

The length of the season may vary between cotton production regions, but the production cycle and production practices used are fairly consistent among geographic regions and between the upland and Pima cotton types. Good cotton management practices allows the plant to produce a high yield at a reasonable cost by channeling energy into harvestable seed cotton within the limitations imposed by soil, length of season, and production cost (Rude, 1984). The majority of the value of the producer's cotton crop is based on the quality and quantity of the lint produced, and with the exception of contracted acres for planting seed production (Monsanto, 2013a).

Production decisions regarding crop rotation, tillage system, soil fertility, variety selection, and row spacing need to be made well in advance of planting the cotton crop, often prior to or immediately after harvest of the previous crop. Cotton production uses specific equipment for each crop's activities, from preplant soil preparation to harvest and ginning (Mitchell et al., 2012; Weersink et al., 1992). For example, cotton may be harvested with spindle pickers, roller gins, or saw ginning, depending on the variety (Rude, 1984; Western Farm Press, 2007). Tillage, crop rotation, and inputs, such as pesticides, are selected from a range of options by each grower to achieve their desired outcomes of yield and environmental stewardship. Key production practices are described in the following sections.

2.2.1 Tillage

Prior to planting, the soil is typically stripped of weeds that would otherwise compete with the crop for space, water, and nutrients. Field preparation is accomplished through a variety of tillage systems, with each system defined by the remaining crop residue on the field. Crop residues are materials left in an agricultural field after the crop has been harvested, including stalks and stubble (stems), leaves and seed pods (USDA-NRCS, 2005).

Conventional tillage is associated with intensive plowing and leaving less than 15 percent crop residue in the field (US-EPA, 2010b). In contrast, reduced tillage is associated with 15 to 30 percent crop residue. Conservation tillage relies on methods that result in less soil disruption and leaves at least 30 percent of crop residue on the surface. These residues aid in conserving soil moisture and reduce wind and water-induced soil erosion (Heatherly et al., 2009; USDA-ERS, 1997; USDA-NRCS, 2005). Residue on the soil surface breaks the impact of raindrops, improves water infiltration into the soil, and reduces evaporation and runoff (TAMU, 2014).

Conservation and reduced tillage practices include: mulch-till, eco-fallow, strip-till, ridge-till, zero-till, and no-till (IPM, 2007). No-till farming only disturbs the soil between crops. The new crop is planted into residue or in narrow strips of tilled soil, which results in less soil disruption. Under no-till practices, there is no turning of the soil to break up compacted areas (USDA-NRCS, 1996). In general, soil conservation practices, such as conservation tillage, reduce field tillage and corresponding soil loss (Papendick and Moldenhauer, 1995; Tyler et al., 1994; USDA-NRCS, 2006b). Increases in total acres dedicated to conservation tillage were facilitated in part by an increased use of HR GE crops, reducing the need for mechanical weed control (Towery and Werblow, 2010c; USDA-NRCS, 2006b; USDA-NRCS, 2010b).

Conservation tillage is highly valued as a means to enhance soil quality and preserve soil moisture, but it also presents potential challenges for disease and pest management (Papendick and Moldenhauer, 1995; Rude, 1984; Tyler et al., 1994). Reducing tillage may enhance conditions for development of economically significant pest populations that normally are efficiently managed with conventional tillage practices (NRC, 2010). For example, cotton aphids migrate into fields using conservation tillage and consistently reach peak population densities more rapidly than in conventionally tilled fields (Leonard, 2007). The surface residues may serve as an inoculum source for certain disease-causing organisms (Robertson et al., 2009). This can become problematic for growers using crop rotation schemes with minimal tillage (Robertson et al., 2009).

Conventional cotton fields are typically tilled just prior to planting (Albers and Reinbott, 1994). Cotton production systems generally rely on multiple-pass tillage, which is costly in labor, time, maintenance of specialized equipment, and fuel (Albers and Reinbott, 1994; Frans and Chandler, 1989; Mitchell et al., 2012). Preplant tillage activities in cotton may include smoothing the soil or creating raised ridges for permanent or semi-permanent beds (Albers and Reinbott, 1994; El-Zik et al., 1989; Mitchell et al., 2012; Rude, 1984). In conventional cotton cultivation, after the prior crop is harvested, the surface material is shredded and roots are undercut and mixed with the soil (Albers and Reinbott, 1994; Mitchell et al., 2012). A series of diskings provides a host-free period that is usually needed to reduce populations of pink bollworm. There may be more than five field operations prior to seeding the cotton crop (plow under weeds, incorporate herbicides, break-up soil clods, shape the uniform planting beds, prepare for furrow irrigation or dry mulch) (Albers and Reinbott, 1994; Mitchell et al., 2012).

Effective pink bollworm and nematode control in cotton requires tillage operations to reduce soil-borne populations of these pests (Kirkpatrick and Thomas; Mitchell et al., 2012). These pests and others overwinter in the soil, and then infect or infest the new crop. Disease control measures include cultivation of resistant hybrids, crop rotation, and careful balancing of conservation tillage with residue management (Robertson et al., 2009).

Information provided by Monsanto on the trends in tillage practices for cotton from 1998 to 2007 (Table 3) indicate that conventional tillage acreage decreased and no-till acres increased across all regions. From 2007-2012, the trends showed variation across the country for those five years (Monsanto, 2013c; USDA-APHIS, 2014d). According to the survey data, growers in the Western United States did not tend to increase use of conventional tillage practices, in contrast to those in the Midsouth. The survey revealed that growers adopt specific tillage practices based on the cost of production, commodity price, need for seed bed preparation, and to manage excessive crop residue or weeds.

Table 3. Trends in Tillage Practices for Cotton.

Region[1]	Tillage System	Trend 1998 – 2007	Trend 2007 – 2012
West	Conventional	Decreased	Decreased
	No-till	Increased	Increased
	Reduced-till	Increased	Increased
Southeast	Conventional	Decreased	No Change/ Increased[2]
	No-till	Increased	Decreased
	Reduced-Till	Increased	Increased

Region[1]	Tillage System	Trend 1998 – 2007	Trend 2007 – 2012
Midwest	Conventional	Decreased	No Change/ Inceased[1]
	No-till	Increased	Decreased
	Reduced-till	Increased	Increased
Midsouth	Conventional	Decreased	Increased
	No-till	Increased	Decreased
	Reduced-till	Increased	Decreased

Source: (Monsanto, 2013c).
[1]Southeast region includes: Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia.
West region includes: Arizona and California.
Southwest region includes: Kansas, New Mexico, Oklahoma, and Texas.
Midsouth region includes: Arkansas, Louisiana, Mississippi, Missouri, and Tennessee.
[2]Where the trend is indicated as two phases (i.e., No Change/Decreased), this means that statistically the trend is for no change over the designated time period but the slop over the last two years of the time period tended to be either reflective of an increase or a decrease.

2.2.2 Crop Rotation

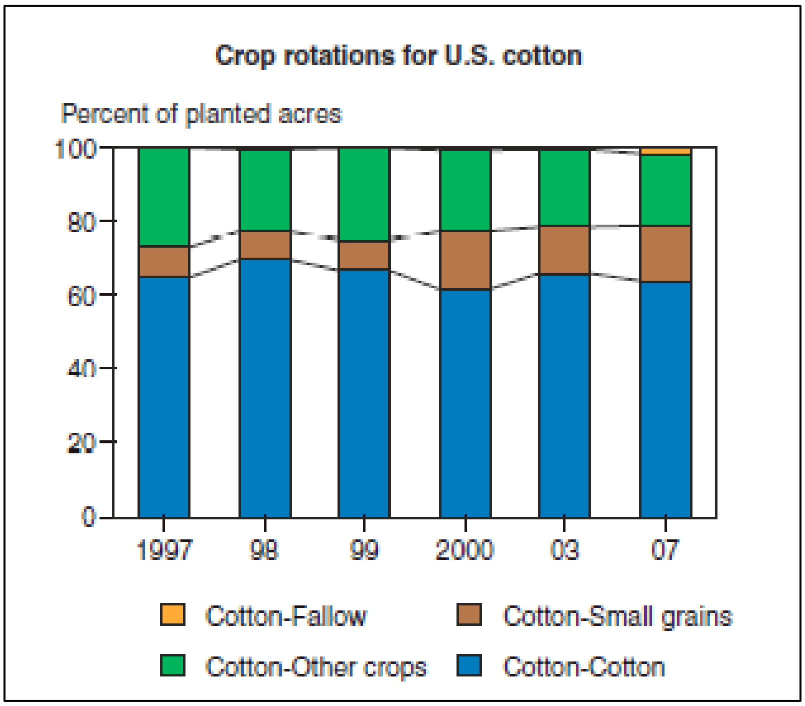
Crop rotation is the successive planting of different crops in the same field over a specific number of years. The goals of crop rotation include maximizing economic returns and sustaining the productivity of the agricultural system (Hoeft et al., 2000). Sustaining the agricultural system is achieved by rotating crops that may improve soil health and fertility with more commercially beneficial commodity crops. Maximizing economic returns is realized by rotating crops in a sequence that efficiently produces the most net returns for a producer over a multi-year period. Moreover, the rotation of crops can effectively reduce disease, pest incidence, weediness, and selection pressure for weed resistance to herbicides (Berglund and Helms, 2003; USDA-ERS, 1997).

Many factors at the individual farm level affect the crop rotation system chosen, including the soil type present in an individual field, the expected commodity price, the need to hire labor, the price of fuel, the availability of funding to buy seed, and the price of agricultural inputs (Duffy, 2011; Hoeft et al., 2000; Langemeier, 1997).

Where it could be grown, cotton became a dominant crop and was grown as a monoculture, particularly in the Mississippi Delta, because cotton provided more income per acre than soybeans, corn, rice, and wheat (Hake et al., 1991). Additionally, capital invested in local infrastructure and regulations related to participation in the U.S. government cotton commodity support program were factors influencing the decision to plant continuous cotton (Pettigrew et al., 2006). Ideally, cotton should be rotated with other crops on a regular basis to maintain soil productivity and reduce the incidence of various weeds, insect pests or diseases (Hake et al., 1996). However, production costs, relative rate of return, and the current market conditions dictate which crops are rotated with cotton or whether to grow continuous cotton.

Figure 4 shows the crop rotation patterns of cotton in the United States from 1996 through 2010. According to the USDA Agricultural Resource Management Survey (ARMS) data, continuous cotton acreage has remained steady, between 60 and 70 percent, during this time period (Osteen et al., 2012). Other crops used in rotation with cotton vary regionally and include corn, soybeans, sorghum, peanut and wheat (Pettigrew et al., 2006). Rotating cotton with monocot crops, such as corn, can help to reduce the soil inoculum level of the seedling disease fungi *Pythium* and *Rhizoctonia*. These seedling diseases can increase in continuous cotton cropping systems (Smith and Cothren, 1999). Crop rotation may also include fallow periods, or sowing with cover crops to prevent soil erosion and to provide livestock forage between cash crops (Hoeft et al., 2000; USDA-NRCS, 2010a).

Effective nematode and disease suppression through crop rotation is a long-term management strategy that depends on the host range of the pathogen, the type of rotational crop used, and the length of the rotation. The goal of the rotation is to reduce pathogen populations below their threshold level by not planting crops that are susceptible to the disease present in the field (Hake et al., 1991; Kirkpatrick and Thomas). For example, rotation to a monocot crop can suppress seedling diseases in subsequently planted cotton, but rotation to a legume cover crop is not likely to reduce cotton seedling disease (Hake et al., 1991).



Source: (Osteen and Fernandez-Cornejo, 2013).

Figure 4. Cropping Patterns for Cotton in the United States, 1996-2010.

Winter cover crops are also utilized in cotton production. Cover crop rotations typically consist of planting a winter cereal or legume in the fall followed by cotton next spring. These cover crops are used to provide winter soil cover and protection, build soil nitrogen and organic matter, reduce nitrogen leaching, suppress weeds, and provide a habitat for beneficial predatory and parasitic insects and spiders (Guerena and Sullivan, 2003). These rotations create an economic control strategy for soilborne diseases, interacting nematodes, and resistant weeds. Typically, cover crop rotations provide erosion control, improved soil tilth, and suppress diseases.

Rotation with wheat-soybean shows the largest benefit from crop rotation (Hake et al., 1991). But most of this benefit is attributed to decreasing disease and nematode populations in the soil, as opposed to supplying nutritional needs. Diversification increases economic stability when profitable crops are rotated with cotton, but rotation out of monoculture may not be needed if pests can be otherwise managed (Hake et al., 1991).

Based on grower interviews conducted by Monsanto in 2010 (Monsanto, 2013a; USDA-APHIS, 2014d), approximately 54 percent of U.S. cotton acres are followed by cotton in the crop rotation sequence (Table 4). By region, this percent is highest in the Southwest (61 percent) and lowest in the West (30 percent). Only in the West region is cotton rotated to another crop, wheat, on the majority of cotton acres. Corn (16 percent), wheat (9 percent), soybean (8 percent), sorghum (8 percent), and peanuts (4 percent) are the other crops most frequently following cotton. When rotational crops are planted, the most common rotation crops by region are as follows: Southeast, soybean; Midsouth, corn; Southwest, sorghum; and West, wheat.

Table 4. Rotational Practices Following Cotton Production in the United States.

Cotton Growing Region (Total Cotton Acres, x1,000)	Rotational Crops Following Cotton	Rotational Crop Following Cotton (acres)	% Rotational Crop Acres
Southeast (2,597)	Cotton	1,311	50.5
	Soybean	507	19.5
	Peanut	410	15.8
	Corn	340	13.1
	Tobacco	30	1.1
West (504)	Wheat	202	40
	Cotton	153	30.4
	Vegetables	50	9.8
	Barley	40	7.9
	Tomatoes	24	4.9
	Onions	6	1.2
Southwest (5,953)	Cotton	3,607	60.6
	Sorghum	808	13.6
	Wheat	765	12.9
	Corn	685	11.5
	Peanuts	22	0.4
	Sunflower	22	0.4
	Alfalfa	18	0.3
	Soybean	17	0.3
Midsouth	Cotton	786	40.9

Cotton Growing Region (Total Cotton Acres, x1,000)	Rotational Crops Following Cotton	Rotational Crop Following Cotton (acres)	% Rotational Crop Acres
(1,920)	Corn	711	37.0
	Soybean	337	17.6
	Wheat	59	3.0
	Sorghum	27	1.4
United States (10,974)[2]	Cotton	5,858	53.4
	Corn	1,736	15.8
	Wheat	1,025	9.3
	Soybean	861	7.8
	Sorghum	836	7.6
	Peanut	432	3.9

Source: Table VIII-20-24, APHIS Petition 12-185-01p (Monsanto, 2012a; USDA-APHIS, 2014d).
Notes:
[1]Cotton acreage reported by Monsanto (Monsanto, 2012a), based on USDA-NASS 2010 planting data (USDA-NASS, 2011c).
[2]Total may not be exact due to rounding.
Southeast region includes: Alabama, Florida, Georgia, North Carolina, South Carolina, Virginia.
West region includes: Arizona, California.
Southwest region includes: Kansas, New Mexico, Oklahoma, Texas.
Midsouth region includes: Arkansas, Louisiana, Mississippi, Missouri, Tennessee.

2.2.3 Nutrient and Fertilizer Use

Commercially available fertilizers usually contain a mixture of the macronutrients nitrogen (N), phosphorus, and potassium which are essential for plant growth (Vitosh, 1996). To fill specific crop needs in soils that are deficient, various concentrations of micronutrients may be included in fertilizer formulations (Jones and Jacobsen, 2003). Fertility needs also can be met by applying organic matter which may alter the soil’s naturally occurring level of nutrients that are available for plant growth (Jones and Jacobsen, 2003). Nevertheless, about half of the N applied in a chemical form is not taken up by plants but is lost to the atmosphere and to above- and below-ground water supplies (Ellington et al., 2007).

The nutritional needs for cotton are generally recognized as lower than other major crops. Cotton's relatively low nutritional needs are attributed to its deep root system, soil microorganisms, and warm season growth habit. Consequently, when cotton is grown in rotations, it is the nutritional needs of the other crops that determine the amounts of phosphorus, potassium and micronutrients that must be added to the soil (Hake et al., 1991). Nevertheless, the nutrients needed in the largest amounts are N, phosphorus, potassium, calcium, magnesium, and sulfur (Rude, 1984). Other essential nutrients needed in very small amounts are iron, boron, manganese, zinc, molybdenum, copper, and chlorine (Rude, 1984).

Maintaining optimum crop nutrition is critical in achieving high yields and quality in cotton. Pre-season soil test results for N, phosphorus, and potassium plus determination of pH, together with previous cropping and fertilization history determine the fertilizer and liming needs for the upcoming cotton crop. Preplant soil analysis and leaf petiole analysis during the season can be very useful in monitoring the nitrogen status of the crop. Early season applications of N at or before planting are seldom recommended unless the residual N content in the soil is very low. This is because young stands of cotton have a very low N requirement and soluble nitrates can be easily leached when irrigation water is applied during germination and early season growth. Efficient fertilizer use in cotton requires there to be no excessive N at the end of the season because N applied too late triggers the need for extra applications of defoliants (El-Zik et al., 1989; Rude, 1984). Increased cotton growth and yield under higher N regimes can be offset in value by increased populations of pest insects leading to reduced lint quality (Ellington et al., 2007).

2.2.4 Insect and Pest Management

Cotton is susceptible to injury at nearly every stage of growth, as a consequence, cotton fields must be monitored regularly. In all cotton production regions in the United States, insect and mite pests are a common and continuous threat which can result in decreased yield and reduced quality. The most damaging insect pests of cotton attack the cotton square (the flower bud) or the cotton boll (the ovary containing developing seeds and fibers) (Gianesi and Carpenter, 1999).

In 2013, the total costs and losses in cotton production due to insects amounted to $715.5 million, with overall yields reduced by 2.68 percent. The top ranked pests in terms of yield loss in 2013 are shown in Table 5. The highest yield losses (0.782 percent) were associated with lygus, followed by stink bugs (0.684 percent) and thrips (0.553 percent). Cotton fleahoppers were fourth at 0.217 percent, while bollworm/budworm complex and spider mites caused reduced yields by 0.161 percent and 0.133 percent, respectively. All other pest caused less than 0.1 percent loss. The direct management costs for arthropods were $61.60 per acre (Williams, 2013).

Table 5. Cotton Insect Losses, 2013.

Insect	Acres Infested	Acres Treated	Number of Applications per Acre Treated	Yield loss (%)
Lygus	2,992,775	2,020,233	3.68	0.782
Stink bugs	4,300,116	2,430,586	2.27	0.684
Thrips	6,704,407	3,404,654	1.36	0.553
Cotton fleahoppers	1,778,425	621,682	1.11	0.217
Bollworm/budworm complex	2,827,071	711,887	0.99	0.161
Spider mites	1,977,503	776,155	1.33	0.133

Source: Table 8 from Williams (2013)

The quantity of pesticide applied to cotton has trended downwards since 1972 due to the replacement of DDT and other older insecticides with more effective products (requiring the use of smaller quantities), the eradication of the boll weevil, and the adoption of insect resistant (Bt) cotton (Fernandez-Cornejo et al., 2014a).

Planting Bt cotton seed is associated with higher net returns when pest pressure is high. Farmers generally use less insecticide when they plant Bt cotton. Pounds of insecticide (per planted acre) applied to cotton crops have declined over the course of the last 15 years. In 2014, cotton growers planted Bt cotton to control pests such as tobacco budworm, cotton bollworm, and pink boll-worm on 84 percent of U.S. cotton acreage, increasing from 35 percent of the cotton acreage in 2000 and 52 percent in 2005 (USDA-ERS, 2014b).

In 2010, approximately 55 percent of cotton acreage planted was treated with insecticide (USDA-NASS, 2011b). A wide variety of insecticides (Table 6) are registered for use in cotton, but growers typically scout for pests and apply insecticides only when economic thresholds are met (Benedict et al., 1989; Higgins, 1997; Rude, 1984). The development of pest populations with resistance to various classes of insecticides requires growers to coordinate the pesticidal chemicals used at various times during the production of a crop.

Table 6. Commonly Used Insecticides for Cotton Pests.

Cotton Pest	Insecticidal Products[1]
Aphids	acetamiprid, clothianidin, flonicamid, imidacloprid, and thiamethoxam
Beet and Fall Armyworms	chlorantraniliprole, emamectin benzoate (R), flubendiamide, indoxacarb, methomyl (R), methoxyfenozide, novaluron, spinosad, and thiodicarb
Bollworm	Bifenthrin (R), chlorantraniliprole, cyfluthrin (R), *beta*- cyfluthrin (R), *gamma*-cyhalothrin, *lambda*-cyhalothrin (R), cypermethrin (R), *zeta*-cypermethrin, *zeta*-cypermethrin / bifenthrin, emamectin benzoate (R), esfenvalerate (R), flubendiamide, indoxacarb, methomyl (R), novaluron, profenofos, spinosad, and thiodicarb
Tobacco Budworm (in Varieties Containing Bt Genes)[2]	chlorantraniliprole, emamectin benzoate (R), flubendiamide, indoxacarb, methomyl (R), novaluron, profenofos, spinosad, and thiodicarb
Cutworms	acephate, bifenthrin, chlorpyrifos, cyfluthrin, *lambda*-cyhalothrin, gamma-cyhalothrin, cypermethrin, zeta-cypermethrin, *zeta*-cypermethrin / bifenthrin, and esfenvalerate
Cotton Fleahopper and Tarnished Plant Bug	acephate, clothianidin, dicrotophos (R), flonicamid, imidacloprid, novaluron, oxamyl (R), and thiamethoxam
Soybean Looper and Cabbage Looper	emamectin benzoate (R), flubendiamide, indoxacarb, methoxyfenozide, novaluron, spinosad, and thiodicarb
Spider Mites	abamectin, bifenthrin (R), chlorpyrifos, dicofol, etoxazole, fepyroximate, propargite, and spiromesifen
Stink Bugs	Non-pyrethroids: acephate, dicrotophos, methyl parathion, novaluron, and oxamyl. Pyrethroids: bifenthrin (R), cyfluthrin (R), *beta*-cyfluthrin (R), *lambda*-

Cotton Pest	Insecticidal Products[1]
	cyhalothrin (R), *gamma*-cyhalothrin (R), cypermethrin (R), *zeta*-cypermethrin (R), *zeta*-cypermethrin / bifenthrin (R), and esfenvalerate (R)
Thrips (at Planting)	aldicarb (R), imidacloprid, and thiamethoxam
Thrips (Foliar Sprays)	acephate, dicrotophos (R), and dimethoate
Whiteflies	acephate, acetamiprid, imidacloprid, pyriproxyfen, and thiamethoxam

Source: (Greene, 2012).

Notes:

[1] (R) means restricted use. Pre-mixed or co-packaged products also may be available when there are multiple pests requiring simultaneous treatment.

[2] Bt - Insect resistant crops (Bt crops) contain a gene from a soil bacterium, *Bacillus thuringiensis* (Bt), which produces a protein that is toxic to specific lepidopteran insects.

Successful and economical management of insect pests in cotton can be accomplished by using a combination of agronomic practices and inputs. This integrated pest management (IPM) approach utilizes an array of alternatives, rather than focusing on only one or two methods of pest control. IPM is based on variety selection and selection of cultural, biological, and chemical strategies (University-of-Georgia, 2011).

Preplant tillage and crop rotation are important agronomic and cultural practices utilized to reduce insect populations prior to planting cotton. Other agronomic practices are utilized to promote early maturity and reduce that period of time the crop is susceptible to insect and mite pests, and to increase the probability that an acceptable yield can be produced before insect pest densities exceed economic threshold levels (Smith and Cothren, 1999). Selection of short-season determinate varieties, adherence to optimum planting periods, and early season insect and disease management strategies can shorten the production season and limit crop exposure to late season insect pressure. In addition, implementation of conservation tillage systems usually provides timely planting and crop management, to promote an earlier-maturing crop. Biological control involves the importation, conservation, and/or augmentation of natural enemies (predators, parasites, and pathogens) of insect pests of cotton and is a major component of integrated pest management programs in cotton production (Smith and Cothren, 1999)

IPM has been used successfully in the eradication program for the pink bollworm, a pest in California, Arizona, New Mexico, and Texas, and adjacent areas of northern Mexico that has increased costs to cotton producers for prevention, control, and yield losses. A three-phase eradication program began in 2002 with four primary components: 1) extensive survey; 2) transgenic Bt cotton; 3) pheromone application for mating disruption; and, 4) sterile pink bollworm moth releases (NCCA, 2015).

In the late 1970s, the National Boll Weevil Eradication Program was launched by APHIS along the Virginia-North Carolina border and, over time, all of the 15 million acres of U.S. cotton have been involved in the program. A Cotton Belt-wide IPM approach has been used in the national program to eradicate the boll weevil. Integrated control, in this case, involves the selection of a particular control method or combination of methods for an individual site, based on factors including variations in boll weevil biology, availability of overwintering sites, environmental concerns, weather patterns, and crop production requirements (USDA-APHIS, 1999). The program uses three main techniques to eradicate the boll weevil: pheromone traps to detect the weevil's presence, cultural practices (i.e., habitat modification) to decrease its food supply, and chemical treatments (primarily malathion) to reduce weevil populations. Through cultural control methods, growers can make it less favorable for pest reproduction and survival, using techniques such as: growing short-season cotton varieties and mandatory stalk destruction (TDA, 1997). Growers destroy cotton stalks by applying herbicides, such as 2,4-D after shredding (Lemon et al., 2003). The weevil has been eradicated in 98 percent of these production areas (USDA-APHIS, 1999).

In addition to cotton insects and mite pests, nematodes cause cotton yield losses. These microscopic, wormlike animals cause damage by feeding on cotton roots. In addition to impacting fiber quality, nematodes are responsible for yield losses in cotton exceeding $400 million annually in the United States (NCCA, 2007). Management options, primarily during the preseason, include planting resistant cotton varieties, crop rotation, cultural practices, and the use of a nematicide (NCCA, 2007).

2.2.5 Weed Management

Effective weed control requires grower implementation of management practices that limit the introduction and spread of weeds, help the crop to compete with weeds, and prevent weeds from adapting. The key components to successfully manage weeds are: 1) knowing the exact identity of all weeds in the field; 2) treating fields (if necessary) while the weeds are small; 3) tailoring control measures to the type of weed and its size (Loux et al., 2013).

Weed control programs vary by crop, weed problem, geography, and cropping system (e.g., no-till, conventional-till, etc.). There are five general weed management strategies: preventive, cultural, mechanical, biological, and chemical. A combination of methods is recommended instead of relying on one particular method of weed control (Ashigh et al., 2012; Burgos et al., 2006; Monsanto, 2013c). The combination of weed control practices that a grower chooses depends upon the weed spectrum, level of infestation, soil type, cropping system, weather, and time and labor available for the treatment option.

Weed control in cotton is essential to maximize both the yield and quality of cotton fiber. The net impact of weeds on cotton production is a reduction in the quantity of marketable products, lint and seed, usually through a reduction in the number of bolls per plant (Arle and Hamilton, 1973; Ashigh et al., 2012). The slow early growth of cotton does not permit the crop to aggressively compete against weed species that often grow more rapidly and utilize the available water, nutrients, light, and other resources for growth

Certain weed species are more competitive than others with cotton often because of differences in growth habit. The primary weed competition factors affecting yield loss potential are the weed species, weed density, and the timing/duration of weed competition. Studies show that control of weeds during the first four to eight weeks after planting is critical to prevent weeds from competing for water, light, nutrients and other resources essential for cotton germination and growth (Ashigh et al., 2012; Burgos et al., 2006; Loux et al., 2013; Merchant et al., 2014b; Smith and Cothren, 1999).

To obtain the best cotton yields, growers manage weeds with a diversification of weed control strategies ranging from mechanical choppers and cross-cultivation to hand-labor and modern herbicides (Frans and Chandler, 1989). Practices that establish a dense, vigorous crop canopy quickly (e.g., higher seeding rates, optimum soil fertility, proper seedbed preparation, seeding depth) provide competition to smother weeds. USDA-Economic Research Service (ERS) (2012a) reports approximately 38 percent of the total cotton acres are cultivated for weed control post-plant in conventional tillage systems, and over 50 percent of cotton acres are cultivated for weed control with as many as five tillage operations occurring after emergence to harvest.

The planting of winter cover crops can be utilized as part of a diversified weed management strategy. The planting of cover crops, such as grasses, legumes, or small grains can protect and improve soil quality, help reduce erosion, serve as surface mulch in no-till cropping practices, and provide habitat for beneficial insects (Guerena and Sullivan, 2003). Small grain crops such as rye are commonly used as a cover crop; incorporating rye or oats as a cover crop have been shown to suppress Palmer amaranth germination and growth (Price et al., 2011). However, the planting of cover crops in general incurs additional costs to the grower and therefore cover crops are not typically a major weed management practice utilized in cotton production systems (Singer, 2006).

HR crops have become adopted widely since their introduction in the mid-late 1990s for several reasons. Increased selection pressure caused by wide-spread adoption of HR crops, reduction in the use of other herbicides and weed management practices, resulted in both weed population shifts and growing numbers of HR individuals among some weed populations (Duke and Powles, 2009; Owen, 2008). With HR cotton planted on 91 percent of U.S. acres, herbicides are the primary basis of weed management programs (USDA-ERS, 2014b).

USDA-NASS estimated that in 2010 herbicides were applied to 99 percent of acres planted to Upland cotton (USDA-NASS, 2011a). Cotton acres also received on average four treatments with herbicides during the 2011 growing season (USDA-ERS, 2012a). According to 2010 market data[5], there were approximately 46.3 million herbicide-treated cotton acres. Herbicides were applied to 21.8 million acres prior to the planting or emergence of cotton (preemergent) and to 24.5 million acres after the emergence of cotton (postemergent). Of these treatments, 50 percent (23.3 million acres) were made with glyphosate herbicides, and the remaining 50 percent of treatments were made with more than 25 other active ingredients. The number of glyphosate applications on an average cotton acre was between 2 and 3 applications per year at an average rate of 2.0 pounds acid equivalent (a.e.) of glyphosate active ingredient per acre per crop year. Table 7 lists the ten most widely used alternative (i.e., non-glyphosate) herbicides in U.S. cotton production.

Growers choose pesticides based on weed, insect and disease pressures, cost of seed and other inputs, technology fees, human safety, potential for crop injury, and ease and flexibility of the production system (Farnham, 2001; Heiniger, 2000). In selecting an herbicide, a grower must

[5] Monsanto Company. 2011. Farmer Survey Data. St. Louis, MO.

consider, among other factors, whether an herbicide can be used on the crop (herbicides are registered by the EPA for specific uses/crops), the potential adverse effects on the crop, residual effects that can limit crops that can be grown in rotation, effectiveness on expected weeds, and cost.

Table 7. Ten Most Widely Used Alternative Herbicides in U.S. Cotton Production.

Herbicide	2007 Applications (million lb)[1]	2010 Applications (million lb)[1]
Trifluralin	2.8	3.1
Diuron	1.3	1.3
Pendimenthalin	1.3	1.2
S-metolachlor	0.6	1.1
Prometryn	0.6	0.4
2,4-D, dimethylamine salt	0.3	0.4
Fluormeturon	0.3	0.4
MSMA	0.4	0.3
Fomesafen	0.05	0.2
2,4-D, ethylhexyl ester	0.1	0.1

1 (USDA-NASS, 2014d)
Source: Table B-18 (Monsanto, 2013a; USDA-APHIS, 2014d).

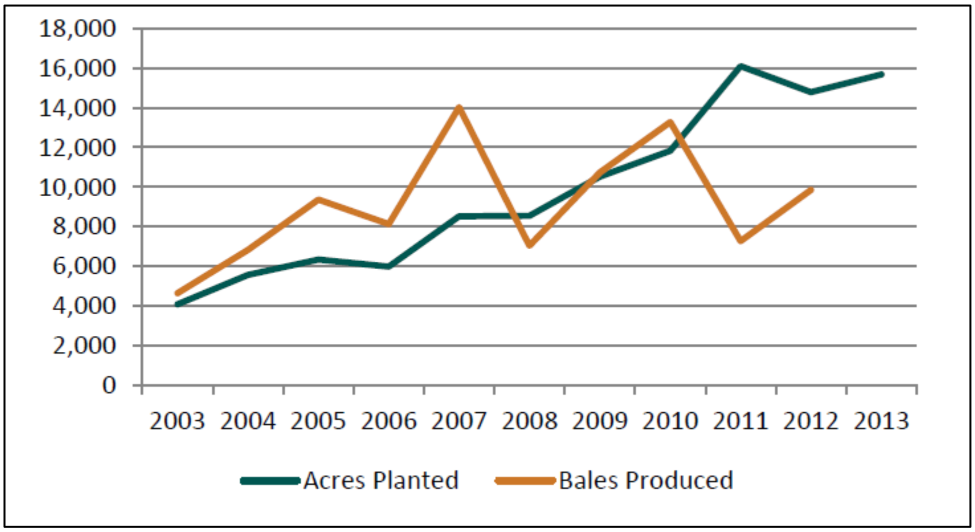
Since more than 53 percent of cotton is repeatedly grown on the same land with only limited utilization of conservation tillage practices (Monsanto, 2013b; USDA-APHIS, 2014d), the use of multiple herbicide modes-of-action with overlapping effectiveness on the targeted weed spectrum is the primary method recommended and employed for weed resistance management (Ashigh et al., 2012; Burgos et al., 2006; Loux et al., 2013; Monsanto, 2013b). The continued emergence of GR weeds will likely require modifications of crop management practices to address these weeds. Herbicide use may increase to meet the need for additional integrated weed management tactics to mitigate HR weeds in different cropping systems (Culpepper et al., 2008; Owen and Zelaya, 2005).

2.3 Organic Cotton Production

Cotton grown without synthetic chemicals such as pesticides and fertilizers is referred to as "organic" (Babu et al., 2013; OTA, 2010) and is certified under the National Organics Program (TOCMC, 2014). Production of organic cotton includes the use of natural defoliants; beneficial insects for pest control; compost, manure, and crop rotations for fertilizers; hand-weeding; mechanical cultivation; cover crops and mulching for weed control. A comparison of conventional cotton and organic fibers showed that morphologically and chemically, the two types of cotton are similar (Babu et al., 2013).

Organic cotton has been produced in the United States since 1991 (Funtanilla et al., 2009). In 2012, the majority of the U.S. organic cotton crop was planted to upland cotton (See Figure 5), with pima cotton representing fewer than 1,000 planted acres (OTA, 2014). Acreage planted in organic cotton increased 36% from 2009 to 2010 (OTA, 2014). According to USDA, in 2011, approximately 12,000 acres of certified organic cotton were planted; this acreage represents 0.08 percent of cotton acreage in the United States (USDA-ERS, 2013b).

The South Plains area of Texas is one of the primary regions for organic cotton production (TOCMC, 2011). Texas (66 percent) and New Mexico (20 percent) together accounted for approximately 86% of this production. In recent years, small and sporadic acreages of organic cotton have been cultivated in other states, including Missouri, Illinois, Kansas, Tennessee, and Colorado (USDA-ERS, 2010). Organic cotton production in the South Plains Texas area benefits from winter temperatures that are cold enough to limit insect pressure and provide a hard freeze to defoliate the cotton plants prior to harvesting, as well as a sunny climate and quick-drying soils to facilitate timely mechanical weed control. As many of these farmers do not irrigate, yields are heavily dependent upon rainfall (TOCMC, 2011).



Source: (OTA, 2014).

Figure 5. U.S. Organic Cotton Acres Planted.

A total of 16,716 acres of organic cotton, representing an additional two percent gain over the next five years, is forecasted to be planted (See Table 8) (OTA, 2014). Limitations on the growth of the U.S. organic cotton industry are tied to challenges also faced by growers of conventional cotton, including weather, geography, weeds, drought, and pests. Also, there is reported to be a limited availability of organic seeds and not much work dedicated to improving cottonseed by traditional breeding techniques (OTA, 2014).

Table 8. Estimated U.S. Organic Acreage Planted.

Year	Organic Planted Acres	Percent Change from Previous Year
2019 Est.	18,614	12%
2014 Est.	16,635	6%
2013	15,685	6%
2012	14,787	-8%
2011	16,050	36%
2010	11,827	12%
2009	10,521	23%
2008	8,539	0%
2007	8,510	43%
2006	5,971	-6%
2005	6,325	14%
2004	5,550	37%
2003	4,060	-55%
2002	9,044	-22%
2001	11,586	-17%
2000	13,926	-17%
1999	16,785	79%
1998	9,368	4%
1997	9,050	-16%
1996	10,778	-56%
1995	24,625	55%
1994	15,856	28%
1993	12,402	97%
1992	6,306	92%
1991	3,290	266%
1990	900	--

Source: (OTA, 2014).

2.4 Physical Environment

2.4.1 Water Resources

Resources analyzed in this section include the quality and quantity of water in surface and groundwater. Impacts from human consumption, particularly irrigation water for agricultural production, are also reviewed. Ground water and surface water in rivers, streams, creeks, lakes, reservoirs, wetlands and estuaries provide water for drinking, irrigation, industrial, recreational and other public uses. About 66 percent of water used in the United States in 2005 (about 410 billion gallons per day) was from fresh surface water sources (USDA-FSA, 2010).

Surface water in rivers, streams, creeks, lakes, and reservoirs provides water for drinking and bathing, irrigation, industrial, and recreational uses. About 66% of water used in the U.S. in 2005 (about 410 billion gallons per day) was from fresh surface water sources (USDA-FSA, 2010). Surface runoff from rain, snowmelt, or irrigation can affect water quality by depositing sediment, minerals, and contaminants into streams, rivers, lakes, wetlands, and coastal waters. The amount of surface runoff is influenced by meteorological factors (such as rainfall intensity and duration), and physical factors (such as vegetation, soil type, and topography).

Groundwater from aquifers sustains ecosystems by releasing a continuous supply of water into wetlands, and permanent streams and rivers. Groundwater flows underground, substantially contributes water to streams and rivers, is stored in natural geologic formations called aquifers, and sustains ecosystems by releasing a constant supply of water. In 2005, groundwater sources contributed about 19 percent of freshwater used in the United States (USDA-FSA, 2010). Approximately 47 percent of the U.S. population depends on groundwater for its drinking water supply (McCray, 2009).

1.1.1.1 Water Use

Both groundwater and surface water can be used for irrigation, which accounted for approximately 28% of withdrawals from fresh surface water sources (USDA-FSA, 2010). Based on 2005 data, the largest use of groundwater in the United States is irrigation, representing approximately 67 percent of all the groundwater pumped each day (McCray, 2009; USDA-FSA, 2010). More than 90 percent of the areas irrigated in Mississippi and Missouri used groundwater (USDA-FSA, 2010). Wells replenished from groundwater often are the only source of irrigation in many locations in the Great Plains (US-EPA, 2012c). Groundwater sources for irrigation are especially important in Arizona, Arkansas, California, Nebraska, and Texas, accounting for nearly 60% of total groundwater withdrawals for irrigation in 2005. In three of these states (Arkansas, Nebraska, and Texas) fresh groundwater accounted for 75 to 96 percent of all irrigation water. In addition to irrigation, water is used in agriculture for pesticide and fertilizer applications, crop cooling (e.g., light irrigation), and frost control (US-CDC, 2013).

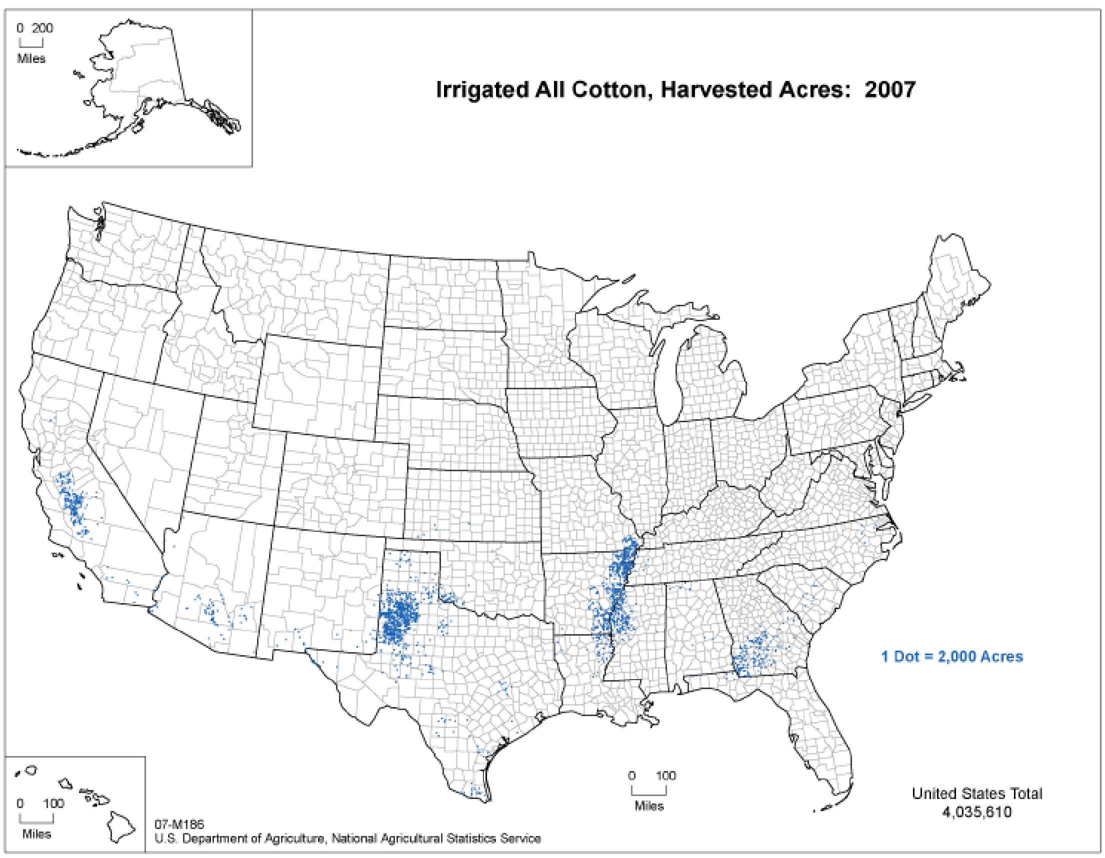
Irrigation maintains adequate moisture for a crop, increasing yields per acre and by making more acreage (i.e., dry lands) usable. Irrigation also moderates fluctuations in product and seed quality. This is because moisture requirements for most cotton crops tend to vary during development, and an adequate water supply allows crop growth during critical periods of the growing cycle. In this way, irrigation can optimize both quality and yield (US-EPA, 2012c). Efficient irrigation can reduce runoff and deep percolation (leaching) losses (TAMU, 2014).

Cotton is generally grown in deep arable soils with good drainage and a high moisture-retention capacity (OECD, 2008). For cotton production, the amount of water needed depends on rainfall and the nature of the soil profile (Rude, 1984). The need for water increases dramatically from less than 1 inch per week at emergence to 2 inches per week at first bloom. The critical period to avoid water stress is during flowering and boll development when peak water use occurs. Drought during this interval causes the plant to shed small squares first. Continued water stress leads to larger squares and then bolls being shed (Rude, 1984; TAMU, 2014). Also, established cotton plants metabolically adapt to cope with periods of water loss, but water stress can cause the shedding of leaves, flowers, and bolls, upset osmosis regulators, and reduce photosynthesis in cotton plants (El-Zik et al., 1989). As water stress increases, cotton plants put more biomass into reproductive growth, and this sequence can be manipulated by growers to increase yield (El-Zik et al., 1989; Gibbs et al., 2005).

On average, at least 500 millimeters of rainfall (about 20 inches) are required during the growing season for non-irrigated cotton crops (OECD, 2008). However, it is also grown as an irrigated crop, where careful timing of irrigation optimizes flowering and boll production (OECD, 2008). From 1980 to 2011, the proportion of irrigated cotton acreage remained relatively constant at approximately 32% (Field to Market, 2012), even though the total irrigated acreage increased because of the increase in total land used for cotton production during that interval. Between 1980 and 2011, total irrigation water applied for U.S. cotton decreased 35% (1.4% compounded annually); total water use was 95.5 million acre inches in 1980 and 62.9 million acre inches in 2011 (Field to Market, 2012).

Irrigation is especially important to agriculture in the western United States and the Mississippi River Valley (Figure 2). Nationally, approximately 40% of cotton acres are irrigated (Schaible and Aillery, 2012; USDA-NASS, 2009). Cotton is heavily irrigated in California, Arizona, western Texas, Georgia, and the Mississippi River Valley (Figure 6).

Figure 6. Irrigated Cotton Acreage in the United States in 2007.



Source: USDA National Agricultural Statistics Service Map # 07-M080 (USDA-NASS, 2009).

1.1.1.2 Water Quality

The principal law governing the nation's water resources is the Federal Water Pollution Control Act of 1972, better known as the Clean Water Act. The Clean Water Act establishes water quality standards, permitting requirements, and monitoring to protect water quality. The EPA sets the standards for water pollution abatement for all waters of the United States under the programs contained in the Clean Water Act, but, in most cases, gives qualified states the authority to issue and enforce permits. Drinking water is protected under the Safe Drinking Water Act of 1974 (Public Law 93-523, 42 U.S.C. 300 *et seq*.) (US-EPA, 2014b).

Unlike a point source, which is a "discernible, confined and discrete conveyance," nonpoint source (NPS) pollution comes from many diffuse sources. Rainfall or snowmelt moving over the ground, also known as runoff, picks up and carries away natural and human-made pollutants, creating NPS pollution. The pollutants may eventually be transported by runoff into lakes, rivers, wetlands, coastal waters, and groundwater. The primary cause of NPS pollution is increased sedimentation in surface waters following soil erosion by surface runoff. Increases in sediment loads to surface waters can directly affect fish, aquatic invertebrates, and other wildlife maintenance and survival. It also reduces the amount of light penetration in water, which directly affects aquatic plants. Indirectly, soil erosion-mediated sedimentation can increase fertilizer runoff, facilitating higher water turbidity, algal blooms, and oxygen depletion (US-EPA, 2005a).

Agricultural NPS pollution is the leading source of impacts on surveyed rivers and lakes and the third largest source of impairment to estuaries, as well as a major source of impairment to groundwater and wetlands (US-EPA, 2011d). Sources of agricultural NPS pollution include animal wastes, fertilizers, and pesticides. Management practices that contribute to NPS pollution include the type of crop cultivated; plowing and tillage; and the application of pesticides, herbicides, and fertilizers.

Use of pesticides for field crop production may introduce these chemicals to water through spray drift, cleaning of pesticide application equipment, soil erosion, or filtration through soil to groundwater. As part of assessing the risk of the exposure of aquatic organisms and the environment to a pesticide, EPA estimates concentrations of pesticides in natural water bodies, such as lakes or ponds. Also as part of the Food Quality Protection Act (FQPA) of 1996, EPA estimates pesticide concentrations in drinking water when it establishes maximum pesticide residues on food (tolerances). For both drinking water and aquatic exposure assessments and for water quality assessments, EPA typically relies on field monitoring data as well as mathematical models to generate exposure estimates (US-EPA, 2012d).

2.4.2 Soil Quality

Soils are a mixture of weathered minerals, organic matter, air and water. Soil properties such as temperature, pH, soluble salts, amount of organic matter, the carbon-nitrogen ratio, numbers of microorganisms, and soil fauna all vary seasonally, and shifts in these parameters also occur over broader extended periods (USDA-NRCS, 1999b).

Cotton is cultivated in a wide variety of soils, but develops best in deep, arable soils with good drainage, high organic content, and a high moisture-retention capacity (OECD, 2008). Irrigation allows cultivation in poor-quality soils with necessary nutrients provided in the irrigation water (OECD, 2008).

Land management practices for crop cultivation also affect soil quality. While practices such as tillage, fertilization, the use of pesticides and other management tools can improve soil health, they can also cause substantial damage if not properly used. Several concerns relating to soil and agricultural practices include increased erosion, soil compaction, degradation of soil structure, nutrient loss, increased salinity, change in pH, and reduced biological activity (USDA-NRCS, 2001).

Conventional tillage removes essentially all plant residues and weeds from the soil surface prior to planting. With conventional tillage, particularly in cotton crops, cultivation may continue to be performed as the crop develops in order to control late emerging weeds (NCGA, 2007);(Frans and Chandler, 1989). This practice increases the potential for soil loss from wind and water erosion (NCGA, 2007). Additionally, soil compaction associated with tillage machinery moving across fields may damage young, developing cotton crops (Mitchell et al., 2012; Rude, 1984).

2.4.3 Air Quality

Agricultural operations can affect air quality by releasing particulates, gases, and other chemicals into the air. Primary sources of emissions associated with crop production include exhaust from motorized equipment, such as tractors and irrigation equipment; suspended soil particulates from tillage and wind-induced erosion; smoke from burning of fields; drift from sprayed pesticides; and nitrous oxide emissions from the use of nitrogen fertilizer (Aneja et al., 2009; Hoeft et al., 2000; US-EPA, 2011b; USDA-NRCS, 2006a).

The Clean Air Act and its amendments identify air pollutants that may affect air quality and, subsequently, human health and the environment. Key pollutants regulated by EPA and states (or local regulatory agencies) are identified under the National Ambient Air Quality Standards (NAAQS) and are known as "criteria pollutants". The Clean Air Act requires the maintenance of NAAQS and establishes health-based limits for six criteria pollutants: ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), lead (Pb), and inhalable particulates (coarse particulate matter [PM] greater than 2.5 micrometers and less than 10 micrometers in diameter [PM_{10}] and fine particles less than 2.5 micrometers in diameter [$PM_{2.5}$]).[6] The main criteria pollutants associated with agricultural activities are PM and ozone precursors (pollutants that lead to the formation of ozone)[7] (USDA-NRCS, 2011).

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[6] Particulate matter is made up of a number of different compounds, including acids (such as nitrates and sulfates), organic chemicals, metals, soil or dust particles, and allergens (pollen or mold spores). According to the EPA, particulates with diameters less than 10 micrometers have the greatest potential to impact human health, as these small particles can get deep into the lungs, with some even entering the bloodstream. Larger particulates do not present as serious health concerns, but may irritate the eyes, nose and throat. (http://www.epa.gov/airnow/particle/pm-color.pdf)
Particulate deposition may adversely affect ecosystems by causing nuisance dusting, changing pH balance, damaging plants or by adding additional nitrogen to the environment.
http://www.airquality.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1080891.pdf

[7] Ground-level ozone is not usually directly emitted, but formed in the atmosphere as a result of chemical reactions of other compounds. As a result, ozone precursors such as VOCs and NO_x are regulated.

The CAA requires states to achieve and maintain the NAAQS within their jurisdiction. Each state may adopt requirements stricter than those of the national standard. Airsheds within each state, mostly broken up as counties, are determined by EPA to be either in attainment or in nonattainment for each criteria pollutant under the NAAQS. For airsheds that are in nonattainment, states are required by EPA to prepare a State Implementation Plan containing strategies to achieve and maintain the national standard of air quality.

Varying sizes of PM emissions, including $PM_{2.5}$, arise from direct releases of dust from roads, harvesting, or tillage, as well as smoke from combustion processes. In addition, PM may be formed by atmospheric chemical reactions of PM precursor pollutants, such as ammonia (NH_3), oxides of nitrogen (NOx), VOCs, and sulfur dioxide (SO_2). Sources of PM precursor gases include engines, fertilizer application, and animal operations (USDA-NRCS, 2012c). In agriculture, VOCs can be formed as a result of decomposition of biological materials, including manure and feed, combustion from farm equipment, burning of biological materials, or pesticide application. NO_x is also formed as a result of the breakdown or decomposition process, primarily from nitrification/denitrification, and fuel combustion and burning (USDA-NRCS, 2012b). Overall, there are not many areas of the U.S. where agricultural sources are substantially responsible for nonattainment of the PM and ozone NAAQS (USDA-NRCS, 2011; USDA-NRCS, 2012b).

Particulates may be released through a variety of agricultural practices (Lemieux et al., 2004; Yang and Sheng, 2003). Burning releases smoke, exhaust from motorized equipment may release criteria pollutants, and cropping activities (such as planting, tillage, and harvesting) generate airborne soil particulates when growers use motorized equipment (Lemieux et al., 2004). Tillage releases particulate matter into the air (Madden et al., 2009) as soil is disturbed. Reductions in tillage generate fewer suspended particulates (Farm-Industry-News) and lower rates of soil wind erosion (Towery and Werblow, 2010c). Tillage also is associated with increased emissions from farm equipment burning fossil fuels. Reducing the number of times tillage is done through a growing season reduces these vehicle emissions. Both of these benefits to air quality are variable and are affected by factors such as soil moisture and the specific tillage regime employed.

Prescribed burning is a land treatment, used under controlled conditions, to accomplish resource management objectives: insect and disease management, reduction in pesticide and herbicide usage, and reducing the potential of wildfires which results in the improvement in long- term air quality (US-EPA, 2012b). Open combustion produces particles of widely ranging size, depending to some extent on the rate of energy release of the fire (US-EPA, 2011a). The extent to which agricultural and other prescribed burning may occur is regulated by individual SIPs to achieve compliance with the NAAQS. Prescribed burning of fields would likely occur only as a pre-planting option for cotton production, based on individual farm needs.

Gases, such as carbon dioxide (CO_2), hydrocarbons, other volatile organic compounds, and methane, are released through equipment exhaust (particularly diesel exhaust), disturbance of the soil inducing population changes among the microbial flora, and animal production facilities, while fertilizer applications are associated with release of oxides of nitrogen, particularly during their manufacture (Aneja et al., 2009; Cambra-Lopez et al., 2010; US-EPA, 2011b; USDA-NRCS, 2006a; Zhao, 2007). Aerosols from pesticide and fertilizer applications to crops are another source of molecules that impact air quality. The effects of aerosols are complex because these various molecules can: 1) drift from the target site, 2) volatilize to increase the area impacted, and 3) adsorb onto soil particles (Felsot, 2005; Hernandez-Soriano et al., 2007). Tillage and wind-induced erosion may lead to suspended soil particles in the air and adsorbed aerosols becoming airborne (Felsot, 2005; Hernandez-Soriano et al., 2007). Vapor aerosol particles contribute to the formation of haze and decrease visibility (Zhao, 2007).

USDA-National Resources Conservation Service (NRCS) has approved conservation systems and activities aimed at targeting air emissions from agricultural sources in areas where these activities are impacting air quality. These practices may be implemented to achieve reasonably available control measure and best available control measure levels of control (USDA-NRCS, 2012a). Other conservation practices, as required by USDA to qualify for crop insurance and beneficial federal loans and programs (USDA-ERS, 2009), effectively reduce crop production impacts to air quality through the employment of windbreaks, shelterbelts, reduced tillage, and cover crops that promote soil protection on highly erodible lands.

Practices to improve air quality include conservation tillage, residue management, wind breaks, road treatments, burn management, prunings shredding, feed management, manure management, integrated pest management, chemical storage, nutrient management, fertilizer injection, chemigation and fertigation (inclusion in irrigation systems), conservation irrigation, scrubbers, and equipment calibration (USDA-NRCS, 2006a). Conservation tillage practices resulting in improved air quality include: fewer tractor passes across a field, thus decreasing dust generation and tractor emissions; and an increase in surface plant residues and untilled organic matter which physically hold the soil in place and reduce wind erosion (Baker et al., 2005; USDA-NRCS, 2006a). The USDA has estimated that the adoption of conservation management plans in the San Joaquin Valley of California had reduced air emissions by 34 tons daily, or more than 20 percent of the total emissions attributed to agricultural practices after a year of implementation (Baker et al., 2005; USDA-NRCS, 2006a).

Fertilizers and pesticides applied to soil and plant surfaces may also introduce chemicals to the air which then may affect nontarget animal or plant species, including humans. Pesticide spraying may impact air quality through both drift and diffusion. Drift is defined by EPA as “the movement of pesticide through air at the time of application or soon thereafter, to any site other than that intended for application” (US-EPA, 2000). Pesticides are typically applied to crops by ground spray equipment or aircraft. Small, lightweight droplets are produced by equipment nozzles. Many droplets are small enough to remain suspended in air for long periods allowing them to be moved by air currents until they adhere to a surface or drop to the ground. Diffusion is gaseous transformation to the atmosphere (FOCUS, 2008). Pesticides applied to crops may volatilize, thereby introducing chemicals to the air. Volatilization occurs when pesticide surface residues change from a solid or liquid to a gas or vapor after application. Once airborne, volatilized pesticides may be carried long distances from the treatment location by air currents. In addition to impacting air quality, vapor drift can lead to injury of nontarget species (this is further discussed under Plant Communities).

The amount of drift varies widely and is influenced by a range of factors, including weather conditions, topography, the crop or area being sprayed, application equipment and methods, and other practices followed by the applicator. For example, the fine droplet size of pesticides applied through center-pivot irrigation systems can lead to evaporation and drift unless minimized by addition of Low Elevation Spray Application applicators or Low Energy Precision Application irrigation methods (New and Fipps, 2000).The EPA defines volatilization as the point "when pesticide surface residues change from a solid or liquid to a gas or vapor after an application of a pesticide has occurred" (US-EPA, 2014c). Volatilization of herbicides and pesticides from soil and plant surfaces introduces these chemicals into the air.

The EPA's Office of Pesticide Programs, which regulates the use of pesticides in the U.S., introduced initiatives to help pesticide applicators minimize off-target drift. Currently, EPA-OPP is evaluating new regulations for pesticide drift labeling, and developing voluntary best management practices (BMPs) to aid in reducing drift, as well as identifying scientific issues surrounding field volatility of conventional pesticides (US-EPA, 2010b). Such practices can effectively reduce crop production impacts to air quality and may include deployment of windbreaks, shelterbelts, reduced tillage, and cover crops that promote soil protection on highly erodible lands (USDA-ERS, 2009).

2.4.4 Climate Change

Climate change represents a statistical change in global climate conditions, including shifts in the frequency of extreme weather (Cook et al., 2008; Karl et al., 2008). EPA has identified carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) as the key greenhouse gases (GHG) affecting climate change. While each of these gases occurs naturally in the atmosphere, human activity has significantly increased the concentrations of these gases since the beginning of the industrial revolution. The level of human-produced gases accelerated even more so after the end of World War II, when industrial and consumer consumption intensified. Since the beginning of the industrial age, there has been a 36 percent increase in the concentration of CO_2, a 148 percent increase in CH_4, and a 18 percent increase in N_2O (US-EPA, 2011c).

U.S. agriculture may influence climate change through various facets of the crop production process (Horowitz and Gottlieb, 2010). The major sources of GHG emissions associated with crop production are soil N_2O emissions, soil CO_2 and CH_4 fluxes, CO_2 emissions associated with agricultural inputs, and farm equipment operation (Adler et al., 2007; Del Grosso et al., 2002; Robertson et al., 2000; West and Marland, 2002). During the 20-year period of 1990 to 2009, total emissions from the agricultural sector grew by 8.7 percent with 7 percent of the total U.S. GHG emissions in 2009 generated from this sector (US-EPA, 2011c).

Agricultural soil management activities including fertilizer application and cropping practices were the largest source of N_2O emissions, accounting for 69 percent of all U.S. N_2O emissions (US-EPA, 2011c). Agricultural practices that produce CO_2 emissions include liming and the application of urea fertilization to agricultural soils. Because CO_2 and CH_4 are two of the key gases most responsible for the "Greenhouse Effect," scientists and policy makers are interested in carbon (C) gases and how they may be removed from the atmosphere and stored. The process of C moving from the atmosphere to the earth and back is referred to as the carbon cycle. Simplified components of the carbon cycle are:

- Conversion of atmospheric C to carbohydrates through the process of photosynthesis;
- Consumption of carbohydrates and respiration of CO_2;

- Oxidation of organic carbon creating CO_2; and
- Return of CO_2 to the atmosphere.

Carbon can be stored in four main pools other than the atmosphere: 1) the earth's crust, (sequestered in fossil fuels and sedimentary rock deposits); 2) the oceans, which contain CO_2 in solution, some of which is incorporated by marine life into shells, corals, and other relatively stable structures composed of calcium carbonate ($CaCO_3$); 3) in soil organic matter (Babu et al.); and 4) within all living and dead organisms that have not been converted to soil organic matter. These pools can serve as "sinks" or storage reservoirs of carbon for long periods, as in the case of C stored in sedimentary rock and in the oceans. Conversely, C may be held for as short a period as the life span of an individual organism.

Humans can affect the carbon cycle through activities such as the burning of fossil fuels, deforestation, or releasing soil organic carbon through activities that disturb the soil. The process of storing C in the ecosystem is termed carbon sequestration. Carbon sequestration includes storage of C in both aerial and below-ground structures of photosynthetic plants ("plant biomass"), and in the soil. Soil C can be found in the bodies of microorganisms (e.g., fungi and bacteria), in non-living organic matter, and in association with inorganic minerals in the soil.

Tillage is one agricultural practice that contributes to the release of GHG because it results in exposure of soil organic matter to the atmosphere, allowing oxidation of carbon compounds in soil, resulting in the evolution of CO_2 that is released to the atmosphere; conversely, reductions in GHG emissions as a result of reduced exposure and oxidation of soil organic matter are often attributed to conservation tillage practices (Adler et al., 2007; CAST, 2009; Towery and Werblow, 2010b; US-EPA, 2009). Also, practices such as 1) eliminating fallow and keeping the soil covered with residue, cover crops or perennial vegetation, which have the potential to increase soil organic carbon; and 2) avoiding over application and using split N application rates to meet plant needs, which would reduce N_2O emission and minimize potential water degradation; can help to improve the accuracy of determining changes in soil organic carbon and GHG emissions, reducing the number of uncertainty in calculating global warming potential (Johnson et al., 2007).

Global climate change may also affect agricultural crop production (USGCRP, 2009). These potential impacts on the agro-environment and individual crops may be direct and include changing patterns in precipitation, temperature, and duration of growing season, or they may cause indirect impacts influencing weed and pest pressure (Rosenzweig et al., 2001; Schmidhuber and Tubiello, 2007).

2.5 Biological Resources

Agricultural land subject to intensive farming practices, such as that used in crop production, generally has low levels of biodiversity compared with adjacent natural areas. Biodiversity is strongly impacted by agricultural practices, including the type of cultivated plant and its associated management practices. Modern conservation practices incorporated in cotton cultivation have brought a positive impact to animal and plant communities through reduced tillage, more carefully controlled and targeted chemical placement (fertilizers and pesticides), and better control of irrigation systems (Ward et al., 2002).

Conservation tillage practices that leave greater amounts of crop residue serve to increase the diversity and density of birds and mammals (Sharpe, 2010a; USDA-NRCS, 1999). Increased residue also provides habitat for insects and other arthropods, increasing this food source for insect predators. The increased use of conservation tillage practices has benefitted wildlife through improved water quality, availability of waste grain, retention of cover in fields, and increased populations of invertebrates (Sharpe, 2010b; Towery and Werblow, 2010b).

The degree of biodiversity in an agroecosystem depends on four primary characteristics: 1) diversity of vegetation within and around the agroecosystem; 2) permanence of various crops within the system; 3) intensity of management; 4) extent of isolation of the agroecosystem from natural vegetation (Altieri, 1999; Carpenter, 2011b).

2.5.1 Animal Communities

Cotton production systems in agriculture are host to many animal species. Mammals and birds may use cotton fields and the surrounding vegetation for food and habitat throughout the year. Invertebrates can feed on cotton plants or prey upon other insects living on cotton plants, as well as in the vegetation surrounding cotton fields. The biological resources described in this section include animals, plants, and microorganisms. This summary provides the foundation to assess the potential impact to plant and animal communities. Threatened and endangered species are discussed in Chapter 6. Insects considered pests to cotton are discussed under Insect and Pest Management, Section 2.2.4.

2.5.1.1 . Birds, Mammals, and Reptiles

Agricultural fields have the potential to provide food, water, and habitat for birds but each landowner's farming practices and the crop type determines the value of these lands to wildlife. In the Cotton Belt, birds generally avoid cotton fields, although some generalist species (geese, egrets, gulls, and blackbirds) may periodically be observed in cotton fields (Butcher et al., 2007). Geese (Canada goose (*Branta canadensis*), snow goose (*Chen caerulescens*), and greater white-fronted geese (*Anser albifrons*) and the northern pintail (*Anas acuta*) have been observed foraging in fallow or disked cotton fields that were flooded to enhance habitat for nonbreeding waterfowl during the fall or winter (Butcher et al., 2007; Fleskes et al., 2003). Cattle egrets (*Bubulcus ibis*) use the cotton fields in the summer, which could be in response to increased invertebrate densities (Mora, 1997).

2.5.1.2 Invertebrates

Invertebrates can feed on cotton plants or prey upon other insects living on cotton plants, as well as in the vegetation surrounding cotton fields. More than 1,326 species of insects have been reported in commercial cotton fields worldwide, but only a small proportion are pests (Boyd et al., 2004; GTR, 2002; Knutson and Ruberson, 2005). Insect injury can impact yield, plant maturity, and seed quality. Consequently, insect pests are managed during the growth and development of cotton to preserve cotton yield (Boyd et al., 2004; Catchot et al., 2008).

Insects and other invertebrates can be beneficial cotton production, providing services such as nutrient cycling and preying on plant pests. Table 9 lists the major beneficial arthropods in cotton fields. Beneficial insects include a wide variety of predators, which catch and eat smaller insects and parasitic insects that live on or in the body of other insects during at least one stage of their life cycle (USDA-NRCS, 2014) (Table 10). Other beneficial insects function as pollinators. Major pollinators of *G. hirsutum* are bumble bees (*Bombus* spp.), black bees (*Melissodes* spp.), and honey bees (*Apis mellifera*) (Catchot et al., 2008; USDA-NRCS, 2014). Other beneficial organisms, including earthworms, termites, ants, beetles, millipedes, and others contribute to the decay of organic matter and the cycling of soil nutrients (Catchot et al., 2008; Ruiz et al., 2008).

Table 9. Major Beneficial Arthropods in Cotton.

Cotton	
Beneficial Species or family	**Targeted Stage or Species**
Honey bee (*Apis mellifera)*	[Pollinator]
Predators	
Ants (Formicidae)	Bollworm eggs and larvae
Ambush and assassin bugs (Reduviidae)	Aphids, bollworm eggs, larvae
Bigeyed bugs (*Geocoris* spp.)	Aphids, bollworm eggs, larvae
Pirate bugs (Anthocoridae)	Aphids, bollworm eggs, larvae, thrips, whiteflies, spider mites
Damsel bugs (Nabidae)	Aphids, bollworm eggs, larvae
Lacewing larvae (Chyrsopidae)	Aphids, bollworm eggs, larvae
Ladybird beetles (Coccinellidae)	Aphids, spider mites, bollworm eggs, budworm eggs
Ant, Fire (*Solenopsis* spp)	Immature boll weevils, bollworm eggs, budworm eggs
Cotton fleahopper	Bollworm eggs, budworm eggs
Spiders	
Parasitoids	
Parasitic wasps *(Trichogramma* spp.)	Bollworm eggs
Parasitic wasps (*Cardiochiles* spp.)	Budworm eggs

Source: (Bohmfalk et al., 2011)

Table 10. Pest Species of Cotton Plants and Beneficial Insects that Prey on These Species

Pest Species	Natural Enemies (Beneficial Predator Insects)
Thrips (Thysanoptera)	Minute pirate bug (N,A), Insidious flower bug (N,A)
Lygus Bugs/ Fleahoppers *(Lygus hesperus)*	Big-eyed bug (N,A), Leafhopper assassin bug (N,A), Spined assassin bug (N,A), Jumping spiders (N,A), Lynx spiders (N,A), Celer crab spider (N,A), Minute pirate bug (N,A), Insidious flower bug (N,A), Damsel bugs (N,A), Spined soldier bug (N,A), Fire ants (N,A), *Anaphes iole* (E)
Cotton Aphid *(Aphis gossypii)*	Seven-spotted lady beetle (N,A), Harmonia or Asian lady beetle (N,A), Convergent lady beetle (N,A), Pink spotted lady beetle (N,A),

Pest Species	Natural Enemies (Beneficial Predator Insects)
	Scymnus lady beetle (N,A), Green lacewings (N,A), Brown lacewings (N,A), Hover flies (N,A), *Lysiphlebus testaceipes* (N,A), Cotton aphid fungus
Boll Weevil *(Anthonomus grandis)*	Fire ants (L), Leafhopper assassin bug (A), Spined assassin bug (A), Jumping spiders (A), *Bracon mellitor* (L), *Catolaccus grandis* (L)
Tobacco Budworm *(Heliothis virescens)*	Seven-spotted lady beetle (E,L), Harmonia lady beetle (E,L), Convergent lady beetle (E,L), Pink spotted lady beetle (E,L), Scymnus lady beetle (E), Green lacewings (E,L), Brown lacewings (E,L), Big-eyed bugs (E,L), Leafhopper assassin bug (L), Spined assassin bug (L), Jumping spiders (E,L), Lynx spiders (L), Celer crab spider (L), Minute pirate bug (E,L), Insidious flower bug (E,L), Damsel bugs (E,L), Spined soldier bug (E,L), Fire ants (E,L), Collops beetle (E,L), Earwigs (E,L), Ground beetles (E,L), *Trichogramma* (E), *Archytas* (L), Other tachinidflies (L), *Cotesia marginiventris* (L), *Cardiochiles nigriceps* (L), *Chelonus insularis* (E), *Microplitis croceipes* (L
Cotton Bollworm *(Helicoverpa zea)*	Seven-spotted lady beetle (E,L), Harmonia lady beetle (E,L), Convergent lady beetle (E,L), Pink spotted lady beetle (E,L), Scymnus lady beetle (E), Green lacewings (E,L), Brown lacewings (E,L), Bigeyed bugs (E,L), Leafhopper assassin bug (L), Spined assassin bug (L), Jumping spiders (E,L), Lynx spiders (L), Celer crab spider (L), Minute pirate bug (E,L), Insidious flower bug (E,L), Damsel bugs (E,L), Spined soldier bug (E,L), Fire ants (E,L), Collops beetle (E,L), Earwigs (E,L), Ground beetles (E,L), *Trichogramma* (E), *Archytas* (L), Other tachinid flies (L), *Cotesia marginiventris* (L), *Chelonus insularis* (E), *Microplitis croceipes* (L)
Pink Bollworm *(Pectinophora gossypiella)*	*Trichogrammatoidea bactrae* (E)
Beet Armyworm/ Fall Armyworm *(Spodoptera exigua)*	Seven-spotted lady beetle (E,L), Harmonia lady beetle (E,L), Convergent lady beetle (E,L), Pink spotted lady beetle (E,L), Scymnus lady beetle (E,) Green lacewings (E,L), Brown lacewings (E,L), Big-eyed bugs (E,L), Leafhopper assassin bug (L), Spined assassin bug (L), Jumping spiders (L), Lynx spiders (L), Celer crab spider (L), Minute pirate bug (E,L), Insidious flower bug (E,L), Damsel bugs (E,L), Spined soldier bug (L), Fire ants (E,L), Collops beetle (E), Earwigs (E), Ground beetles (E,L), *Archytas* (L), Other tachinid flies (L), *Cotesia marginiventris* (L), *Meteorus* (L), *Chelonus insularis* (E), Nuclear polyhedrosis virus (L).
Soybean Looper/ Cabbage Looper (*Copidosoma* is specific to soybean looper) **(***Acrosternum hilare)*	Seven-spotted lady beetle (E,L), Harmonia lady beetle (E,L), Convergent lady beetle (E,L), Pink spotted lady beetle (E,L), Scymnus lady beetle (E), Green lacewings (E,L), Brown lacewings (E,L), Big-eyed bugs (E,L), Leafhopper assassin bug (L), Spined assassin bug (L), Jumping spiders (L), Lynx spiders (L), Celer crab

Pest Species	Natural Enemies (Beneficial Predator Insects)
	spider (L), Minute pirate bug (E,L), Insidious flower bug (E,L), Damsel bugs (E,L), Spined soldier bug (L), Fire ants (E,L), Collops beetle (E), Earwigs (E), Ground beetles (E,L), *Trichogramma* (E), *Cotesia marginiventris* (L), *Meteorus* (L), *Copidosoma* (E), Nuclear polyhedrosis virus (L)
European Corn Borer *(Ostrinia nubilalis)*	*Macrocentrus grandii* (L)
Stink Bugs *(Halyomorpha halys)*	*Telenomus wasps* (E), *Trissolcus* wasps (E)
Spider Mites ***(****Tetranychus urticae)*	Six-spotted thrips (E), Western predatory mite (E,N,A), Stethorus (E,N,A), Minute pirate bug (E,N,A), Insidious flower bug (E,N,A), Green lacewings (E,N,A)
Whiteflies ***(****Bemisia argentifolii)*	Minute pirate bug (N,A), Green lacewings (N,A), Collops beetles (N,A), Big-eyed bugs (N,A), Whitefly parasites (N), Convergent lady beetles

Source: (Knutson and Ruberson; USDA-NRCS, 2014)
Source: (Knutson and Ruberson, 2005).
Notes:
Parenthetical letters designate life stages of the pest attacked by the natural enemy: (E) = eggs, (N) = nymphs, (L) = larvae, (A) = adults

Aquatic ecosystems potentially impacted by agricultural activities include water bodies adjacent to or downstream from crop field, including impounded bodies, such as ponds, lakes, and reservoirs, and flowing waterways, such as streams or rivers. If near coastal areas, aquatic habitats affected by agricultural production may also include marine ecosystems and estuaries. Aquatic species that may be exposed to sediment from soil erosion and, nutrients and pesticides from runoff and atmospheric deposition include freshwater and estuarine/marine fish and invertebrates, and freshwater amphibians. Although some ecological research has shown that farming practices can be detrimental to stream health (Genito et al., 2002), recently some research suggests that agricultural lands may support diverse and compositionally different aquatic invertebrate communities when compared to nearby urbanized areas (Lenat and Crawford, 1994; Stepenuck et al., 2002; Wang et al., 2000).

2.5.2 Plant Communities

The landscape surrounding a cotton field varies depending on the region. In certain areas, cotton fields may be bordered by other cotton (or other crop) fields or may also be surrounded by woodland, rangelands, and pasture or grassland areas. These plant communities may be natural or managed plant habitats for the control of soil and wind erosion and serve as wildlife habitats. Surrounding plants may be impacted, both positively and negatively, by agricultural operations. Fertilizers and water may run off into adjacent lands, resulting in increased plant growth outside the field margins.

The affected environment for growing cotton plants can generally be considered the agroecosystem (managed agricultural fields), plus some area extending beyond intended plantings. Plants, extraneous to the crop, which grow in planted fields, can be considered weeds . Cotton agronomic performance can be reduced by weed competition for water, nutrients, and light.

Plants are classified as annuals, biennials, or perennials. An annual is a plant that completes its lifecycle in 1 year or less and reproduces only by seed. Biennials are plants that complete their life cycles in two years. Perennials are plants that live for more than two years. Plants are also classified as broadleaf (dicots) or grass (monocots). Plants can reproduce by seeds, rhizomes (underground creeping stems), or other underground parts. Many plant species occur as weeds in fields. Cotton is a dicot perennial plant but mostly grown as an annual as it cannot withstand frost.

Weeds allowed to compete with crops can ultimately result in crop yield loss. Once the critical period of weed control has been reached, if weed control is delayed, the yield loss can increase fairly rapidly (Knezevic et al., 2003). As with other crops, damage to cotton due to competition with weed populations is a function of species composition, density, and duration of that population (Coble and Byrd, 1992). Across the Cotton Belt, many annual and perennial weeds occur, resulting in economic damage to cotton yield, fiber quality, and economic returns. Barnyardgrass, crabgrass, pigweed spp. (including Palmer amaranth), morningglory spp., common cocklebur, and common lambsquarters are common annual weed species in almost all cotton-growing regions. Johnsongrass, bermudagrass, and nutsedge are common perennial weed species. Nightshade spp. and groundcherry are more common in the Southwest and West regions. Palmer amaranth, morningglory spp., and nutsedge spp. have been frequently reported as hard-to-control weed species in cotton (Webster et al., 2009). Table 11 summarizes the most common weeds for each of the four major cotton growing regions (Southeast, Midsouth, Southwest and West).

Table 11. Common Weeds in Cotton Production.[1]

Common Weeds in Cotton		
Southeast Region[2]		
Crabgrass spp. (6)	Pigweed spp (3)	Crowfootgrass (1)
Morningglory spp (6)	Common cocklebur (2)	Horseweed (marestail) (1)
Prickly sida (5)	Common lambsquarters (2)	Jimsonweed (1)
Florida pusley (4)	Common ragweed (2)	Johnsongrass (1)
Nutsedge spp. (4)	Florida beggarweed (2)	Smartweed spp. (1)
Sicklepod (4)	Palmer amaranth (2)	Spurge spp (1)
Broadleaf signalgrass (3)	Texas millet (2)	Volunteer peanut (1)
Goosegrass (3)	Bermudagrass (1)	
Midsouth Region[3]		
Morningglory spp (5)	Velvetleaf (3)	Common cockleburr (1)
Broadleaf signalgrass (4)	Barnyardgrass (2)	Cutleaf evening-primrose (1)
Crabgrass spp (4)	Horseweed (marestail) (2)	Goosegrass (1)
Nutsedge spp (4)	Johnsongrass (2)	Hemp sesbania (1)
Prickly sida (4)	Palmer amaranth (2)	Henbit (1)
Spurge spp (4)	Bermudagrass (1)	Spurred anoda (1)
Pigweed spp (3)	Browntop millet (1)	

Common Weeds in Cotton		
Southwest Region[4]		
Johnsongrass (4)	Pigweed spp (2)	Smartweed (1)
Nutsedge spp (4)	Russian thistle (2)	Smellmelon (1)
Common cockleburr (3)	Barnyardgrass (1)	Spurred anoda (1)
Palmer amaranth (3)	Bermudagrass (1)	Red Sprangletop (1)
Silverleaf Nightshade (3)	Bindweed, field (1)	Sunflower (1)
Common lambsquarters (2)	Foxtail spp (1)	Texas blueweed (1)
Large Crabgrass (2)	Groundcherry spp (1)	Texas millet (2)
Devil's claw (2)	Kochia (1)	Velvetleaf (1)
Morningglory spp (2)	Horseweed (marestail) (1)	Woolyleaf bursage (1)
Mustard spp (2)	Shepardspurse (1)	
West Region[5]		
Barnyardgrass (2)	Common lambsquarters (1)	Silverleaf Nightshade (1)
Morningglory spp (2)	Johnsongrass (1)	Palmer amaranth (1)
Sprangletop (2)	Junglerice (1)	Common Purslane (1)
Bermudagrass (1)	Nutsedge spp (1)	Horse Purslane (1)
Field Bindweed (1)	Pigweed spp (1)	Volunteer corn (1)
Cupgrass, southwestern (1)	Black Nightshade (1)	
Groundcherry spp (1)	Hairy Nightshade (1)	

1 Source: (Monsanto, 2013b)
2 Number provided in parenthesis is the number of states out of the six total states (AL, FL, GA, NC, SC, and VA) in the Southeast Region reporting each weed as one of the ten most common weeds.
3 Number provided in parenthesis is the number of states out of the five total states (AR, LA, MS, MO, and TN) in the Midsouth Region reporting each weed as one of the ten most common weeds.
4 Number provided in parenthesis is the number of states out of the four total states (KS, OK, TX, and NM) in the Southwest Region reporting each weed as one of the ten most common weeds.
5 Number provided in parenthesis is the number of states out of the two total states (AZ and CA) in the West Region reporting each weed as one of the ten most common weeds.

With increased rates of conservation tillage, there has been an observed decrease in large-seeded broadleaf weeds and an increase in perennial, biennial, and winter annual weed species (Durgan and Gunsolus, 2003; Green and Martin, 1996). The growth and spread of some perennial species that reproduce by spread of underground structures, e.g., rhizomes, may be encouraged by conservation tillage, requiring modification of tillage and/or herbicide treatments for effective control. This has in some cases led to increased use of glyphosate, which when applied repeatedly to areas infested with perennial weeds can be effective in eliminating them. However, this practice also exposes these weed populations to repeated selection with this herbicide and could lead to the evolution of GR populations that must then be managed by other means, including the use of herbicides with different modes of action and more aggressive tillage regimes (Shrestha et al., 2006). Winter perennials are particularly competitive and difficult to control because these weeds re-grow every year from rhizomes or root systems (DAS, 2010b).

It is recognized that in some agricultural systems, cotton can volunteer in a subsequent rotational crop. Cotton is not listed as a weed in major weed references, nor is it present on the lists of noxious weed species distributed by the federal government (7 CFR part 360). Cotton does not possess any of the attributes commonly associated with weeds, such as long persistence of the seed in the soil, ability to disperse, invade, or become a dominant species in new or diverse landscapes, or the ability to compete well with native vegetation.

Volunteer cotton is an issue for growers when much seed may germinate in a spring crop after a dry fall (Fromme et al., 2011). Following harvest, cotton volunteers are an important issue, because most cotton-producing states have an active Boll Weevil Eradication Program, one of whose goals is to destroy cotton so that it cannot persist after harvest and support weevil growth. These programs are directed by various state and regional organizations. Directives from the Program authorities for support of weevil control measures are enforced by state laws and authorities. Cotton producers must destroy cotton stalks after cotton harvest for successful boll weevil eradication, which focuses on removal of over-wintering habitat and breeding sites for boll weevils. Growers must destroy cotton stalks by a published date each year. Growers remove these cotton stalks by applying the herbicide 2-4,D and additionally may shred cotton stalks or plow them up (Robertson et al., 2002).

2.5.3 Microorganisms

The inorganic and organic matter comprising soil is home to a wide variety of fungi, bacteria, and arthropods, as well as the growth medium for terrestrial plant life (USDA-NRCS, 2004). These organisms are responsible for a wide range of activities that impact soil health and plant growth. Soil microorganisms play a key role in soil structure formation, decomposition of organic matter, toxin removal, nutrient cycling, and most biochemical soil (Garbeva et al., 2004). These microorganisms also suppress soil-borne plant diseases and promote plant growth (Doran et al., 1996). The main factors affecting microbial population size and diversity include soil type (texture, structure, organic matter, aggregate stability, pH, and nutrient content), plant type (providers of specific carbon and energy sources into the soil), and agricultural management practices (crop rotation, tillage, application of herbicide and fertilizer, and irrigation) (Garbeva et al., 2004).

Decomposers, such as bacteria, actinomycetes (filamentous bacteria), and saprophytic fungi, degrade plant and animal remains, organic materials, and some pesticides (USDA-NRCS, 2004). Other organisms, such as protozoa, mites, and nematodes, consume the decomposer microbes and release macro- and micronutrients, making them available for plant usage.

Plant roots, including those of cotton, release a variety of compounds into the soil, creating a unique environment for microorganisms in the rhizosphere. Microbial diversity in the rhizosphere may be extensive and differs from the microbial community in the bulk soil (Garbeva et al., 2004). Also, another important group of soil microorganisms are the mutualists—the mycorrhizal fungi, nitrogen-fixing bacteria, and some free-living microbes that have co-evolved with plants and supply nutrients to and obtain food from their plant hosts (USDA-NRCS, 2004).

The occurrence and abundance of soil microorganisms are affected by 1) soil characteristics like tilth, organic matter, nutrient content, and moisture capacity, 2) typical physico-chemical factors such as temperature, pH, and redox potential, and 3) soil management practices. Agricultural practices such as fertilization and cultivation may also have profound effects on soil microbial populations, species composition, colonization, and associated biochemical processes (Buckley and Schmidt, 2001; Buckley and Schmidt, 2003; Donegan and Seidler, 1999). Consequently, significant variation in microbial populations is expected in agricultural fields. Agricultural practices such as fertilization and cultivation may also have profound effects on soil microbial populations, species composition, colonization, and associated biochemical processes (Buckley and Schmidt, 2001; Buckley and Schmidt, 2003). Consequently, significant variation in microbial populations is expected in agricultural fields.

2.6 Human Health

The human health environment consists primarily of agricultural worker health and the health of the general public. Agricultural workers are most often directly exposed to agricultural activities. In contrast, the general public is directly exposed to agricultural activities to a much lesser extent, with indirect exposure to agricultural activities and the products of agricultural production occurring much more frequently.

2.6.1 Worker Health and Safety

Approximately 3.1 million people in the United States are reported as farm workers, representing approximately 1 percent of the total US population (US-EPA, 2014a). Agriculture is one of the most hazardous industries for U.S. workers. Farmers and, in some instances, family members who share the work and live on the premises, are at a very high risk for fatal and nonfatal injuries. Worker hazards in farming are common to all types of agricultural production, and include hazards associated with operation of farm machinery and common agricultural management practices, such as pesticide application. Cuts, bruises, loss of fingers and limbs are examples of injuries resulting from mechanical hazards.

As a result, in 1990, Congress directed the National Institute of Occupational Safety and Health (NIOSH) to develop an agricultural safety and health program to address the high risks of injuries and illnesses experienced by agricultural workers and families. NIOSH supports and funds programs conducting research on agricultural injuries, as well as pesticide exposure, pulmonary disease, musculoskeletal disorders, hearing loss, and stress.

Pesticides, which include insecticides and herbicides, are used on most U.S. cotton fields to manage weeds and pests. Agricultural workers, including pesticide applicators, may be exposed to pesticides through mixing, loading, or applying chemicals, or by entering a previously treated field. As discussed in Subsection 1.3 – Coordinated Framework Review and Regulatory Review, all pesticides labeled for use on crops in the United States must first be registered by the EPA and used in accordance with label instructions. Among other elements, the EPA pesticide registration process involves the design of use restrictions that, if followed, have been determined to be protective of worker health. Worker safety precautions and use restrictions are noted clearly on pesticide registration labels. These restrictions provide instructions as to the appropriate levels of personal protection required for agricultural workers to use herbicides. These may include instructions on personal protective equipment, specific handling requirements, and field reentry. Used in accordance with the EPA label, registered herbicides are determined to not present a health risk to workers.

In consideration of the risk of pesticide exposure to field workers, EPA's Worker Protection Standard (WPS) (40 CFR Part170) was published in 1992 to require actions to reduce the risk of pesticide poisonings and injuries among agricultural workers and pesticide handlers. The WPS offers protections to more than two and a half million agricultural workers who work with pesticides at more than 560,000 workplaces on farms, forests, nurseries, and greenhouses. The WPS contains requirements for pesticide safety training, notification of pesticide applications, use of personal protective equipment, restricted entry intervals following pesticide application, decontamination supplies, and emergency medical assistance; furthermore, the Occupational Safety and Health Administration (OSHA) require all employers to protect their employees from hazards associated with pesticides and herbicides.

On February 20, 2014, the EPA announced proposed changes to the agricultural WPS to increase protections from pesticide exposure for agricultural workers and their families.[8] The EPA is proposing to strengthen the protections provided to agricultural workers and handlers under the WPS by improving elements of the existing regulation, such as training, notification, communication materials, use of personal protective equipment, and decontamination supplies. The proposed changes to the current WPS requirements, specifically improved training on reducing pesticide residues brought from the treated area to the home on workers and handlers' clothing and bodies and establishing a minimum age for handlers and early entry workers, other than those covered by the immediate family exemption, mitigate the potential for children to be exposed to pesticides directly and indirectly. The EPA expects the revisions, once final, to prevent unreasonable adverse effects from exposure to pesticides among agricultural workers and pesticide handlers; vulnerable groups, such as minority and low-income populations, child farmworkers, and farmworker families; and the general public.

2.6.2 Public Health

Cotton seed and associated linters are processed to produce cottonseed oil and cottonseed meal which is used for human food and animal feed. After ginning to remove fibers for textile manufacturing, cottonseed is processed into four major products: oil, meal, hulls, and linters. Processing of cottonseed typically yields (by weight): 16% oil, 45% meal, 26% hulls, and 9% linters, with 4% lost during processing (Cherry, 1983). Approximately 56% of cottonseed oil is used for salad or cooking oil, 36% for baking and frying fats, and the remaining 8% goes into margarine and other uses (OECD, 2009). In addition, linters[9] or cotton fiber may be minor ingredients in processed meats (sausage casing), ice cream, salad oil and other foods (OECD, 2009). Food and food ingredients derived from cotton have been used safely for human food for more than 100 years in most cotton producing countries (NCPA, 1993).

Only highly refined products (refined, bleached, and deodorized (RBD) oil and linters) are suitable for human consumption due to the presence of anti-nutrients in cottonseed, including gossypol, and cyclopropenoid fatty acids. Cottonseed oil or refined, bleached, and deodorized (RBD) oil is highly refined to remove these naturally occurring toxicants (Reeves and Weihrauch, 1979; US-FDA, 2013), drastically reducing the levels of these anti-nutrients during processing (AOCS, 2009; Harris, 1981; NCPA, 1993). RBD oil contains undetectable amounts

[8] For the proposed changes see: http://www.epa.gov/oppfead1/safety/workers/proposed/index.html
[9] Cotton linters are short fibers that remain on cotton seeds after the long fibers have been removed at the ginning process for textile manufacturing US-FDA. 2013. Completed Consultations on Bioengineered Foods BFN No. 135. US Food and Drug Administration.
http://www.accessdata.fda.gov/scripts/fcn/fcnDetailNavigation.cfm?rpt=bioListing&id=97.

of protein (Reeves and Weihrauch, 1979). Linters are a highly processed product composed of nearly pure (i.e., >99.9%) cellulose (NCPA, 2002a; Nida et al., 1996).

Consumers may be exposed to residual levels of pesticides through the consumption of processed products or in animal-based food products. Pursuant to the Federal Food, Drug, and Cosmetic Act (FFDCA), EPA must establish the tolerance value for pesticide residues that can remain on the crop or in foods processed from that crop (US-EPA, 2010a). Before establishing a pesticide tolerance, the EPA is required to reach a safety determination based on a finding of reasonable certainty of no harm under the FFDCA, as amended by the FQPA. In addition, the FDA and the USDA monitor foods for pesticide residues and enforce these tolerances (USDA-AMS, 2010). Tolerance levels for various pesticides have been established for a wide variety of commodities (including refined cotton oil, cotton meal, and undelinted cottonseed) and are published in the *Federal Register*, CFR, and the *Indexes to Part 180 Tolerance Information for Pesticide Chemicals in Food and Feed Commodities* (US-EPA, 2011e).[10]

There are multiple ways in which organisms can be genetically modified through human intervention. Traditional methods include breeding or crossing an organism to elicit the expression of a desired trait, while more contemporary approaches include the use of biotechnology such as genetic engineering to produce new organisms (NRC, 2004). As noted by the National Research Council, unexpected and unintended compositional changes arise with all forms of genetic modification, including both conventional hybridizing and genetic engineering (NRC, 2004). The National Research Council also noted in its 2004 report that no adverse human health effects attributed to genetic engineering have been documented. Reviews on the nutritional quality of GE foods generally have concluded that there are no biologically meaningful nutritional differences in conventional versus GE plants for food or animal feed (Aumaitre et al., 2002; Faust, 2002; Van Deynze et al., 2005).

Foods derived from biotechnology also undergo a comprehensive safety evaluation before entering the market, including reviews under the The Codex Alimentarius Commission (of the Food and Agriculture Organization and World Health Organization),, the European Food Safety Agency, and the World Health Organization (FAO, 2009; Hammond and Jez, 2011). Food safety reviews frequently will compare the compositional characteristics of the GE crop with non-transgenic, conventional varieties of that crop (see also Aumaitre et al., 2002; FAO, 2009). Moreover, this comparison also evaluates the composition of the modified crop under actual agronomic conditions, including various agronomic inputs. Following the recommendations of the Organization for Economic Cooperation and Development (OECD), composition characteristics of cotton seed evaluated in these comparative tests include proximates (protein, fat, ash, moisture and carbohydrate by calculation), fiber fractions (acid detergent fiber (ADF), neutral detergent fiber (NDF) and crude fiber (CF)), amino acids, fatty acids, vitamin E, minerals (calcium, phosphorus, potassium, magnesium, iron and zinc) and anti-nutrients (gossypol and cyclopropenoid fatty acids) (OECD, 2009).

[10] Index to Pesticide Chemical Names, Part 180 Tolerance Information, and Food and Feed Commodities (by Commodity): http://www.epa.gov/opp00001/regulating/tolerances-commodity.pdf.

Under the FFDCA, it is the responsibility of food and feed manufacturers to ensure that the products they market are safe and labeled properly. GE organisms used for food or feed purposes undergo a voluntary consultation process with the FDA prior to release to the U.S. market. The FDA established this voluntary consultation process to review the safety of foods and feeds derived from GE crops for human and animal consumptions. During the consultation, FDA evaluates the scientific and regulatory assessment summary of the food and feed safety of a product submitted by a developer, and responds to the developer by letter (US-FDA, 2014b). Although a voluntary process, thus far, all applicants who have wished to commercialize a GE crop variety that would be included in the food supply have completed a consultation with the FDA.

In such a consultation, a developer who intends to commercialize a bioengineered food meets with the agency to identify and discuss relevant safety, nutritional, or other regulatory issues regarding the bioengineered food and then submits to the FDA a summary of its scientific and regulatory assessment of the food. Developers intending to commercialize a bioengineered food meet with the FDA to identify and discuss relevant safety, nutritional, or other regulatory issues regarding the bioengineered food. This process includes: (1) an estimate of the concentration of any expression product in the bioengineered crop or food derived thereof; (2) the expected effect on the composition or characteristic properties of the food or feed; (3) a comparison of the composition or characteristics of the bioengineered food to that of food derived from the parental variety or other commonly consumed varieties with special emphasis on important nutrients, and toxicants that occur naturally in the food; (4) an evaluation of the amino acid sequence introduced into the food crop to confirm whether the protein is related to known toxins and allergens, (5) an assessment of the protein's potential for digestion, and (6) an evaluation of the history of safe use in food (US-FDA, 1997). The FDA evaluates the submission and responds to the developer by letter with any concerns it may have or additional information it may require.

Many international agencies also conduct food safety reviews of GE-derived food items, including the European Food Safety Agency (EFSA), Australia and New Zealand Food Standards Agency (ANZFS), Health Canada, China's National Agricultural GMO Biosafety Committee, Japan's Ministry of Health Labor and Welfare, and South Korea's Rural Development Administration.

Health effects to the general public, including children in the vicinity of the cotton fields may arise from pesticide exposures via incidental ingestion, inhalation, and dermal contact. Drift may also allow chemical entry into water bodies that may be used for drinking water. Pesticide exposures may occur from drift or accidental entry to the field during pesticide application. Adverse health effects to the general public, however, are not anticipated because of the pesticide label directions and restrictions. Health effects on agricultural workers of herbicides and appropriate safety practices are assessed by EPA. EPA requires training for agricultural workers on proper pesticide usage, and also signage following pesticide applications where specified chemical choices require entry restrictions.

2.7 Animal Feed

Cottonseed residue remaining after fiber removal for textile production includes cottonseed meal, cottonseed hulls, and whole cottonseed which are utilized in the animal feed industry as sources of protein, fiber and energy (NCPA, 2002b; OECD, 2009). Cottonseed meal, which makes up over a third of the value of cottonseed, is an excellent source of protein for ruminant animals (i.e., cattle) and is widely used in animal feed (Blasi and Drouillard, 2002; Calhoun, 2011). Highly processed cottonseed meal is also fed to non-ruminant farm animals in limited quantities (OECD, 2009).

Cottonseed contains the anti-nutrients gossypol and cyclopropenoid fatty acids. Gossypol helps protect the cotton plant from pathogens, but is an anti-nutrient for which sensitivity is species-dependent. Gossypol is also toxic to some species (Gadberry, 2011). Cottonseed is typically fed to ruminants, because they have a relatively low sensitivity to gossypol and can tolerate moderate gossypol inclusion in their diets. Cyclopropenoid fatty acids interfere with the metabolism of saturated fats (Cao et al., 1993; Rolph et al., 1990) and reportedly have adverse effects on egg yolk discoloration and reduced hatchability in chickens (Lordelo et al., 2007; OECD, 2008; OECD, 2009).

Cottonseed meal is the product obtained after removal of oil from whole cottonseed flakes or cake and is used as a protein supplement in animal feed. Cottonseed meal, which makes up over a third of the value of cottonseed, is an excellent source of protein for ruminant animals and is widely used in animal feed (Blasi and Drouillard, 2002; Calhoun, 2011). Cottonseed contains the anti-nutrients gossypol and cyclopropenoid fatty acids. Gossypol helps protect the cotton plant from pathogens, but is an anti-nutrient for which sensitivity is species-dependent. Gossypol is also toxic to some species (Gadberry, 2011). Cottonseed is typically fed to ruminants (i.e., cattle), because they have a relatively low sensitivity to gossypol and can tolerate moderate gossypol inclusion in their diets. Highly processed cottonseed meal is also fed to non-ruminant farm animals in limited quantities (OECD, 2009).

Cottonseed hulls are used as a source of fiber in feeds (US-FDA, 2013). The cottonseed hull is the tough, protective covering of the cottonseed that is removed prior to processing the seed for oil and meal. It is used as feed for livestock and can be an economical roughage that provides fiber, as well as serving as a good carrier for cottonseed meal and grain (NCPA, 2002c). Gin by-products, the dried plant material cleaned from the fiber during ginning, is also used as a source of roughage for livestock feeds.

Similar to the regulatory oversight for direct human consumption of food derived from GE cotton under the FFDCA, it is the responsibility of feed manufacturers to ensure that the products they market are safe and properly labeled. Feed derived from GE cotton must comply with all applicable legal and regulatory requirements, which in turn protects human health. GE crops used for feed may undergo a voluntary consultation process with FDA before release onto the market, which provides the applicant with any needed direction regarding the need for additional data or analysis, and allows for interagency discussions regarding possible issues.

Growers must adhere to the EPA label use restrictions for pesticides used to produce a cotton crop. Under Section 408 of FFDCA, the EPA regulates the levels of pesticide residues that can remain on food or food commodities from pesticide applications (US-EPA, 2010a). The tolerance level is the maximum residue level of a pesticide that can legally be present in food or feed, and if pesticide residues are found to exceed the tolerance value, the food is considered adulterated and may be seized.

2.8 Socioeconomics

2.8.1 Domestic Socioeconomic Environment

Cotton is a crop that produces two commodities: fiber and seed. The fiber is the more valuable product, normally accounting for approximately 85 percent of the value of harvested cotton.

Annual cotton production in the United States varied between 12.2 million to 19.2 million bales (480 pounds/bale) over the seven-year period from 2007 to 2013 (Table 12). The annual farm gate value ranged from $3.0 billion to $7.3 billion. The average area planted in cotton over the seven years totaled about 11 million acres, of which about 9 million acres were harvested. Variations in cotton acreage and production are largely driven by rainfall, either by deficiencies or excesses of precipitation at inopportune times for crop development (USDA-ERS, 1996). The 2014 cotton crop is forecast to reach 16.5 million bales, 3.4 million bales above the 2013 level of production (USDA-FAS, 2014a).

Table 12. U.S. Cotton Production and Value, 2007-2013.

Year	Area Planted (Acres)	Area Harvested (Acres)	Production (480 lb bales)	Value of Production (million dollars)
(x1,000)				
2007	10,827	10,489	19,207	5,653
2008	9,471	7,569	12,815	3,021
2009	9,150	7,529	12,188	3,788
2010	10,973	10,707	18,315	7,348
2011	14,735	9,461	15,673	7,262
2012	12,314	9,372	17,315	N/A
2013	10,337	7,781	13,105	N/A
Average	11,031	9,151	15,517	5,414

Source: USDA-ERS, U.S. cotton supply and use (USDA-ERS, 2014f)

Cotton is produced in 17 southern States identified as the Cotton Belt: Alabama, Arizona, Arkansas, California, Florida, Georgia, Kansas, Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. The six major cotton-producing states are Texas with 5.2 million acres harvested in 2014 followed by Georgia (1.4 million), North Carolina (460,000), Mississippi (420,000), Alabama (353,000) and Arkansas (325,000) (USDA-NASS, 2014b).

For every 100 pounds of fiber produced by cotton plants, there is also about 162 pounds of cottonseed. Approximately one-third of the cottonseed is crushed for oil and livestock meal. The oil is the more valuable product of cottonseed, and is further processed to produce cooking oil, salad dressing, shortening and margarine. Limited quantities of the oil are used in soaps, pharmaceuticals, cosmetic, textile finishes, and other products (NCPA, 2002a)

The average operating cost for producing cotton was about $490 per acre, 2011 through 2013 (Table 13). Gross earnings (value of the production less operating cost) were about $122 per planted acre over this period (USDA-ERS, 2014e) These earnings do not include government program payments that can significantly improve producers' returns.

Costs and returns (USDA-ERS, 2014e) vary among cotton-growing regions (Table 14). The Mississippi Portal area (Arkansas, Louisiana, Mississippi, Tennessee) had the highest 2013 gross earnings per acre, about $360. While operating costs were highest in the Fruitful Rim region (Arizona, California, Florida, and southern Texas), the gross earnings were second highest of all the regions. In the Prairie Gateway region (Kansas, New Mexico, Oklahoma, and northern Texas), which is the largest, gross earnings were only about $22 per acre in 2013. In 2011, growers in this region incurred gross earning losses that averaged $53 per acre (USDA-ERS, 2013a). Severe drought, especially in Texas, has historically resulted in these very low or negative returns, with many growers not harvesting their fields.

Table 13. U.S. Cotton Production Costs and Returns, 2011-13.

Item	2011	2012	2013	Average
Total, gross value of production (cotton and cottonseed)	588.01	620.51	628.02	612.08
Operating costs				
Seed	96.61	98.6	100.74	98.65
Fertilizer	95.06	99.6	96.72	97.13
Chemicals	66.72	69.28	70.04	68.68
Ginning	80.85	110.8	102.25	97.97
Other	125.79	128.72	128.71	127.74
Total, operating costs	465.03	507	498.46	490.16
Allocated overhead	283.82	299.39	307.13	296.78
Total costs listed	748.5	806.39	805.59	786.94
Value of production less total costs listed	-160.8	-185.88	-177.57	-174.75
Value of production less operating costs	122.98	113.51	129.56	122.02
Supporting information:				
Cotton yield: pounds per planted acre	496	667	591	584.67
Price: dollars per pound	0.96	0.72	0.82	0.83
Cottonseed yield: pounds per planted acre	802	1079	956	946
Price: dollars per pound	0.14	0.13	0.15	0.14
Enterprise size (planted acres)	687	687	687	687
Production practices				
Irrigated (percent)	43	43	43	43
Dryland (percent)	57	57	57	57

Source: (USDA-ERS, 2014e)

Table 14. Regional Cotton Production Costs and Returns, 2013.

Item	Heartland	Prairie Gateway	Southern Seaboard	Fruitful Rim	Mississippi Portal
	2013	2013	2013	2013	2013
Total, gross value of production (cotton and cottonseed)	898.2	382.32	783.26	1089.72	1063.99
Operating costs:					
Seed	171.07	80.18	116.31	107.29	145.9
Fertilizer	123.97	56.92	153.94	128.85	131.59
Chemicals	94.95	44.88	96.14	104.08	111.11
Ginning	154.2	64.55	121.42	164.29	189.28
Other	127.81	113.89	116.2	266.94	126.4
Total, operating costs	672	360.42	604.01	771.45	704.28
Total, allocated overhead	416.31	257.66	328.46	436.1	386.71
Total costs listed	1088.31	618.07	932.47	1205.55	1091.09
Value of production less total costs listed	-190.11	-235.75	-149.21	-117.83	-27.1
Value of production less operating costs	226.2	21.9	179.25	318.27	359.61
Supporting information					
Cotton yield: pounds per planted acre	922	357	806	756	1081
Price: dollars per pound	0.78	0.78	0.81	1.15	0.79
Cottonseed yield: pounds per planted acre	1492	577	1304	1224	1750
Price: dollars per pound	0.12	0.18	0.1	0.18	0.12
Enterprise size (planted acres)	861	770	453	507	954
Production practices:					
Irrigation (percent)	61	46	28	57	45
Dryland (percent)	39	54	72	43	55

Source: (USDA-ERS, 2014e)

2.8.2 Organic Cotton Production

The USDA Census of Organic Agriculture reported organic cotton farming on 30 farms in the United States in 2008, two in Arizona, three in New Mexico, four in California, and 21 in Texas (USDA-NASS). In recent years, organic cotton production reached its highest level in 2007, at about 14,000 bales (less than 0.1 percent of total cotton production) (Table 15). Most organic cotton is upland; less than 1,000 acres of organic Pima cotton was planted in 2012. As with conventional producers, drought conditions have negatively affected returns for organic cotton growers (U.S.-Organic-Trade-Association, 2011)

Table 15. U.S. Organic Cotton, Planted Acres and Production, 2007-2012.

Year	Planted Acres	Bales
2007	8,510	14,025
2008	8,539	7,026
2009	10,521	10,791
2010	11,827	13,279
2011	16,050	7,259
2012	14,787	8,867
6-Year Average	11,706	10,208

Source: (OTA, 2014)

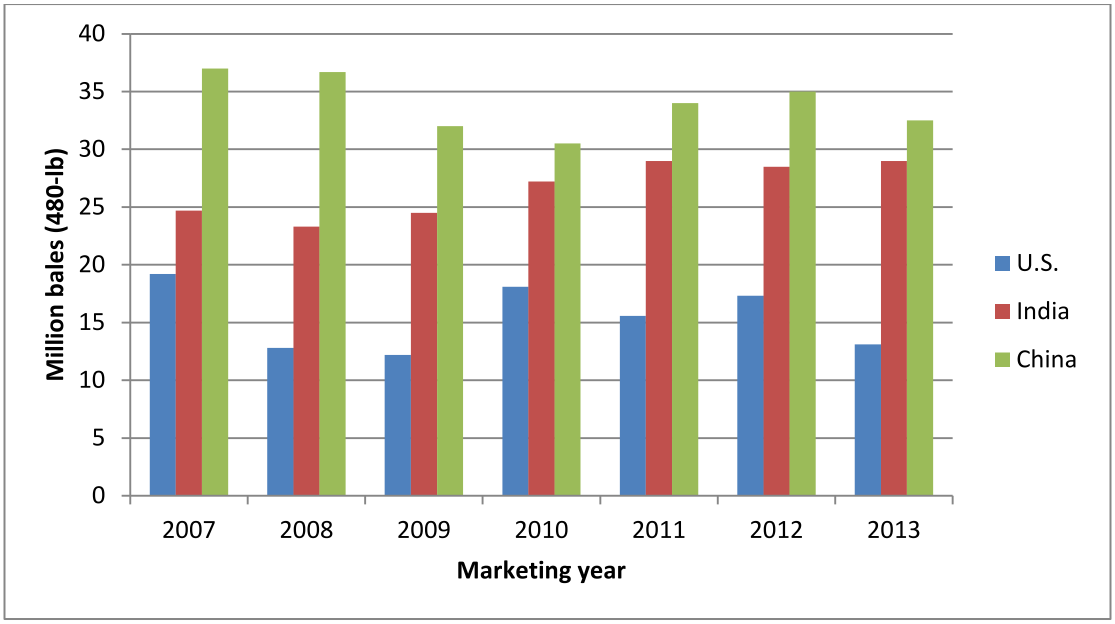
During the marketing year (MY) 2013-2014, cotton prices ranged from $1.35 to $2.00 per pound, changing minimally from MY 2012-2013 prices of $1.40 to $1.90. Organic trade associations reported prices for organic cotton at $1.50 per pound, with prices ranging from $1.35 per pound for one organic upland producer, to $2.40 per pound for organic Pima cotton. Organic cottonseed prices ranged from $500 to $700 per ton during MY 2013-2014, compared to $240 to $320 for conventional cotton. Operating costs to grow organic cotton ranged from $350 to $650 per acre, with an average cost reported at $440 per acre in 2010.

2.8.3 International Economic Environment

The latest USDA estimates for 2014/2015 project world cotton production at 118 million bales, slightly lower than last year and the lowest in four seasons. The three leading cotton-producing countries are China, India, and the United States (Figure 7). China produces approximately 30 percent of world supply, while India and the United States produce 21and 14 percent, respectively. In 2014/15, India is forecast to produce 30 million bales, slightly higher than the 29.5 million-bale estimate for China. Yields in India have increased with the adoption of Bt cotton.

Approximately 420 million acres of GE crops were planted in 28 countries in 2012. U.S acreage accounted for 21 percent; Argentina, 14 percent; Canada, 7 percent; India, 6 percent; and China, Paraguay, South Africa, and Pakistan, each roughly 2 percent (USDA-ERS, 2014a).

Figure 7. Cotton Production in China, India, and the United States, 2007-2013.



Source: (USDA-ERS, 2014c)

In 2013, the United States exported 10.4 million bales of cotton, which accounted for 32 percent of the world's cotton exports, followed by India (21 percent) and Australia (12 percent).[11] U.S. cotton exports averaged 11.7 million bales, 2011-2013 (Table 16). The major foreign markets are China, Mexico, Turkey, and Honduras. For 2014/15, U.S. cotton exports are forecast to be lower due to the reduced foreign import demand and reduced U.S. production (USDA-ERS, 2014d).

The United States was a slight net exporter of cotton in 2013, with imports totaling 10 million bales. During 2013, 24 percent of U.S. cotton imports came from China, followed by South Korea (13 percent), Pakistan (10 percent), India (9 percent), and Italy (6 percent) (Table 17).

China imports 47 percent of the world's cotton, followed by the United States at 42 percent. China's total imports are expected to decrease due in part to the tightening of market access by the government in response to mounting government stocks.

[11] Economic Research Services, Cotton and Wool yearbook http://www.ers.usda.gov/data-products/cotton,-wool,-and-textile-data/cotton-and-wool-yearbook.aspx

Table 16. U.S Cotton Exports, 2011-2013.

Country	Exports (bales)		
	2011	2012	2013
China	2,694	5,471	3,224
Mexico	1,406	1,303	1,144
Turkey	1,171	937	1,040
Honduras	1,054	1,037	832
Vietnam	351	391	520
Indonesia	469	261	312
Others	4,568	3,628	3,328
Total	11,714	13,026	10,400

Note: 1,000 bales = 480 lb
Source: USDA Economic Research Service and Global Trade Atlas

Table 17. U.S. Cotton Imports, 2011-2013.

Country	Exports (1,000 480 lb bales)		
	2011	2012	2013
China	4,402	2,384	2,467
South Korea	2,394	1,381	1,328
Pakistan	2,753	1,227	1,038
India	1,507	806	907
Italy	1,214	678	670
Japan	1,007	616	622
Mexico	1,140	502	511
Turkey	758	442	427
Others	3,825	1,964	2,030
Total	19,000	10,000	10,000

Note: 1,000 bales = 480 lb
Source: USDA Economic Research Service (USDA-ERS, 2014d) and Global Trade Atlas (proprietary) (www.gtis.com/gta/)

Cottonseed currently comprises about 10 percent of the world's oilseed production. Cottonseed is processed into four major products: oil, meal, hulls, and linters. In 2013, the U.S. exported 85,500 metric tons (MT) of refined cottonseed oil, valued at $50.4 million (Table 18). Mexico received 67 percent, while Canada received 26 percent. In 2013, the U.S. also exported 6,800 MT of crude cottonseed oil valued at $3.3 million (Table 19).

Table 18. Refined U.S. Cottonseed Oil Exports, 2011-2013.

Country	2011		2012		2013	
	Value $1,000	Quantity (Metric Tons)	Value $1,000	Quantity (Metric Tons)	Value $1,000	Quantity (Metric Tons)
World Total	47,228	80,803	52,722	85,491	50,422	85,487
Mexico	20,568	40,916	31,349	53,794	29,662	57,380
Canada	25,625	38,371	19,201	28,902	16,910	22,439
Others	1,035	1,516	2,172	2,795	3,850	5,668

Source: FAS Global Trade Atlas (USDA-FAS, 2014b) and Global Trade Information Service (www.gtis.com) proprietary

Table 19. Crude U.S. Cottonseed Oil Exports, 2011-2013.

Country	2011		2012		2013	
	Value $1,000	Quantity (Metric Tons)	Value $1,000	Quantity (Metric Tons)	Value $1,000	Quantity (Metric Tons)
World Total	2,289	4,377	5,994	12,445	3,384	6,785
Mexico	731	1,393	4,691	10,066	2,647	5,316
Trinidad and Tobago	251	462	308	567	356	655
Others	1,307	2,522	995	1,812	381	814

Source: FAS Global Trade Atlas (USDA-FAS, 2014b) and Global Trade Information Service (www.gtis.com) proprietary

3 ALTERNATIVES

This document analyzes the potential environmental consequences of a determination of nonregulated status of DAS-81910-7 cotton. In responding to the petitions, APHIS must determine that DAS-81910-7 cotton is unlikely to pose plant pest risks. Based on its PPRA (USDA-APHIS, 2014f), APHIS has concluded that DAS-81910-7 cotton is unlikely to pose plant pest risks. Therefore, APHIS must determine that DAS-81910-7 cotton is no longer subject to 7 CFR part 340 or the plant pest provisions of the PPA.

APHIS evaluated two alternatives in this draft EA: 1) No Action Alternative and 2) determination of nonregulated status of DAS-81910-7 cotton (Preferred Alternative). APHIS has assessed the potential for environmental impacts for each alternative in the Environmental Consequences chapter of this document.

3.1 No Action Alternative: Continuation as a Regulated Article

Under the No Action Alternative, APHIS would deny the petition. DAS-81910-7 cotton and progeny derived from DAS-81910-7 cotton would continue to be regulated articles under the regulations at 7 CFR Part 340. Permits issued or notifications acknowledged by APHIS would still be required for introductions of DAS-81910-7 cotton and measures to ensure physical and reproductive confinement would continue to be implemented. APHIS might choose this alternative if there were insufficient evidence to demonstrate the lack of plant pest risk from the unconfined cultivation of DAS-81910-7 cotton.

This alternative is not the Preferred Alternative because APHIS has concluded through a Plant Pest Risk Assessment (USDA-APHIS, 2014f) that DAS-81910-7 cotton is unlikely to pose a plant pest risk. Choosing this alternative would not satisfy the purpose and need of making a determination of plant pest risk status and responding to the petition for nonregulated status.

3.2 Preferred Alternative: Determination that DAS-81910-7 Cotton Is No Longer a Regulated Article

Under this alternative, DAS-81910-7 cotton and progeny derived from them would no longer be regulated articles under the regulations at 7 CFR Part 340. DAS-81910-7 cotton is unlikely to pose a plant pest risk (USDA-APHIS, 2014f). Permits issued or notifications acknowledged by APHIS would no longer be required for introductions of DAS-81910-7 cotton and progeny derived from this event. This alternative best meets the purpose and need to respond appropriately to a petition for nonregulated status based on the requirements in 7 CFR part 340 and the agency's authority under the plant pest provisions of the Plant Protection Act. Because the agency has concluded that DAS-81910-7 cotton is unlikely to pose a plant pest risk, a determination of nonregulated status of DAS-81910-7 cotton is a response that is consistent with the plant pest provisions of the PPA, the regulations codified in 7 CFR part 340 and the biotechnology regulatory policies in the Coordinated Framework. Under this alternative, growers may have future access to DAS-81910-7 cotton and progeny derived from this event if the developer decides to commercialize DAS-81910-7 cotton.

3.3 Alternatives Considered But Rejected from Further Consideration

APHIS assembled a list of alternatives that might be considered for DAS-81910-7 cotton. The agency evaluated these alternatives, in light of the agency's authority under the plant pest provisions of the Plant Protection Act, and the regulations at 7 CFR part 340, with respect to environmental safety, efficacy, and practicality to identify which alternatives would be further considered for DAS-81910-7 cotton. Based on this evaluation, APHIS rejected several alternatives. These alternatives are discussed briefly below along with the specific reasons for rejecting each.

3.3.1 Prohibit Any DAS-81910-7 Cotton from Being Released

In response to public comments that stated a preference that no GE organisms enter the marketplace, APHIS considered prohibiting the release DAS-81910-7 cotton, including denying any permits associated with the field testing. APHIS determined that this alternative is not appropriate given that APHIS has concluded that DAS-81910-7 cotton is unlikely to pose a plant pest risk (USDA-APHIS, 2014f).

In enacting the Plant Protection Act, Congress found that:

[D]ecisions affecting imports, exports, and interstate movement of products regulated under [the Plant Protection Act] shall be based on sound science… § 402(4).

On March 11, 2011, in a Memorandum for the Heads of Executive Departments and Agencies, the White House Emerging Technologies Interagency Policy Coordination Committee developed broad principles, consistent with Executive Order 13563, to guide the development and implementation of policies for oversight of emerging technologies (such as genetic engineering) at the agency level. In accordance with this memorandum, agencies should adhere to Executive Order 13563 and, consistent with that Executive Order, the following principle, among others, to the extent permitted by law, when regulating emerging technologies:

"[D]ecisions should be based on the best reasonably obtainable scientific, technical, economic, and other information, within the boundaries of the authorities and mandates of each agency"

Based on our Plant Pest Risk Assessment (USDA-APHIS, 2014f) and the scientific data evaluated therein, APHIS has concluded that DAS-81910-7 cotton is unlikely to pose a plant pest risk. Accordingly, there is no basis in science for prohibiting the release of DAS-81910-7 cotton.

3.3.2 Approve the Petition in Part

The regulations at 7 CFR 340.6(d)(3)(i) state that APHIS may "approve the petition in whole or in part." For example, a determination of nonregulated status in part may be appropriate if there is a plant pest risk associated with some, but not all lines described in a petition. Because APHIS has concluded that DAS-81910-7 cotton is unlikely to pose a plant pest risk, there is no regulatory basis under the plant pest provisions of the Plant Protection Act for considering approval of the petition only in part.

3.3.3 Isolation Distance between DAS-81910-7 Cotton and Non-GE Cotton Production and Geographical Restrictions

In response to public concerns of gene movement between GE and non-GE plants, APHIS considered requiring an isolation distance separating DAS-81910-7 cotton from non-GE cotton production. However, because APHIS has concluded that DAS-81910-7 cotton is unlikely to pose a plant pest risk (USDA-APHIS, 2014f), an alternative based on requiring isolation distances would be inconsistent with the statutory authority under the plant pest provisions of the Plant Protection Act and regulations in 7 CFR part 340.

APHIS also considered geographically restricting the production of DAS-81910-7 cotton based on the location of production of non-GE cotton in organic production systems in response to public concerns regarding possible gene movement between GE and non-GE plants. However, as presented in APHIS' plant pest risk assessment for DAS-81910-7 cotton, there are no geographic differences associated with any identifiable plant pest risks for DAS-81910-7 cotton (USDA-APHIS, 2014f). This alternative was rejected and not analyzed in detail because APHIS has concluded that DAS-81910-7 cotton does not pose a plant pest risk, and will not exhibit a greater plant pest risk in any geographically restricted area. Therefore, such an alternative would not be consistent with APHIS' statutory authority under the plant pest provisions of the Plant Protection Act, the regulations codified in 7 CFR Part 340 and the biotechnology regulatory policies in the Coordinated Framework.

Based on the foregoing, the imposition of isolation distances or geographic restrictions would not meet APHIS' purpose and need to respond appropriately to a petition for nonregulated status based on the requirements in 7 CFR Part 340 and the agency's authority under the plant pest provisions of the Plant Protection Act. Nevertheless, APHIS is not expecting significant impacts. However, individuals might choose on their own to geographically isolate their non-GE cotton productions systems from DAS-81910-7 cotton or to use isolation distances and other management practices to minimize gene movement between cotton fields.

3.3.4 Requirement of Testing for DAS-81910-7 Cotton

During the comment periods for other petitions for nonregulated status, some commenters requested USDA to require and provide testing to identify GE products in non-GE production systems. APHIS notes there are no nationally-established regulations involving testing, criteria, or limits of GE material in non-GE systems. Such a requirement would be extremely difficult to implement and maintain. Additionally, because DAS-81910-7 cotton does not pose a plant pest risk (DAS, 2013b; USDA-APHIS, 2014f), the imposition of any type of testing requirements is inconsistent with the plant pest provisions of the Plant Protection Act, the regulations at 7 CFR Part 340 and the biotechnology regulatory policies embodied in the Coordinated Framework. Therefore, imposing such a requirement for DAS-81910-7 cotton would not meet APHIS' purpose and need to respond appropriately to the petition in accordance with its regulatory authorities.

3.4 Comparison of Alternatives

A summary of the potential impacts associated with selection of the Alternatives evaluated in this EA are compared below (Table 20). The potential environmental consequences are presented in Sections 4 and 5 of this EA.

Table 20. Summary of Issues and Potential Impacts of the Alternatives.

Attribute/Measure	Alternative 1: No Action (Deny the Petition)	Alternative 2: Preferred Alternative-Determination of Nonregulated Status for DAS-81910-7 Cotton
Meets Purpose and Need	No	Yes
Land Use	Acreage of cotton plantings are anticipated to increase modestly after 2015 through 2024 (USDA-OCE, 2015). Cotton plantings are anticipated to fluctuate as market prices change. Locations of cotton production are not expected to change.	Acreage of plantings generally the same as No Action Alternative The nonregulated cotton variety might replace other cotton varieties currently grown in the United States. Locations of production unchanged.
Agronomic Practices	Weeds resistant to glyphosate and other herbicides will continue to increase. As HR weeds become more prevalent, growers are expected to shift to more costly alternative weed control measures or other HR crops that are economically viable. Conventional growers are likely to use additional herbicides or abandon conservation tillage practices and return to more aggressive conventional tillage systems to maintain yields.	Use of 2,4-D and glufosinate in cotton cropping systems is expected to increase, but 2,4-D use is contingent on EPA's decision to approve the new uses of 2,4-D on DAS-81910-7 cotton. More efficient weed control is expected to reduce the need for more aggressive tillage. Conventional growers are likely to continue the use of herbicides and retain or increase conservation tillage practices if resistant weeds do not develop over time.
Organic Production Systems	Planting of organic cotton is not likely to change.	Planting of organic cotton is not likely to change.
Use of GE Crops: Herbicide and Resistant Weeds	Planting of GE HR crops is likely to remain at current levels with adoption of GE crops high.	Planting of GE HR crops is likely to remain at current levels with adoption of GE crops high.
Human Health and Safety	Cotton varieties are associated with all the normal risks of agricultural production. The EPA label use restrictions are designed to protect humans during herbicide use in cotton cropping systems to achieve a standard of a "reasonable certainty of no harm".	This variety does not present any additional risks to workers. The revised EPA label use restrictions for Enlist cotton are designed to achieve the same level of human health and safety as those that currently exists for non-GE varieties.

Attribute/Measure	Alternative 1: No Action (Deny the Petition)	Alternative 2: Preferred Alternative-Determination of Nonregulated Status for DAS-81910-7 Cotton
Biological Diversity	Cropping systems generally are not expected to change, so biodiversity in regions where cotton are produced will not change. Herbicide use may decrease weed prevalence or modify the weed species complex in some regions. These changes could modify the species complex of organisms that rely on these weeds as a food source or habitat.	Crop biodiversity is not expected to substantially change relative to the No Action Alternative. Use of DAS-81910-7 cotton varieties will allow for stable levels of conservation tillage, which will not decrease biodiversity and might increase it. Use of DAS-81910-7 cotton will likely allow decreased use of some non-glyphosate herbicide uses as 2,4-D substitutes for these, which will not reduce biodiversity and might increase it. Selection pressure for 2,4-D and glufosinate resistance in weed populations may modify the weed species complex in some regions, which might modify the species complex of organisms that rely on these weeds as a food source or habitat.
Animal Communities	Cultivated cotton currently provides limited food and habitat for wildlife in regular cropping situations.	Expected to be the same as No Action Alternative because toxicological studies and studies of allergenicity of the added traits did not reveal any impacts on animals.
Plant Communities / Weed Complexes	Currently cultivated cotton varieties are not potential plant pests because they do not compete with native plant species, so do not adversely impact natural plant communities. Selection pressure for HR weed development will continue.	DAS-81910-7 cotton is not a potential plant pest because it does not compete with native plant species and lacks the potential to do so, so will not adversely impact natural plant communities. If growers fail to adopt best management practices and diversify weed control methods, selection pressure to develop 2,4-D and glufosinate resistance in weed populations will increase, including the potential for development of weeds with multiple resistance to more than one herbicide mode of action.
Soil Quality	Increased tillage to manage HR weeds may occur in cotton cropping systems and cause decreased soil quality from increased soil erosion.	New options to avoid tillage would be accompanied by decreased soil erosion. This cotton variety is not expected to change the existing composition of soil microflora in cropping systems.
Water Quality	Increased tillage to manage HR weeds may occur in cotton cropping systems.	This cotton variety will support continued use of current conservation

Attribute/Measure	Alternative 1: No Action (Deny the Petition)	Alternative 2: Preferred Alternative-Determination of Nonregulated Status for DAS-81910-7 Cotton
	This could increase evaporative water loss and demand on water resources for irrigation, and cause increased soil erosion accompanied by diminished water quality from sedimentation.	tillage practices in the short term. In the long term, unless growers follow practices of best management for weeds, development of HR weeds may be accompanied by increased tillage with negative impacts (as described in the No Action Alternative).
Air Quality	Increased tillage to manage HR weeds may occur in cotton cropping systems. This could reduce air quality from increased air particulates and exhaust from farm equipment. Increased use of herbicides may occur to manage HR weeds. This would increase drift from herbicides that would reduce air quality.	Use of this cotton variety is expected to stabilize current tillage trends. This will be accompanied by a reduction in airborne particulates and exhaust emissions, which will increase air quality Overall use of herbicides will remain the same or be reduced by better management of HR weeds. Drift from herbicides will remain the same or be reduced with the substitution of the Enlist formulation that includes 2,4-D.
Climate Change	Increased tillage to manage HR weeds may occur in cotton cropping systems. This would Increase the release of GHGs (primarily CO_2 and methane).	Use of this cotton variety is expected to stabilize current conservation tillage. This will be accompanied by a reduction in the release of GHGs (primarily CO_2 and methane).
Socioeconomic Resources	The U.S. will continue to be an exporter of cotton. The percentage of GE varieties in the market is not expected to change.	DAS has submitted or is planning to submit requests for regulatory approvals in the main export markets for the proposed variety of cotton. These traits and this variety are not substantially different from what is already in commerce. Their presence in exported commodities are not likely to affect trade differently than that of other currently approved GE traits in commerce. The percentage of GE varieties in the market is not expected to change.
Other U.S. Regulatory Approvals: FDA Consultations and EPA Registrations	Consultations with the FDA and changes to the EPA registrations would be unnecessary.	Dow completed consultations with the FDA for DAS-81910-7 cotton on November 14, 2014 (BNF No. 00142). The EPA reregistration decision for 2,4-D was issued in 2005 (US-EPA, 2005b). EPA concluded that 2,4-D and

Attribute/Measure	Alternative 1: No Action (Deny the Petition)	Alternative 2: Preferred Alternative-Determination of Nonregulated Status for DAS-81910-7 Cotton
		its metabolites were moderately nontoxic to practically nontoxic in ecological assessments. EPA concludes that the measures to control spray drift are expected to reduce the risk of 2,4-D to non-target plants. The EPA registration decision for glufosinate was issued in 2000 for crop use (US-EPA, 2008b). The EPA is currently evaluating the proposed new uses of 2,4-D choline salt for DAS-81910-7 cotton.
Applicable U.S. Laws	Compliant	Compliant

4 POTENTIAL ENVIRONMENTAL CONSEQUENCES

This chapter examines the potential environmental impacts associated with the alternatives on the affected environment (as identified in Chapter 2). In this chapter, APHIS only examines the direct and indirect impacts of its decision regarding the regulatory status of DAS-81910-7 cotton. For the purposes of this EA, those aspects of the human environment are: cotton production practices, the physical environment, biological resources, public health, animal feed and socioeconomic issues. Relevant components of the physical environment, biological resources, human health, and socioeconomic resources are considered. They include soil, water and air quality, climate change, land cover and land uses, cotton production practices, animal, plant and microbial communities, food and feed uses, worker safety and human health.

Under the No Action Alternative, APHIS would not approve the petition for deregulation of DAS-81910-7 cotton. This alternative represents the status quo, or the situation that would occur if APHIS denies the petitions. This section describes the impacts of cotton production on the human environment that are occurring and are anticipated to continue to occur if APHIS selects the No Action Alternative. The analysis examines the impacts of cotton production on resources to allow meaningful comparison to the other alternative reviewed in this document.

While the Agency recognizes that DAS-81910-7 cotton was engineered to be resistant to applications of the herbicide 2,4-D, EPA has the regulatory authority to approve new uses of all pesticides, including those for 2,4-D on DAS-81910-7 cotton. The EPA is currently evaluating the proposed new uses of 2,4-D for DAS-81910-7 cotton, and is the Federal agency which determines the possible human health and environmental effects of pesticide use in the environment. EPA registers a pesticide use when consistent with a conclusion of no unreasonable adverse environmental effects. In this chapter, we assume that any use of 2,4-D should be discussed as a cumulative impact of APHIS' action combined with future actions that may be taken by EPA or other agencies. Thus, the analysis of these possible cumulative impacts is discussed in Section 5 of the EA.

4.1.1 Land Use and Acreage

4.1.1.1 No Action Alternative: Land Use and Acreage

In the U.S., cotton is grown exclusively in the southern states because this is the only U.S. region with a growing season long enough for cotton to mature. During the past 10 years, total U.S. cotton acreage has varied from approximately 9.15 to 15.77 million acres, with the lowest acreage recorded in 2009 and the highest in 2001 (See Figure 3) (USDA-NASS, 2014a). In 2013, the harvested acreage for all types of cotton was 9.71 million acres, an increase of 22% percent from the previous year (USDA-NASS, 2015b)

The most recent USDA projections for plantings of Upland cotton anticipate an increase to 11 million acres in 2014 (USDA-OCE, 2014). Prices for competing crops are projected to fall more than cotton prices, making cotton cultivation more favorable. The trend for cotton acreage plantings over the projection period to 2023 shows a decrease to 10 million acres in 2015 and remains near that level for the remainder of the projection period, as a result of projected world and U.S. cotton prices below the recent 5-year average (USDA-OCE, 2014). Under the No Action Alternative, the projected acreage of cotton production is not expected to change over the next decade.

4.1.1.2 Preferred Alternative: Land Use and Acreage

Under the Preferred Alternative there are no expected direct or indirect impacts on land use and cotton acreage resulting from the decision to approve this petition. The drivers of land used for cotton production include the market price of cotton and the suitability of the land for this production. The decision to approve this petition will not affect these factors.

In 2014, GE cotton, including stacked and HR varieties, covered approximately 91 percent of the total acreage planted to cotton in the United States (USDA-ERS, 2014b). Under the Preferred Alternative, it is not anticipated that the availability of DAS-81910-7 cotton will chance the acreage of GE cotton as compared to acreage under the No Action Alternative.

4.1.2 Agronomic Practices in Cotton Production

4.1.2.1 No Action Alternative: Agronomic Practices

Under the No Action Alternative, DAS-81910-7 cotton would continue to be regulated by APHIS. Currently available cotton varieties (both GE and non-GE) would continue to be available and be commercially grown under the No Action Alternative.

Current cotton management practices would be expected to continue under the No Action Alternative; the types of agronomic practices used to cultivate these cotton varieties, such as tillage, crop rotation, fertilization, and pesticide use, would be similar to those currently used. Growers are expected to continue choosing certain pesticides based on weed, insect and disease pressures, cost of seed and other inputs, technology fees, human safety, potential for crop injury, and ease and flexibility of the production system (Farnham, 2001; Heiniger, 2000; University of Arkansas, 2008). Agricultural production of existing nonregulated herbicide-resistant GE and non-GE cotton would continue to utilize EPA-registered pesticides.

Although growers have faced challenges in the past due to weed species resistant to herbicides, the problems associated with GR weeds have been increasing rapidly over the past 10 years throughout much of the United States. As discussed in Subsection 2.5.2, *Plant Communities*, the continued evolution and spread of HR weeds is a major concern for cotton growers, especially in the southern regions of the United States. For example, GR Palmer amaranth has infested all cotton producing counties in Georgia, to some degree and, although grower herbicide input costs have more than doubled, chemically-based control of Palmer amaranth is still not adequate (Sosnoskie and Culpepper, 2014). Under the No Action Alternative, HR weed biotypes would likely continue to affect cotton production. Although the primary concern relates to weeds with resistance against single, widely used herbicides, such as glyphosate, it is also likely that weeds with resistance to multiple chemistries with different modes of action would also be expected to persist. Existing populations of resistant weeds are also likely to continue to spread over time under the No Action Alternative. Further, additional new weeds with multiple-herbicide resistance can be expected to continue to evolve.

The continued emergence of GR weeds will likely require cotton growers to continue modifying crop management practices to address these weeds. Herbicide use is likely to increase to meet the need for additional integrated weed management tactics to mitigate HR weeds in different cropping systems (Culpepper et al., 2008; Owen and Zelaya, 2005). The increase of GR weeds makes glyphosate use less attractive, although, glyphosate still controls large numbers of weeds (Monsanto, 2013a). Growers have been adding alternative herbicides with different modes-of-action into glyphosate-resistant systems to manage the development of GR weeds and control GR weeds. Between 2009 and 2011, there was a 113 percent and 220 percent increase in pre- and post-application, respectively, of non-glyphosate treatments on GR cotton. From 2008 to 2011, there was also a 177 percent and 345 percent increase in the use of pre- and postemergence herbicide applications, respectively, of non-glyphosate herbicides on GR soybeans (Monsanto, 2013a). In Georgia, the presence of GR Palmer amaranth has increased herbicide pounds of active ingredient applied in cotton by a factor of 2.5 when compared to herbicide use prior to resistance (S. Culpepper, Georgia Extension Agronomist, public comment this docket).

No-till practices are being maintained in many areas, but the presence of HR weeds and rapidly increasing presence of GR weeds in particular, sometimes has necessitated the inclusion of tillage and even hand weeding in weed control strategies (Arbuckle and Lasley, 2013; Sosnoskie and Culpepper, 2014). Although conventional tillage in U.S. cotton acreage decreased from 77 percent in 1999 to 38 percent in 2007, some growers have been reverting back from conservation tillage to conventional tillage as an additional means to control problematic HR weeds. GR Palmer amaranth has forced many Georgia cotton growers to return to tillage, with more than 40 percent of the crop cultivated from 2011-2013 and more than 25 percent in 2014 (Sosnoskie and Culpepper, 2014). Similarly, in Tennessee, the development of glyphosate resistance in Palmer amaranth, as well as GR horseweed, has increased expenditures not only on herbicides, but on hand weeding of cotton fields (L. Steckel, public comments, APHIS-2013-0043-3204-A1). An Iowa poll disclosed that farmers there used mechanical weed control (i.e., cultivation) 25 percent of the time, and 55 percent found it to be effective or very effective for weed control (Arbuckle and Lasley, 2013). Farmers apparently value soil cultivation for weed control, but practice it only to a limited extent (25 percent) at present.

The future use of tillage for weed control, however, is not expected to return to historical levels. Most growers are not expected to increase tillage due to the economic (reduced fuel use, less time in the field) and environmental benefits (reduced soil erosion and better moisture retention) associated with these practices. In addition to the added expenses associated with tillage operations, the equipment and expertise may no longer be available (Norsworthy et al., 2012). Additionally, growers may be participating in programs that discourage or restrict the use of tillage on their lands or provide financial incentives for adopting conservation tillage.

Agronomic practices such as row spacing, the use of cover crops and crop rotation, are likely to change over time. In an attempt to offset the increase in tillage that might otherwise result in the effort to manage HR weeds, the USDA-Natural Resources Conservation Service (NRCS) is offering farmers technical and financial assistance to manage HR weeds while maintaining conservation stewardship through two programs: the Conservation Security Program and the Environmental Quality Incentives Program. Among the practices that qualify for financial and technical incentives are the use of cover cropping and crop rotation. As a result, cover cropping and crop rotation, both of which have been shown to reduce weed pressure, are practices that are expected to increase under the No Action Alternative.

4.1.2.2 Preferred Alternative: Agronomic Practices

Under this alternative, growers would be able to plant DAS-81910-7 cotton, but would not be able to make applications of 2,4-D, other than currently approved by the EPA. The new post-emergent use of 2,4-D on this cotton event is not permitted until the EPA approves the new uses.

The types of agronomic practices used to grow DAS-81910-7 cotton, such as tillage, crop rotation, fertilization, and pesticide use, would be similar to those currently used and expected under the No Action Alternative. Growers would continue to manage weeds using a combination of chemical and cultural methods described in the No Action Alternative. Under the Preferred Alternative, similar to the No Action `Alternative, growers may continue to rely on glyphosate, glufosinate and other EPA-approved herbicides to manage weeds in cotton. Weed scientists will continue to encourage growers to use best management practices.

Under the Preferred Alternative, a potential indirect impact on cotton agronomic practices as a result of deregulation of DAS-81910-7 cotton is the choice of control measures used for cotton stalk destruction associated with current boll weevil control measures. As noted earlier, destruction of overwintering cotton plants is mandated by many Boll Weevil Control programs. Control of cotton plants arising after harvest, either those regrowing from cut stems or from germination of spilled seeds, are of special concern where the boll weevil is present and can serve as host plants and negatively influence the control of these pests (Texas Department of Agriculture 2013).

Methods available for the management of cotton stalks include mechanical destruction or removal (shredding, tillage, and stalk pullers), flood irrigation, and herbicide application. Applied herbicides may include 2,4-D, dicamba, thifensulfuron-methyl + tribenuronmethyl and others (DAS, 2013b). Post-harvest cotton control is often accomplished by applications of 2,4-D, which growers may combine with mechanical destruction (Robertson et al., 2002). Specifically Louisiana and Texas provide that 2,4-D is a key and preferred method to kill regrowth (Miller 2011; USDA APHI S 2012). Where 2,4-D-resistant DAS-81910-7 cotton is grown, other herbicide regimes would have to replace the use of 2,4-D for this purpose. A number of methods for control of volunteer cotton in the season that follows cotton production are available (that is, of seedlings) (DAS, 2013b; Morgan et al., 2011b; Thompson, 2008). Dow recognizes the utility of 2,4-D in the eradication of the boll weevil and has been actively engaged in research focused on identifying alternative herbicides that can be used for cotton stalk control (DAS, 2013b).

4.2 Physical Environment

4.2.1 Water Resources

4.2.1.1 No Action Alternative: Water Resources

If drought conditions west of the Mississippi continue, particularly in Texas where approximately 50 percent of the U.S. cotton crop is grown, and cotton prices remain competitive, growers may choose to plant cotton over other crops requiring more water such as corn, wheat or grain sorghum (Cotton-Inc., 2014) Corn and soybeans are less tolerant of drought conditions than cotton which has low sensitivity to drought (Table 21) (Brouwer and Heibloem, 1986).

Table 21. Comparison of Water Needs and Drought Sensitivity for Some Globally Important Crops.

Crop	Minimum-maximum water (mm needed over total growing period)	Sensitivity to drought
Alfalfa	800-1600	low-medium
Citrus	900-1200	low-medium
Cotton	700-1300	low
Corn (Maize)	500-800	medium-high
Soybean	450-700	low-medium
Sugarbeet	550-750	low-medium
Sugarcane	1500-2500	high
Sunflower	600-1000	low-medium
Tomato	400-800	medium-high

Source: (Brouwer and Heibloem, 1986)

In the Western states (i.e., Arizona, California, New Mexico, and Oklahoma), 43 percent of cotton is irrigated while 39 percent of the total U.S. cotton crop is irrigated. USDA projections indicate that demands on agricultural water supplies are likely to increase over time as alternative non-farm uses of water continue to grow. Potential Native American water-right claims were estimated at nearly 46 million acre-feet annually and could impact the distribution and cost of irrigation water in the West. For many states, the scope of water demands for the environment have expanded from a minimum in-stream flow to an “environmental-flows” standard (i.e., a concept requiring water to meet the needs for water quality, but to also rehabilitate ecosystem habitats). Energy-sector growth is expected to significantly increase water demands for an expanding biofuels sector, utility-scale development of solar power, innovation in thermoelectric generating capacity, and commercial oil-shale and deep shale natural gas development. (Schaible and Aillery, 2012).

Projected climate change - through warming temperatures, shifting precipitation patterns, and reduced snowpack - is expected to reduce water supplies and increase water demand across much of the West. These trends are placing greater pressure on existing water allocations, heightening the importance of U.S. water management and conservation for the sustainability of irrigated agriculture (Schaible and Aillery, 2012). Expansion in competing areas of national water demand may present U.S. cotton producers with more difficult farming decisions and fewer socioeconomic options (e.g., whether to purchase enough water for a crop, or to clear or even sell land).

Under the No Action Alternative, water allotment for agricultural use is expected to be restricted as demand for water increases globally. Pressure for the conservation of existing surface water and groundwater resources is expected to increase, as growers shift to produce more cotton. In areas where increased tillage is used to control weeds, soil erosion may occur and may impact nearby water bodies.

4.2.1.2 Preferred Alternative: Water Resources

Under the Preferred Alternative, the overall agricultural impacts on water quantity are expected to be the same as those described under the No Action Alternative. Choosing the Preferred Alternative does not change grower choices on how to grow cotton or manage weeds in their fields. Any reduction in tillage compared to the amount of tillage occurring under the No Action Alternative would be associated with relatively less agricultural runoff and sedimentation. This would result in less water quality impacts. The converse is also true. In areas where tillage is used or increased to control weeds in cotton, water may be affected by sedimentation from surface runoff (Robertson et al., 2009).

Approving the petition would allow DAS-81910-7 cotton to be planted, but it does not allow for the new post-emergence use of 2,4-D on the plant. The EPA regulates the use of herbicides under FIFRA and is making a separate decision which may or may not allow its use on DAS-81910-7 cotton. APHIS considers the potential cumulative impacts on water quality of its decision combined with the EPA's decision in Chapter 5.

4.2.2 Soil Quality

4.2.2.1 No Action Alternative: Soil Quality

Under the No Action Alternative, current cotton management practices would be expected to continue. Agronomic practices that benefit soil quality, such as contouring, use of cover crops to limit the time soil is exposed to wind and rain and introduce certain soil nutrients, crop rotation, and windbreaks would not change as a result of the continued regulated status of DAS-81910-7 cotton.

GR weeds would continue to be a concern in the Southeast region, and the likely expansion of resistant weeds into other regions would require modifications of crop management practices to address these weeds, which can affect soils. These changes may include diversifying the mode of action of herbicides applied to cotton and making adjustments to crop rotation and tillage practices (Owen et al., 2011b). Growers in the Southeast region, who currently are experiencing extreme impacts of HR weed infestations, appear especially anxious to diversify their overall weed management strategies (Prostko, 2013; Wright, 2013). Many growers who have adopted no-till production are now resorting to increased tillage in their management programs, thus reducing the soil benefits of no-till production in that region (Prostko, 2013). Growers in the states of Arkansas, California, Georgia, Louisiana, Mississippi, Missouri, and Texas, are using more tillage to manage weeds (Monsanto, 2013c). Some of these adjustments may have the potential to impact soil quality. Residue management that employs intensive tillage and leaves low amounts of crop residue on the surface results in greater losses of soil organic matter (SOM) (USDA-NRCS, 1996).

Herbicide use is likely to continue to increase to meet the need for additional integrated weed management tactics to mitigate HR weeds (Culpepper et al., 2008; Owen and Zelaya, 2005; Owen, 2008). Pesticide use has the potential to affect soil quality due to the impact to the soil microbial community. The environmental risks of pesticide use are assessed by EPA in the pesticide registration process and are regularly reevaluated by EPA for each pesticide to maintain its registered status under FIFRA. EPA's process ensures that each registered pesticide continues to meet the highest standards of safety to protect human health and the environment.

4.2.2.2 Preferred Alternative: Soil Quality

The impacts on soil quality of choosing the Preferred Alternative are not expected to be any different than under the No Action Alternative. Under the Preferred Alternative, DAS-81910-7 cotton would not be regulated by APHIS and could be made available for commercial production, but the new post-emergence use of 2,4-D on the plant would not be allowed.

DAS-81910-7 cotton has been found to be compositionally, agronomically and phenotypically equivalent to commercially cultivated cotton (DAS, 2013b) . As a result, agronomic practices that impact soil quality would not change as a result of planting DAS-81910-7 cotton. Soil quality in U.S. cotton fields is not expected to be affected by choosing the Preferred Alternative.

4.2.3 Air Quality

4.2.3.1 No Action Alternative: Air Quality:

Agricultural activities such as tillage, pesticide application, prescribed burning, and farm equipment use can all impact air quality. Growers choose those activities that are most suited for their operations. To manage weeds growers may use a combination of activities including pesticide use. In some areas of the South tillage is increasing under the No Action Alternative. This activity indirectly affects air as particulate matter can increase with increasing tillage. Also, conventional tillage can use more fossil fuels than conservation tillage methods.

Under the No Action Alternative, these potential emissions may cause some transient impacts to local air quality. These impacts are unlikely to affect areas with impaired air quality because of the potential for chemical dispersion in air currents and the relatively large distances from agricultural production areas to areas under air quality management plans, which generally encompass urban areas.

4.2.3.2 Preferred Alternative: Air Quality:

Under the Preferred Alternative, a determination of nonregulated status of DAS-81910-7 cotton is not expected to impact air quality compared to the No Action Alternative. DAS-81910-7 cotton has been shown to be phenotypically and agronomically similar to other commercially grown cotton varieties; therefore, agronomic practices associated with cotton cultivation are not expected to change.

Approving the petition would allow DAS-81910-7 cotton to be planted, but it does not allow for the additional new uses of 2,4-D. The use of the herbicide is pending registration by the EPA under FIFRA, and the EPA is making a separate decision on the proposed new uses of 2,4-D on these plants. APHIS considers the potential impacts on air quality of its decision combined with the EPA's decision in Chapter 5 (Cumulative Impacts).

4.2.4 Climate Change

4.2.4.1 No Action Alternative: Climate Change

Under the No Action Alternative, cropping practices to manage weeds will likely increase in intensity. Increases in herbicide applications or the use of tillage would increase the contribution of cotton cultivation to GHG emissions. This increase would occur from the combustion of fossil fuels for equipment used to apply herbicides and to till fields. The magnitude of the impact will depend on the specific weed management practices that growers choose to use.

4.2.4.2 Preferred Alternative: Climate Change

As described in Section 4.1.1.2, the range and area of U.S. cotton production is not expected to expand under the Preferred Alternative. Agricultural practices in cotton production, such as tillage, cultivation, irrigation, pesticide application, fertilizer applications, and use of agriculture equipment that may contribute GHG emissions are not expected to change with the introduction of DAS-81910-7 cotton. Therefore, the potential impacts on climate change are the same under the Preferred and the No Action Alternative.

4.3 Biological Resources

Modern conservation practices incorporated in cotton cultivation have brought positive benefits to animal and plant communities through reduced tillage, more carefully controlled and targeted chemical placement (fertilizers and pesticides), and better control of irrigation systems (Ward et al., 2002). This summary provides the foundation to assess the potential impact to plant and animal communities. The biological resources of No Action Alternative and Preferred Alternative described in this section include animals, plants, microorganisms, biodiversity, and cotton gene movement.

4.3.1 Animal Communities

4.3.1.1 No Action Alternative: Animal Communities

Under the No Action Alternative, terrestrial (insect, bird, and mammal) and aquatic (fish, benthic invertebrate, and herptile) species would continue to be affected by current agronomic practices associated with conventional methods of cotton production. These impacts include exposure to current types of cotton being grown (96 percent of which are GE) (USDA-ERS, 2014a), tillage, cultivation, pesticide and fertilizer applications, and the use of agricultural equipment.

Terrestrial and aquatic species in the agroecosystem have been exposed to the CP4 EPSPS protein in GR crops for more than 15 years, without any indication of adverse effects on the animals from that protein, including any allergic effects or toxicity (European Commission, 2010; Snell et al., 2012). The plants expressing that protein that represents habitat for some of those animals do not vary substantially in nutritional composition or physical structure. The enzyme protein is not biologically active in soil or water, and it is rapidly and fully biodegradable in the environment.

Animal species have also been exposed to the PAT protein in glufosinate-resistant crops for many years, likewise without ill-effects from that protein (European Commission, 2010; Snell et al., 2012). The safety of food and feed containing the PAT protein was reviewed as part of previous assessments and was shown to present no significant food or feed safety risk. A biotechnology consultation on the PAT protein was conducted in 1998 and does not require additional evaluation by FDA (US-FDA, 1998a; US-FDA, 1998b).

Growers likely would still experience the continued emergence of GR weeds, requiring modifications of crop management practices to address these weeds. These changes may include diversifying the mode of action of herbicides applied to cotton and making adjustments to crop rotation and tillage practices (Owen et al., 2011b). Herbicide use may increase to meet the need for additional integrated weed management tactics to mitigate HR weeds in different cropping systems (Culpepper et al., 2008; Heap, 2011; Owen and Zelaya, 2005; Owen, 2008). Some of these adjustments may have the potential to impact the adoption of conservation tillage practices. If tillage rates were to increase as a means of weed suppression, it could possibly diminish the benefits to wildlife provided by conservation tillage practices.

Growers would continue to choose certain pesticides based on weed, insect and disease pressures, cost of seed and other inputs, technology fees, human safety, potential for crop injury, and ease and flexibility of the production system (Farnham, 2001; Heiniger, 2000; University of Arkansas, 2008). Agricultural production of existing nonregulated herbicide-resistant GE and non-GE cotton would continue to utilize EPA-registered pesticides, including glyphosate, 2,4-D, and glufosinate for weed management. 2,4-D would continue to be used as currently authorized by EPA for pre-plant application to cotton. Glyphosate and glufosinate would continue to be used in accordance with EPA regulations.

The environmental risks of pesticide use on wildlife and wildlife habitat are assessed by the EPA during the pesticide registration process, and are regularly reevaluated by the EPA for each pesticide to maintain its registered status under FIFRA. Offsite impacts are diminished when herbicides are applied in accordance with label instructions. EPA's process ensures that each registered pesticide continues to meet the highest standards of safety to protect human health and the environment.

The range of potential impacts of GE and non-GE cotton production practices on non-target terrestrial (insect, bird, and mammal) and aquatic (fish, benthic invertebrate, and reptile) species would be expected to continue under the No Action Alternative.

Preferred Alternative: Animal Communities

Under the Preferred Alternative, the direct and indirect impacts on wildlife from approving this petition for deregulation would be similar to the potential impacts under the No Action Alternative. Wildlife would continue to visit cotton fields on a limited basis with preferences for other agricultural fields, including cotton fields. As described in the No Action Alternative, animal populations could be indirectly impacted by changes in agricultural practices, such as tillage, pesticide and fungicide use, and cultivation. However, there would be no difference in the potential of DAS-81910-7 cotton cultivation to impact wildlife or habitat from that of other nonregulated HR or non-GE cotton varieties.

Data submitted by Dow indicate that DAS-81910-7 cotton has been shown to be substantially equivalent to non-transgenic cotton based on the compositional analysis of cottonseed, except for the inserted *aad-12* and *pat* genes (DAS, 2013b). The *aad-12* gene and expressed protein are present in nature in the soil bacterium *Delftia acidovorans*. The *pat* gene and the expressed protein are present in other crops grown in the United States with no effects on non-target organisms. Based on information provided by Dow, the AAD-12 and PAT proteins are not potential food allergens or toxins in animal diets (DAS, 2013b). As a result, animals that may consume these cotton varieties are not expected to be affected from deregulation of DAS-81910-7 cotton under the Preferred Alternative.

Under the Preferred Alternative, since agronomic characteristics of DAS-81910-7 cotton were found to be equivalent to non-transgenic cotton, it is expected that production of DAS-81910-7 cotton will not result in any changes in current agricultural practices. Growers will continue to use cultural and mechanical practices and herbicides to manage weeds, and biodiversity within a field is expected to remain unchanged. Agricultural production of cotton is expected to continue relying upon EPA-registered pesticides for weed management. The EPA regulates the use of herbicides under FIFRA and is making a separate decision which may or may not allow the use of 2,4-D on DAS-81910-7 cotton. APHIS considers the potential cumulative impacts on animal communities of its decision combined with the EPA's decision in the Cumulative Impacts analysis in Chapter 5.

As discussed previously, DAS-81910-7 cotton would likely replace other glyphosate- or glufosinate-resistant cotton cultivars that currently comprise the majority of the cotton acres planted with HR cultivars. No changes to agronomic practices such as cultivation, crop rotation, irrigation, tillage, or agricultural inputs with potential impacts to wildlife and their habitat would likely occur under this alternative. Based on the above, the impacts of determining nonregulated status for DAS-81910-7 cotton to animal communities would be similar to those of the No Action Alternative.

4.3.2 Plant Communities

4.3.2.1 No Action Alternative: Plant Communities

Under the No Action Alternative, environmental releases of DAS-81910-7 cotton would continue to be under APHIS regulation. Plant species (i.e., weeds) that typically inhabit GE and non-GE cotton production systems will continue to be managed with current agronomic practices, including the use of mechanical, cultural, and chemical control methods.

Weed communities within agricultural fields, including cotton, are impacted primarily by tillage practices and herbicide treatments (Owen and Zelaya, 2005). Non-target plant communities in areas surrounding production fields would be exposed to the impacts associated with agricultural production, including exposure herbicides or to various other typical agronomic inputs. Management practices such as herbicide use and mechanical cultivation can select for weeds that are adapted to these management practices.

Under the No Action Alternative, numerous weeds are commonly found in cotton fields. Common weeds in cotton fields include barnyardgrass, crabgrass, pigweed species (including Palmer amaranth), morning glory spp., common cocklebur, and common lambsquarters. These are common annual weed species in almost all cotton-growing regions. Johnsongrass, bermudagrass, and nutsedge are common perennial weed species.

A weed biotype is a sub-type or sub-population of a weed species; in this case one that has developed resistance to one or more herbicides. The emergence of herbicide resistance is not a new occurrence; new weeds may emerge as cropping practices change and growers fail to recognize or properly identify a plant as a weed (Iowa State University, 2003). Report of a resistant biotype for a given weed species does not mean that weed resistance is common, widespread, or persistent in that species. HR weed biotypes in the United States include both grass and broadleaf species, including *Lolium rigidum* (Rigid ryegrass), *Lolium multiflorum*

(Italian ryegrass), *Sorghum halepense* (Johnsongrass), *Amaranthus palmeri* (Palmer amaranth), *Amaranthus rudis* (Common waterhemp), *Ambrosia artemisiifolia* (Common ragweed), *Ambrosia trifida* (Giant ragweed), *Conyza canadensis* (Horseweed), and *Conyza bonariensis* (Hairy fleabane).

GR weed biotypes may continue to evolve under the No Action Alternative. According to a 2012 survey across 31 states in the United States, 49 percent of growers reported the presence of GR weed on their farms (Pucci, 2013), an increase from 2011, when the number was 34 percent. The problem is more pronounced in the South, with 92 percent of growers reporting GR weeds. These weed shifts are occurring predominantly, but not exclusively, with difficult-to-control broadleaf weeds. Some examples include *Ipomoea*, *Amaranthus*, *Chenopodium*, *Taraxacum*, and *Commelina* species(Heap, 2014d). GR Palmer pigweed (amaranth) is a major economic problem in the Southeast United States, while GR waterhemp is an economically important weed in Midwestern states (Culpepper et al., 2006; Owen, 2008). In the United States, species such as waterhemp have developed resistance to as many as four different herbicide sites of action (WSSA, 2015).

Currently there are 32 confirmed GR weed species globally (Heap, 2015a). Fourteen are confirmed in the United States, and all occur in cotton-growing states. At present, five 2,4-D-resistant weed species (Heap, 2015b) have been identified in the United States. Thus far, there have been no reports of 2,4-D- or auxin-resistant weed biotypes in cotton fields. Italian ryegrass with resistance against both glyphosate and glufosinate has also been observed in orchards in Oregon (Heap, 2014a). Under the No Action Alternative, HR weeds, including weeds with resistance to multiple herbicide modes of action, would likely continue to evolve in all regions of the United States.

Cotton volunteers can arise from spilled cotton seeds growing in the previous cropping season, or at the start of the next growing season in a rotation crop. These volunteers may become another source of boll weevil infestations for successive cotton plantings. However, existing agronomic practices are effective in the management of such volunteer cotton. Volunteers may be controlled by the application of cotton-active herbicides (Fromme et al., 2011; Morgan et al., 2011a), by typical technologies used in other crops, including by mechanical means, and by rotation of crops with resistance to different herbicide modes of action (Beckie and Owen, 2007; DAS, 2013b; Zollinger et al., 2011). Post-harvest destruction of cotton for Boll weevil control is a different issue, and will be discussed later.

Under the No Action Alternative, producers are diversifying weed management tactics in cotton production to include alternating crops resistant to different herbicide modes of action grown in a field, alternating the herbicide modes of action used, practicing more crop rotation, and increasing tillage to better control HR weeds (Owen et al., 2011a). Weeds are developing resistance to multiple herbicides, but are also controlled with adjustments to standard practices, so as to include crop rotation and tillage when overreliance on herbicides obviates such changes (Owen et al., 2011a).

4.3.2.2 Preferred Alternative: Plant Communities

Under the Preferred Alternative, the direct and indirect impacts of approving these petitions on plant communities, including weed complexes, is expected to be the same as those under the No Action Alternative.

Agronomic practices and inputs associated with DAS-81910-7 cotton would not be different than what is utilized on current commercially available GE cotton variety, if EPA does not approve use of 2,4-D on this cotton event.

The agronomic and phenotypic characteristics of DAS-81910-7 cotton have been evaluated in field trials (DAS, 2013b). DAS-81910-7 cotton has been shown to be phenotypically and agronomically similar to other commercially grown cotton varieties. DAS-81910-7 cotton expresses the PAT and AAD-12 proteins conferring resistance to the herbicides glufosinate and 2,4-D. Other deregulated GE cotton varieties are available with resistance to glufosinate and glyphosate. DAS-81910-7 would be cultivated similarly to other HR cotton, and have impacts to plant communities similar to those described under the No Action Alternative.

In the event of a determination of nonregulated status of DAS-81910-7 cotton , the risks to wild plants and agricultural productivity from weedy cotton populations are low; volunteer cotton populations are easily managed (Morgan et al., 2011a) and feral populations occur rarely in the U.S. Cotton Belt (Charles et al., 2013; Morgan et al., 2011a; Wozniak, 2002). Agronomic studies conducted by Dow tested the hypothesis that the weediness potential of DAS-81910-7 cotton is unchanged with respect to conventional cotton (DAS, 2013b). No differences were detected between DAS-81910-7 cotton and non-GE cotton in growth, reproduction, or interactions with pests and diseases, other than the intended effect of 2,4-D and glufosinate resistance (DAS, 2013b).

DAS-81910-7 cotton volunteers could potentially arise either as overwintering plants or as new plants arising from seed in the subsequent season. As DAS-81910-7 cotton is similar to other nonregulated cotton cultivars, its volunteers would be controlled by common agronomic practices. Excepting 2,4-D and glufosinate, DAS-81910-7 cotton is expected to be sensitive to the same herbicides as other cotton varieties. Where growers may have previously been able to use 2,4-D or glufosinate, volunteers could be effectively controlled by tillage or with other herbicide modes of action. Herbicides with diverse modes-of-action (e.g., ALS inhibitor, chloroacetamide, 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), PPO inhibitor, Photosystem I (PSI) disruption, Photosystem II (PSII) inhibitor, synthetic auxin (aside from 2,4-D), and tubulin inhibitor classes) could be used on volunteer DAS-81910-7 cotton (Monsanto, 2013a). Herbicides such as paraquat in burndown, atrazine to control 2,4-D cotton volunteers in corn fields, and flumioxazin to control 2,4-D resistant cotton volunteers in soybean fields (Morgan et al., 2011a). Additionally, agronomic practices such as appropriate variety selections, crop rotation, and rotation of herbicides with different modes of action can be used to avoid or manage volunteer cotton resistance to one or a few herbicides.

Deregulation of DAS-81910-7 cotton by APHIS under the Preferred Alternative is not expected to change current agronomic practices. Agronomic practices that would be associated with DAS-81910-7 cotton cultivation, such as tillage, are not different than currently used. APHIS expects that use of these other herbicides will increase, but as replacements for those which cannot be used because DAS-81910-7 cotton is resistant to them. Based on these findings, choosing the Preferred Alternative would not result in changes to the plant communities in or around cotton fields. Therefore, there are no changes in potential impacts to plant communities under the Preferred Alternative when compared to the No Action Alternative.

The decision to approve the petition will not directly or indirectly affect these grower decisions to use 2,4-D to manage weeds. While DAS-81910-7 cotton can resist applications of 2,4-D, nonregulated status determined by APHIS under the Preferred Alternative would not allow for the new 2,4-D uses on these varieties unless EPA approves registration of the use of 2,4-D and glufosinate.   The EPA regulates the use of herbicides under FIFRA and is making a separate decision on the proposed new uses of 2,4-D.

4.3.3 Microorganisms

4.3.3.1 No Action Alternative: Microorganisms

Soil microorganisms play a key role in soil structure formation, decomposition of organic matter, toxin removal, nutrient cycling, and most biochemical soil (Garbeva et al., 2004). These microorganisms also suppress soil-borne plant diseases and promote plant growth (Doran et al., 1996). The main factors affecting microbial population size and diversity include soil type (texture, structure, organic matter, aggregate stability, pH, and nutrient content), plant type (providers of specific carbon and energy sources into the soil), and agricultural management practices (crop rotation, tillage, application of herbicide and fertilizer, and irrigation) (Garbeva et al., 2004).

Residual toxicity or long term presence of herbicide in the soil in an active form does occur in some herbicides (Monaco et al., 2002). Factors that affect the persistence of a herbicide in the soil are classified as either degradation process or transfer process and involve herbicide and soil characteristics, soil biota, and the environment (Hanson, 2012; Hanson et al., 2004; Monaco et al., 2002; Norwine et al., 2005). GE plants potentially impact soil microbes either 1) directly from the transfer of introduced genetic material, 2) by exposure to expressed proteins through root exudation and crop residue incorporated into soil, or 3) changes in agronomic practices used to produce crops. Indirect impacts may arise from 1) impacts of the glyphosate or 2) changes in the amount and composition of residue from crops.

Cotton cultivation, including the production of GR cotton and glyphosate's potential impacts to soil microorganisms, is expected to continue under the No Action Alternative. More than 99 percent of cotton cultivated in the United States today is HR and the majority of HR cotton is GR (USDA-NASS, 2013c). Farmers have access to non-GR cotton varieties, and manage their crops by implementing practices to control pests and weeds, including the use of appropriate herbicides.

4.3.3.2 Preferred Alternative: Microorganisms

The potential impacts on soil quality of choosing the Preferred Alternative are no different than the impacts under the No Action Alternative. Soil microorganisms are affected by agricultural management practices, as described in the No Action analysis. One factor that drives a grower's selection of agricultural practices is how weed management might be implemented; in the absence of EPA approval to use 2,4-D for weed control with DAS-81910-7 cotton, there is likely to be no difference in potential impacts of nonregulated status for the DAS-81910-7 cotton compared to other cotton except that post emergent 2,4-D herbicides would not be usable on the crop, and others would need to be used instead. Another factor is the trend toward increased herbicide use to control HR weeds in different cropping systems (Culpepper et al., 2008; Heap, 2014c; Owen and Zelaya, 2005; Owen, 2008) and the trend will likely be similar under the No Action and the Preferred Alternative.

DAS-81910-7 cotton has been determined to be agronomically and compositionally similar to other nonregulated cotton varieties. Based on the data presented by Dow, the cultivation of DAS-81910-7 cotton is not expected to impact microbial populations and associated biochemical processes in soil (DAS, 2013b). Therefore, microbial populations and associated biochemical processes in soil are not expected to change with the introduction of DAS-81910-7 cotton. The potential impacts of choosing the Preferred Alternative on soil quality are no different than the impacts under the No Action Alternative.

Since the use of glufosinate may replace some of the existing use of glyphosate for cotton production under the Preferred Alternative, there would be no potential impacts to microorganisms compared to those of the No Action Alternative, since glufosinate has already been used under approved EPA labels for considerable number of seasons.

4.3.4 Biodiversity

Biodiversity in an agroecosystem depends on four primary characteristics: 1) diversity of vegetation within and around the agroecosystem; 2) permanence of various crops within the system; 3) intensity of management, including selection and use of insecticides and herbicides; and 4) extent of isolation of the agroecosystem from natural vegetation (Altieri, 1999). Additional enhancement strategies include intercropping (the planting of two or more crops simultaneously to occupy the same field), agroforestry, crop rotations, cover crops, no-tillage, composting, green manuring (growing a crop specifically for the purpose of incorporating it into the soil in order to provide nutrients and organic matter), addition of organic matter (compost, green manure, animal manure, etc.), as well as the introduction of hedgerows and windbreaks (Altieri, 1999). To some degree these practices currently are being used by cotton growers to increase biodiversity (Cotton Incorporated, 2010a). The adoption of GE crops, with the concomitant reduction in insecticide use and enhanced soil conservation practices, has also contributed to the increase in biodiversity of soil microorganisms, beneficial organisms, and plants (Dively and R., 2003; Naranjo, 2009).

4.3.4.1 No Action Alternative: Biodiversity

Agricultural lands, including cotton fields, are frequently disturbed and impacted by crop production activities, including tillage, bed preparation, planting of a monoculture crop, and application of fertilizers and pesticides. As a result, these areas are associated with low levels of biodiversity compared to adjacent natural areas (Lovett et al., 2003).

Under the No Action Alternative, DAS-81910-7 cotton would continue to be a regulated article. Growers and other parties who are involved in production, handling, processing, or consumption of cotton would continue to have access to GE glyphosate and other HR cotton products that are no longer subject to the plant pest provisions of the Plant Protection Act and 7 CFR part 340, including stacked varieties, and conventional cotton varieties. The implications of agronomic practices associated with cotton production, whether traditional or GE varieties would not change.

4.3.4.2 Preferred Alternative: Biodiversity

Herbicide use in agricultural fields can impact biodiversity by decreasing weed quantities or causing a shift in weed species. This can affect insects, birds, and mammals that use these weeds. The quantity and type of herbicide use associated with conventional and GE crops depends on many variables, including cropping systems, type and abundance of weeds, production practices, and individual grower decisions. Although DAS-81910-7 cotton does provide the grower with another glufosinate-resistant variety, without EPA approval of use of 2,4-D, cultivation of DAS-81910-7 cotton will not otherwise require any changes in agronomic practice such as in the rates of fertilizer or herbicide application, tillage, or planting practices (DAS, 2013b). Therefore, the impact of cotton production on biodiversity is likely to be unchanged from the No Action Alternative.

A determination of nonregulated status of DAS-81910-7 cotton will not change cultivation or agronomic practices, or agricultural land acreage associated with growing cotton. DAS-81910-7 cotton would be an additional HR cotton variety providing resistance to glufosinate for growers; in the absence of an EPA decision to allow use of 2,4-D on this crop, no new use of 2,4-D could be made. Therefore, a determination of nonregulated status of DAS-81910-7 cotton for the control of weeds would have no additional impacts on biological diversity compared to the No Action Alternative. Glufosinate is highly unlikely to have any direct toxic effects on non-target organisms and is likely to be neutral or beneficial to animal and plant biodiversity compared to non-transgenic cotton managed with other herbicides and with conventional broad-spectrum insecticides.

4.4 Human Health

4.4.1 No Action Alternative: Worker Health and Safety

No changes to current worker safety are anticipated under the No Action Alternative. Grower exposure to DAS-81910-7 cotton would be limited to individuals involved in their cultivation under regulated conditions. Cotton growers and farm workers will continue to be exposed to existing traditional and GE cotton varieties and their respective cultivation practices. The greatest risk to worker safety in agriculture would continue to be associated with physical injuries, typically occurring during the maintenance and use of farm machinery. Agronomic practices associated with cotton production are expected to follow current trends.

Adverse health impacts that may be associated with cotton production include ergonomic injuries arising from the repetitive nature and prolonged exertions of the hands associated with hand-weeding (OSHA, 2013). For example, some farmers have had to resort to hand-weeding in order to achieve satisfactory control of Palmer amaranth. Georgia cotton growers have increased hand-weeding on 17 percent of the acreage in 2000 through 2005 to 52 percent of the acreage in 2006 through 2010 (Sosnoskie and Culpepper, 2012). Similarly, in 2010, at least 20 percent of the cotton acres in Tennessee were hand-weeded (Culpepper et al., 2011). Additionally, the cotton dust generated during cotton handing and processing, which has been identified as a chemical hazard by the National Institute for Occupational Safety and Health (NIOSH), may present a worker health hazard (CDC, 2013; OSHA, 2014). The inhalation of cotton dust by mill workers can lead to asthma-like conditions called byssinosis (Salvaggio et al., 1986).

Cotton growers and farmworkers may be exposed to a variety of EPA-registered pesticides in both GE and non-GE production systems. Herbicide use may increase to meet the need for additional integrated weed management tactics to mitigate HR weeds in different cropping systems (Culpepper et al., 2008; Owen and Zelaya, 2005; Owen, 2008). However, worker safety is taken into consideration when a pesticide label is developed during the EPA registration process. When use is consistent with the label, pesticides present minimal risks to the worker.

4.4.2 No Action Alternative: Public Health

Cottonseed, which is a by-product of fiber production, is used in human food, animal feed, and a range of industrial products. Food uses of cottonseed include cottonseed oil and, to a lesser degree, cotton linters (US-FDA, 2013). Unprocessed cottonseed contains natural toxicants (gossypol) and anti-nutrients (cyclopropenoid fatty acids); therefore, only highly processed cotton-derived food products can be consumed by humans. Cottonseed oil is primarily consumed as a salad or cooking oil, for frying, in mayonnaise, and shortening. Processed cottonseed oil has been used safely for human food for over a century. Linters are removed from the seeds and processed into pure cellulose, which may be used in casings for processed meats and in ice cream and salad dressings (US-FDA, 2013).

Under the No Action Alternative, DAS-81910-7 cotton would continue as a regulated article under APHIS. Currently 96 percent of the cotton grown in the United States is genetically engineered (USDA-ERS, 2014a), including GE varieties with resistance to the herbicides glufosinate ammonium, glyphosate and sulfonylurea (OECD, 2008). This market share is expected to continue under the No Action Alternative.

Cotton with the CP4 EPSPS protein, which confers resistance to the herbicide glyphosate, was first evaluated by FDA in 1995 (US-FDA, 1995); GR cotton has been present in commerce since 1996. Cotton with the PAT protein, conferring resistance to glufosinate, was evaluated by FDA in 2003 (US-FDA, 2003a), and has been in commerce since 2004. Both of these proteins are considered by FDA to be safe for consumption by humans and animals. Consumer exposure to existing conventional and GE cotton varieties and their byproducts is not expected to change for the No Action Alternative.

4.4.3 Preferred Alternative: Worker Safety

APHIS has not identified any direct or indirect adverse impacts on worker safety associated with the selection of the Preferred Alternative. Because DAS-81910-7 cotton is agronomically and compositionally similar to conventional cotton (DAS, 2013b), no significant impact is expected on current crop production practices. As a result, existing hazards to workers occurring from the various agronomic production practices that are used to grow cotton are expected to continue. Workers will continue to use farm equipment and agricultural chemicals. The decision to approve this petition does not authorize a change in herbicide use on this cotton variety. The EPA regulates the use of herbicides under FIFRA and considers the potential effects on human health when approving the use of herbicides.

4.4.4 Preferred Alternative: Public Health

Upon deregulation and commercialization of DAS-81910-7 cotton, cotton byproducts produced from this cotton event would enter the food and feed chain and would be consumed by humans and animals.

Following the FDA's guidance to industry, "Recommendations for the Early Food Safety Evaluation of New Non-Pesticidal Proteins Produced by New Plant Varieties Intended for Food Use" (71 FR 35688; June 21, 2006), Dow initiated a new protein consultation with FDA and submitted an early food safety evaluation of the AAD-12 protein (NPC 000009) on December 15, 2008 (Krieger, 2008).[12] The information presented by Dow indicated that the AAD-12 protein was determined to have no amino acid sequence similar to known allergens, lacked toxic potential to mammals, and was degraded rapidly and completely in gastric fluid. As such, the submission concluded that the presence of the AAD-12 protein in food or feed should be of no significant concern (Krieger, 2008). FDA completed its evaluation with no further questions on May 19, 2010 (US-FDA, 2010).

Dow submitted a safety and nutritional assessment of food and feed derived from DAS-81910-7 cotton to FDA in June 2013 (BNF No. 000142) in support of the consultation process for the commercial distribution of DAS-81910-7 cotton. The FDA evaluated the information in Dow's submission to ensure that regulatory and safety issues regarding the human food and animal feed from the new plant variety have been resolved prior to commercial distribution. As part of its evaluation, the FDA reviewed information submitted by Dow on the identity, function, and characterization of the genes, including expression of the gene products in DAS-81910-7 cotton, as well as information on the safety of the AAD-12 and PAT proteins and DAS-81910-7 cotton itself, including a dietary risk assessment.

A detailed safety assessment of the AAD-12 and PAT proteins expressed by DAS-81910-7 cotton was conducted by Dow to assess any potential adverse effects to humans or animals resulting from the environmental release of DAS-81910-7 cotton (Codex Alimentarius Commission, 2009). The food and feed safety assessment of AAD-12 and PAT proteins expressed in DAS-81910-7 cotton considered several factors including safety of the donor organism, history of safe use, allergenic potential, toxicity potential and dietary risk assessment based on consumption patterns.

DAS-81910-7 cotton contains the *aad-12* and *pat* genes that result in the expression of the AAD-12 and PAT proteins, respectively. The AAD-12 protein in DAS-81910-7 cotton is derived from the common gram-negative soil bacterium *Delftia acidovorans*. The *pat* gene expressing the PAT protein was derived from a gram-positive soil bacterium *Streptomyces viridochromogenes*. The *aad-12* and *pat* genes introduced into DAS-81910-7 cotton are the same as those introduced into DAS-68416-4 soybean (USDA Petition Number 09-349-01p) and DAS-44406-6 soybean (USDA Petition Number 11-234-01p) that have been reviewed by FDA and deregulated by USDA-APHIS (2014c).

[12] Submission of an early food safety evaluation for a new protein is not meant to substitute for a biotechnology final consultation with FDA about a food derived from a new bioengineered plant variety. Field testing of new bioengineered plants could result in the inadvertent, intermittent, low-level presence in the food supply of proteins that have not been evaluated through FDA's biotechnology consultation process.

According to Dow, a compositional analysis of DAS-81910-7 cotton demonstrates that it is comparable with currently available varieties of cotton, and, thus, is not expected to have different nutritional qualities than other available cotton varieties. Neither the AAD-12 nor PAT proteins have relevant amino acid sequences similar to known allergens, toxins or other proteins that may have adverse effects on mammals. Furthermore, the AAD-12 and PAT proteins in DAS-81910-7 cotton are rapidly digested in simulated gastric and intestinal fluids, and these studies did not show any observable adverse effects in mouse acute oral toxicity analyses. The low level or negligible of these proteins presents a low exposure risk to humans and animals, and the results of the overall safety assessment of AAD-12 and PAT indicate that DAS-81910-7 cotton is unlikely to cause allergenic or toxic effects in humans or animals.

For the human diet, cottonseed is used in food applications in which the seeds are mainly used to obtain refined edible oil. The AAD-12 and PAT proteins represent a very small portion of the total protein in the cottonseed from DAS-81910-7 cotton. The mean percent dry weight of total protein in DAS-81910-7 cottonseed is approximately 25 percent dry weight, the amount of AAD-12 protein in DAS-81910-7 cottonseed is calculated to be 0.008 percent of total protein and that of PAT to be 0.002 percent (DAS, 2013b). Furthermore, refined cottonseed oil contains undetectable amounts of protein (OECD, 2009; Reeves and Weihrauch, 1979). In the course of processing to food grade quality oil, proteins are destroyed by high temperatures and pressure, or are separated out by extraction with a non-polar solvent. Subsequent alkali treatment and deodorisation steps are likely to remove any last detectable traces of protein in the refined oil. Deodorisation also greatly reduces the cyclopropenoid fatty acid content (DAS, 2013b; FSANZ, 2014). Refined, bleached and deodorised cottonseed oil produced from DAS-81910-7 cotton will contain extremely low levels to no detectable levels of AAD-12 and PAT proteins. Therefore, no exposure to AAD-12 or PAT proteins is anticipated for food uses of DAS-81910-7 cotton.

Additionally, the PAT protein, expressed in DAS-81910-7 cotton has already been reviewed by the FDA and has been in commercially produced crops. An FDA biotechnology consultation on cotton lines containing the PAT protein (BNF No. 000086) (US-FDA, 1998a) was completed on April 2, 2003 (US-FDA, 1998a) and does not require reevaluation. Additionally, EPA previously concluded, after reviewing data on the acute toxicity and digestibility of the PAT protein, that there is a reasonable certainty that no harm will result from aggregate exposure of the U.S. population, including infants and children, to the PAT protein and the genetic material necessary for its introduction (US-EPA, 1997b). EPA has consequently established an exemption from tolerance requirements pursuant to FFDCA section 408(j)(3) for PAT and the genetic material necessary for its production in all plants.

According to Dow, the overall safety assessment of the inserted AAD-12 and PAT genes supports the conclusion that food and feed products containing DAS-81910-7 cotton or derived from DAS-81910-7 cotton are as safe as cotton currently on the market for human and animal consumption (DAS, 2013b). Consultation with the FDA for DAS-81910-7 cotton (US-FDA, 2014a) has been completed on October 31, 2014, and the FDA has no further questions about food and feed derived from this cotton varieties.

No potential negative impacts on humans are expected to result from exposure to the introduced AAD-12 and PAT proteins in food and feed derived from DAS-81910-7 cotton. As a result, the direct and indirect effects on food and feed are not expected to be different under the Preferred Alternative when compared to the No Action Alternative.

4.5 Animal Feed

Processing of cotton generally provides cottonseed meal, cottonseed hulls, and whole cottonseed to be utilized in the animal feed industry as sources of protein, fiber and energy (NCPA, 2002a; OECD, 2009). Whole cottonseed, cottonseed meal, hulls, and cotton gin trash are used in animal feeds for cattle, sheep, goats, horses, poultry, swine, fish, and shrimp.

4.5.1 No Action Alternative: Animal Feed

Under the No Action Alternative, DAS-81910-7 cotton would continue as a regulated article under APHIS. Most of the cotton currently grown in the United States is genetically engineered (USDA-ERS, 2014b) and this market share is expected to continue under the No Action Alternative. Livestock are routinely exposed to GE cotton in animal feed. Livestock exposure to cotton would continue to be limited to currently available varieties being grown in commerce, including non-GE and GE varieties. All currently-available GE cotton varieties used in animal feed are considered safe for animal consumption and this is not expected to change under the No Action Alternative.

4.5.2 Preferred Alternative: Animal Feed

Upon deregulation and commercialization, cotton, cottonseed oil and byproducts produced from DAS-81910-7 cotton would enter the food and feed chain and would be consumed by animals. Livestock will continue to consume GE cotton-based products. As described in the petition, DAS-81910-7 cotton is compositionally similar to currently available varieties of cotton. Therefore, DAS-81910-7 cotton is not expected to have different nutritional qualities than other available cotton varieties.

Dow provided the FDA with information on the identity, function, and characterization of the genes in DAS-81910-7 cotton. The FDA evaluated the information in Dow's submissions to ensure that regulatory and safety issues regarding the human food and animal feed from the new plant varieties have been resolved prior to commercial distribution (see details under Section 4.3.7.2, Preferred Alternative: Human Health).

Dow estimated livestock dietary exposure for expressed levels of the AAD-12 protein in DAS-81910-7 cotton with conservative (i.e., protective) livestock dietary assumptions. The assessment conservatively assumed that 100 percent of cotton consumed by animals is derived from DAS-81910-7 cotton. Actual dietary exposure to AAD-12 protein will be lower because: 1) cotton is a blended commodity; thus, cotton-derived food and feed will contain cotton from a mixture of sources, 2) degradation of the protein will occur during transport and storage, and 3) heat applied during preparation of cotton derived foods and feeds may lessen exposure to AAD-12, as AAD-12 is functionally unstable when heated (see discussion in Section 4.3.7.2, Preferred Alternative: Human Health). This assessment includes several cotton commodity forms as potential animal feeds: seed, meal, hulls and gin byproducts, and assessed consumption by swine, poultry and cattle. The results of the dietary exposure assessment showed large margin of exposure values for the AAD-12 protein in DAS-81910-7 cotton, indicating negligible risk to animal health when AAD-12 is present in their food.

Consultation with the FDA for DAS-81910-7 cotton (US-FDA, 2013) has been completed and the FDA has no further questions about food and feed derived from this cotton variety. The direct and indirect effects on animals as a result of consumption of feed containing DAS-81910-7 cotton are not expected to be different under the Preferred Alternative when compared to the No Action Alternative.

4.6 Socioeconomics

4.6.1 Domestic Socioeconomic Environment

4.6.1.1 No Action Alternative: Domestic Socioeconomic Environment

Under the No Action Alternative, DAS-81910-7 cotton would continue to be regulated articles under 7 CFR Part 340. Growers and other parties who are involved in production, handling, processing, or consumption of cotton will continue to have access to nonregulated GE and non-GE cotton varieties. Domestic growers will continue to use GE and non-GE cotton varieties based upon availability and market demand. Input costs, net returns to growers, and overall value of cotton would not be affected.

Good cotton management allows the plant to produce a high yield at a reasonable cost by channeling energy inputs into harvestable cotton lint and to do so within the limitations imposed by soil, length of season, weather patterns and production cost (Rude, 1984). Table 22 summarized some recent costs of cotton production in the United States. Farm income may be benefitted by GE cotton when production costs can be reduced, which may include reduced tillage practices for weed management, creating greater farm flexibility and efficiency, plant-expressed insect toxins and, also freeing additional resources of grower time compared to non-GE cotton. While most growers are expected to continue benefiting from the adoption and cultivation of this and currently deregulated GE crops, growers in some U.S. regions with HR weed problems may incur increased costs because of the increased need for more pesticide treatments or increased tillage. These trends have been noted in the No Action Alternative. From recently collected data (2012 and 2013), average U.S. operating costs for cotton production have been subject to only small increases and USDA-ERS does not project large increases in 2014-2016 (Table 22). However, changes from slightly earlier times, especially in chemical costs of cotton have been apparent as the importance of GR weeds have arisen in cotton acreage since 2000.

Table 22. U.S. Cotton Production Operating Costs per Planted Acre, 2012-2016

Operating costs	2012[2]	2013[2]	2014[3]	2015[3]	2016[3]
Seed	98.60	100.74	103.46	104.49	104.90
Fertilizer[1]	99.60	96.72	96.40	89.79	87.60
Chemicals	69.28	70.04	71.34	72.51	72.95
Custom operations	23.66	24.07	24.87	25.14	25.29

1: Commercial fertilizer, soil conditioners, and manure.
2: Developed from survey base year, 2007.
3: Forecasts as of November 2014. Projected costs are based on 2013 production costs and projected changes in 2014, 2015, and 2016 indexes of prices paid for farm inputs.
Source: (USDA-ERS, 2015)

A detailed budget for the costs of chemicals for agronomic purposes, and for pest control in cotton in Tennessee for 2015 show an increase over that presented for 2007 (University-of-Tennessee, 2007; University-of-Tennessee, 2015). Total costs of chemicals increased from $204.33 to $278.23 per acre in this eight year period. Costs of herbicides increased from $48.26 to $91.82 (See Table 23), and the numbers of herbicides applied in 2007 increased from seven, including four low-cost glyphosate applications to eight including a higher priced Liberty application.

Table 23. 2015 Typical Non-Irrigated Budget for Chemicals Applied to Tennessee Cotton Fields.

Chemical	Function	Description	Unit	No of apps	Qty.	Price ($)	Total ($/Acre)
Herbicide	Burndown	Roundup Power Max	qt.	1	1	$5.70	$5.70
	Burndown	Clarity 4EC	qt.	1	8	$0.72	$5.76
	Pre-Emerge	Cotoran 4L	qt.	1	2	$5.00	$10.00
	Over The Top	Roundup Power Max	qt.	1	1	$5.70	$5.70
	Over The Top	Dual Magnum	qt.	1	1	$15.97	$15.97
		Liberty 280 SL	qt.	1	29	$0.57	$33.06
	Hooded Sprayer	Gramoxone SL	qt.	1	32	$0.29	$9.28
		Surfactant	pt.	1	0.2	$2.38	$0.48
		Valor	oz.	1	1	$6.11	$6.11
Growth Regulator		Mepex (Mepiquat Chloride)	pt.	1	2	$1.00	$2.00
Defoliant			oz.	1	12	$0.55	$6.60
Boll Opener		Ethephon	oz.	1	32	$0.19	$6.00
Insecticides		Seed Treatment	acre	1	1	$9.00	$9.00
		In-Season	acre	1	1	$35.00	$35.00
Fungicides		Seed Treatment	acre		1	$7.50	$7.50
Fertilizers		Urea, Phos., Pot., Lime, Boron				(several)	$120.07
Total							**$278.23**

Source: (University-of-Tennessee, 2015).

Sosnokie and Culpepper (2014) show that the increased presence of GR weeds, especially Palmer amaranth, produced several new costs for growers. This problem weed began to be present in Georgia crops beginning in the period 2000-2005, and growers doubled applications of Palmer specific herbicides by 2006- 2010. Because of inadequate chemical control, growers were forced in 52 percent of cotton acres to hand weed to prevent seed production at $57/hectare.

Additional use was made of paraquat, glufosinate, and residual herbicides to control Palmer. To incorporate additional preplant herbicides, 20 percent of acres need a tillage pass. Growers increased harrowing (in crop tillage) to 44 percent of acres. About 19 percent of acres require deep tillage every three years, which is contrary to typical constraints placed on no-till cotton production. APHIS has noted that these are some of the adverse impacts for which improved tactics of weed management are needed.

4.6.1.2 Preferred Alternative: Domestic Socioeconomic Environment

Under this alternative, DAS-81910-7 cotton would not be regulated by APHIS. Production and acres planted in cotton are expected to remain the same as under the No Action Alternative. Over the past 15 years of commercial use, GE traits have not been shown to increase yield potentials (the maximum possible yield under ideal conditions). Several studies have found mixed results of differences between the actual yields and net returns of adopters and non-adopters of HR cotton; some find no differences, others find a slight yield advantage (Fernandez-Cornejo et al., 2014b). Some of the increases are the likely results of seed providers using only the most productive germplasm when stacking newer traits.

Potential increases in costs may accompany offering of the 2,4-D-resistant cotton varieties, but only if EPA approves registration for use of this chemical and Enlist on DAS-81910-7. GE seed prices are influenced by the combination (stacking) of different traits or genes and costs of seed development, production, marketing, and distribution. The price depends on the competitiveness of the particular seed market, and the pricing behavior of those firms that hold large shares of the market. In recent decades, private sector research and development costs have been rising with the application of new technologies, which have contributed to increased seed prices. Over the three years, 2011-2013, the price of cotton seed increased from about $97 to about $143 per planted acre. The increase in GE seed prices is due in part to the rising share of GE seeds with more than one trait or more than one mode of action for a particular pest. Another factor contributing to the increase in GE seed prices is improvements in seed genetics. The rapid adoption of GE crops indicates that many farmers are willing to pay higher seed prices because of improved seed performance and the additional pest management traits offered by GE seeds (Fernandez-Cornejo et al., 2014b). APHIS concludes that this potential for increase in seed cost for DAS-81910-7 cotton is one that appears to be part of the expected economic pattern for GE crops, should the herbicides designated for use on the HR crop receive registration by EPA.

HR crops have some benefits over conventional crops, including production efficiencies and often, fewer resources are needed for weed control operations. Producers who plant HR crops expect to achieve at least the same crop yield while lowering weed control costs using mainly chemicals and only some or no mechanical methods rather than reliance on tillage, harrowing and time intensive field operations for weed and insect control. Another avoided cost derives from the demonstrated broad spectrum of effective weed control typical of HR crops (especially expressing glyphosate resistance) so that multiple herbicides might not be needed. Consequently, growers have historically expected that the need for weed scouting would be reduced (Mississippi-State-University, 2010); however, both endpoints, reduced herbicide complexity and reduced scouting are not necessarily attained nor is the avoidance of scouting a recommended practice. APHIS concludes that DAS-81910-7 cotton, resistant to the herbicides 2,4-D and glufosinate, will provide growers with greater flexibility in selection of herbicides for the improved control of economically important weeds; allow an increased application window for effective weed control; and provide an effective weed resistance management solution to GR weeds thus lowering costs engendered by increasing numbers of herbicides needed to control problem weeds.

DAS-81910-7 cotton will also be combined with the trait for glyphosate resistance using traditional breeding techniques. The combination of HR traits will allow the use of multiple herbicides in an integrated program to control a broad spectrum of grass and broadleaf weed species in cotton. These two herbicides will provide distinct modes of actions for use in conjunction with other herbicide active ingredients and modes of action. Further, both together also provide value to growers as well as facilitating sustainable weed control by means of extending the usefulness of other herbicides now subject to overuse and weed resistance.

4.6.2 International Socioeconomic Environment

4.6.2.1 No Action Alternative: International Socioeconomic Environment

Under this alternative, DAS-81910-7 cotton would remain a regulated article. Accordingly, cotton or cotton products derived from DAS-81910-7 cotton could not be exported and there would be no impacts to trade under the No Action Alternative.

4.6.2.2 Preferred Alternative: International Socioeconomic Environment

A determination of nonregulated status of DAS-81910-7 cotton is not expected to adversely impact trade under the Preferred Alternative. Although the primary U.S. cotton export destinations do not present major barriers to trade in cotton from existing GE plants, Dow would need to obtain approval of DAS-81910-7 cotton in destination countries before commercialization to avoid adversely affecting current trade in cotton products. Dow has submitted applications to several international agencies, including the regulatory authorities in Australia, New Zealand, Canada, Japan, Korea, and Mexico. DAS-81910-7 cotton has been approved in some countries and is pending in others. The regulatory status in six countries, as of February 10, 2015, is summarized in Table 24.

Table 24. Current Approval Status of DAS-81910-7 Cotton.

Country	Status
Australia/New Zealand (Food)	Approved
Canada (Food, Feed, Cultivation)	Pending
Japan (Food/Feed, Environmental Import)	Pending
Korea (Food/Feed)	Pending
Mexico (Food/Feed)	Pending
United States (Food/Feed)	Approved
United States (Cultivation)	Pending

As of February 10, 2015.

Source: (DAS, 2015).

When regulatory approvals for major U.S. trading partners are gained for this crop and trait, DAS-81910-7 cotton is not expected to impact levels of international cotton trade. Accordingly, impacts to the international economic environment under the preferred alternative would be similar to impacts under the no action alternative.

5 CUMULATIVE IMPACTS

Cumulative impacts are defined as the "impact on the environment, which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions" (40 CFR 1508.7).

This section assesses current and reasonably foreseeable future impacts if APHIS chooses either the No Action or the Preferred Alternative. APHIS considers the impacts of both alternatives when combined with past, present, and reasonably foreseeable future actions.

Impacts on physical and biological resources were considered in the analyses. Possible implications of how these impacts might affect the availability of those resources for human use and consumption were also analyzed. The initial step in this process is an analysis of the potential changes in management practices likely to occur if APHIS approves the Dow petition for DAS-81910-7 cotton. A second step is that EPA would need to approve the application rate changes for 2,4-D on this GE cotton variety requested by the petitioner. In this EA, changes in management practices were analyzed along with how these might impact physical and biological resources. Possible impacts of an interaction with other APHIS actions (past and those currently pending) were also considered.

Environmental issues were assessed individually in Section 4. From that analysis, APHIS determined there are no direct or indirect impacts from DAS-81910-7 cotton, because these varieties are not agronomically different from other GE cotton cultivars that are no longer regulated by the Agency. However, the analysis did not consider potential cumulative impacts that might result if the requested EPA actions are approved in conjunction with those of APHIS. An APHIS determination of nonregulated status for DAS-81910-7 cotton and the independent action by EPA to approve registration of Enlist Duo™ on this crop is reasonably foreseeable. Enlist Duo is a premix of 2,4-D choline salt and glyphosate. It is specifically formulated for use on the crops that are genetically engineered to be resistant to applications of 2,4-D and glyphosate (i.e., Enlist crops).

The factors that would contribute to increased 2,4-D use on cotton include the application rate (i.e., the pounds applied per acre) and the number of acres to which 2,4-D is applied. Presently, 2,4-D can only be applied for preplant or burndown purposes, and that must occur at three or more weeks before cotton planting. Additionally, if approved by EPA, 2,4-D will be applied in fields where Enlist corn and soybean might be rotated with cotton, since nonregulated status has been attained for these 2,4-D-resistant crops. One consideration about possible cumulative impacts is that more 2,4-D will be applied to multiple crops, resulting in increased selection for 2,4-D-resistant weeds. Because this impact would occur only if both APHIS and EPA take the actions already described here, APHIS has analyzed the potential cumulative impacts of its action combined with potential Enlist Duo applications in more detail in this section. More specifically, this cumulative impacts section analyzes the potential cumulative impacts of the development of additional weeds resistant to 2,4-D arising from the cumulative use of 2,4-D on the three new Enlist crops where growers do not diversify their weed management practices, combined with other past, present, and reasonably foreseeable future actions within the affected environment.

5.1 Management Practices Considered in the Analysis of Cumulative Impacts

This cumulative impacts analysis addresses the potential impacts of the proposed alternatives on physical and biological resources and their interrelated socioeconomic impacts. DAS-81910-7 cotton will not affect physical or biological resources directly, but the management practices (e.g., pesticide applications) associated with cultivation of these crops may impact physical and biological resources. If EPA registers Enlist Duo for use on DAS-81910-7 cotton, APHIS expects that 2,4-D use will increase under the Preferred Alternative. Increased use of 2,4-D could accelerate the selection and distribution of 2,4-D-resistant weeds if growers fail to follow best management practices and diversify weed management methods. As a result, growers of other crops that use 2,4-D for weed control may need to modify their management practices to delay or manage 2,4-D-resistant weeds. These changes would increase the complexity and cost of weed management programs for these growers. Because the use of DAS-81910-7 cotton does not require a single specific set of agronomic practices, the magnitude of the impacts discussed depend on the adoption rates of various practices by growers. This section analyzes the cumulative impacts related to changes in management practices that are likely to be associated with the adoption of DAS-81910-7 cotton in the context of the impacts that agriculture in general has on these resources in the areas where cotton is grown.

5.2 Risk Assessments Used for the Analysis of Cumulative Impacts

The EPA uses risk assessment for registration decisions. It evaluates risk based on exposure and hazard to both humans and other organisms. A pesticide cannot be registered, nor can an existing registration be amended, unless the registered use conforms to the EPA standard of "no unreasonable adverse effects on the environment" as described in FIFRA. There are four general steps in the risk assessment process: hazard identification, exposure assessment, dose/response assessment, and risk analysis. Once the EPA determines that this standard can be met, it issues a registration or modifies an existing one. The registration label includes strict limits on the quantities and methods allowed for the use of a pesticide to ensure that the standard is met.

The EPA has developed exposure assessments for this process to characterize environmental persistence of pesticides and their byproducts from degradation following application. These assessments are based in part on scientific studies that sample and measure residue concentrations for specified time frames. The data are analyzed with statistical procedures referred to as models to extrapolate estimates for environmental fate (i.e., persistence of residues) over longer time frames than the ones sampled.

The EPA uses environmental fate data to predict potential concentration of the pesticide and its degradation products in air, soil, and surface and groundwater. These data are also used to estimate residue levels in the drinking water component of human dietary risk assessments.

Results of environmental fate studies enable the EPA to determine where a pesticide and its degradates (byproducts) go in the environment (i.e., air, water, and soil), how long they persist, and in what quantities. This information is used by the EPA to develop estimated environmental concentrations (EECs) that can be compared to toxicity and ecotoxicology data as part of the risk assessment process. EEC values are based on the maximum allowable application rate for a pesticide although typical application rates are usually lower than the maximum allowed. This approach, along with other factors, such as the conditions on the farm field, result in "high-end" to "bounding" estimates of exposure. When these are compared to the most sensitive toxicological endpoints in human and ecological effects studies, the results are conservative risk estimates. If these estimates exceed concern levels, the EPA will refine the exposure estimates using additional information or may perform a probabilistic assessment of risks. The EPA has conducted independent assessments of direct and indirect effects associated with the use of 2,4-D on DAS-81910-7 cotton concurrent with the development of this EA (US-EPA, 2013a; US-EPA, 2013b; US-EPA, 2013c). These effects are outside the scope of this EA. In the proposed registration, the EPA will establish label restrictions for the use of Enlist Duo on Enlist cotton that, when followed, will ensure no unreasonable adverse effects to human health or the environment. APHIS' analysis in this section focuses on cumulative impacts associated with the DAS-81910-7 cotton, including the development of new HR weeds, arising from herbicide application and changes in management practices needed because of their use.

5.2.1 No Action Alternative. Current Management Practices Considered in the Analysis of Cumulative Impacts

This analysis addresses the potential impacts on physical and biological resources and their interrelated socioeconomic impacts within the United States on APHIS' determination of nonregulated status for DAS-81910-7 cotton. First, the Affected Environment presented the overall background in which U.S. cotton is produced. Herbicide use is a dynamic process, in that various agronomic factors are changing. This includes an increase in GR weeds and other HR weeds, as well as the presence and time of appearance of these weeds. Superimposed on this is the price of commodities, which determines what economic practices can be used for cotton production and which are not economically justifiable. Part of this complex interaction also includes rotation crops and their economies and needs. Alternatives available for production practices on cotton and rotation crops are relevant. Thus, cultural and physical methods to control weeds are a large and important part of the active inputs into the agroecosystem, as are decisions of cotton growers to select certain production practices. In this milieu, application of 2,4-D is already a part of the possible agronomic input practices, along with that of other herbicides. In the Environmental Consequences section (Section 4), APHIS has presented these issues and facts, and this section of Cumulative Impacts focuses on the changing patterns of 2,4-D use and tillage, both important considerations in the potential for environmental impacts that might derive from planting of DAS-81910-7 cotton.

5.2.1.1 Current 2,4-D Use

Agronomic practices that already include application of 2,4-D will also contribute to any impacts of additional application of the herbicide on other resources, and thus may be affected by nonregulated status for DAS-81910-7 cotton. Contributing to increased 2,4-D use in the cotton agroecosystem and in production of other crops are the application rate and any additional number of acres to which 2,4-D would be applied with the new resistant cotton variety. EPA analyzes these impacts and assesses the safety of the new use of 2,4-D.

In 2012, the highest use of 2,4-D was on pasture land, with almost 10.6 million pounds per active ingredient (lb ai) used (see Table 25). This represented on average, about 10 to 15 percent of the total pasture acres. The second highest use was made on wheat with 5.9 million lb ai used, on 30 to 65 percent of the wheat acreage. The third highest use of 2,4-D herbicides was on corn acreage with 3.2 million lb ai (at 5-10% of the corn acreage) and soy acreage with 2.9 million lb ai (10 to 15 percent of the soybean acreage). Cotton with 700,000 lb ai of 2,4-D applied to 10 to 15 percent of cotton acres represents only a modest use of 2,4-D. Fallow acres had the fourth most frequent use of 2,4-D, and the highest percentage of use of the herbicide was for sugarcane, attaining to 40 percent of the acres (US-EPA, 2012a). Historically, the use of 2,4-D on cotton since around 1998 was nearly none (Table 26), but increased use was made of the herbicide for burndown in successive years. By 2012, usage had attained to about 10 percent of the cotton acres (US-EPA, 2012a; USDA-NASS, 2014d).

More recently, an analysis of grower and extension responses to a University of Georgia questionnaire (Sosnoskie and Culpepper, 2014) indicated increasing use of 2,4-D on cotton. When compared to the period from 2000 to 2005, preemergent use of 2,4-D has more than doubled from 2006 to 2010, according to county extension agents surveyed about trends in their counties; when growers responded to the same survey, a 15 percent increase was reported. This trend in 2,4-D use was also accompanied by significant declines in preemergent use of glyphosate.

Table 25. Agricultural Uses of 2,4-D.

Crop		Amount Used - Pounds Active Ingredient (lbs a.i.)	Percent Crop Treated	
			Average	Maximum
1	Almonds	200,000	15	20
2	Apples	80,000	20	25
3	Apricots	2,000	10	25
4	Asparagus	5,000	10	30
5	Barley	500,000	25	40
6	Cherries	30,000	15	25
7	Corn	3,200,000	5	10
8	Cotton	700,000	10	15
9	Fallow	2,300,000	25	30
10	Grapefruit	10,000	10	25
11	Grapes	50,000	5	15
12	Hazelnuts (Filberts)	20,000	25	35
13	Nectarines	5,000	15	35
14	Oats	300,000	15	20
15	Oranges	100,000	20	30
16	Pasture	10,600,000	10	15
17	Peaches	30,000	20	30
18	Peanuts	50,000	5	10
19	Pears	10,000	15	20
20	Pecans	40,000	10	15
21	Pistachios	9,000	5	20
22	Plums	5,000	15	30

Crop		Amount Used - Pounds Active Ingredient (lbs a.i.)	Percent Crop Treated	
			Average	Maximum
23	Prunes	20,000	15	25
24	Rice	300,000	10	15
25	Sorghum	90,000	20	30
26	Soybeans	2,900,000	10	15
27	Sugarcane	400,000	40	65
28	Sunflowers +	60,000	5	10
29	Sweet Corn	7,000	5	10
30	Tangelos	1,000	30	45
31	Tangerines	2,000	10	20
32	Walnuts	40,000	10	15
33	Wheat	5,900,000	30	65

Source: (US-EPA, 2012a)

Table 26. Percentage of Cotton Acres Treated with 2,4-D.

Year	2010	2005	2003	2001	2000	1999
Percent cotton acres treated	7	7	4	3	1	1

Source: (USDA-NASS, 2014d)

5.2.1.2 Current Tillage Patterns

The relationship of weed control to changes in tillage practices may be evident in different regions of cotton production. Surveys and studies of cotton management practices reveal some trends in a four-region tillage report, comprising West, Midwest, Mid-South and Southeast regions (Monsanto, 2013c). Conservation tillage practices increased in the 10-year period from 1998 to 2007, especially no till acres, at the expense of conventional tillage for cotton, corn and soybean, but subsequently began to change (see Appendix 9 of the Monsanto ER (Monsanto, 2014)).

Recent tillage trends in cotton. Conventional tillage of cotton fields in the Mid-South increased from 2007 to 2012/2013, while conservation tillage substantially declined. In the Southeast and Midwest, no till declined, but appears to be replaced by reduced-till methods, since conventional tillage is flat but only trending toward an increase in both areas. The survey of experts from both Southern regions together showed that the first factor identified that led to the decline of no-till practices was economics, while the second reason was to manage existing weeds (Monsanto, 2013c); the first factor was likely a part of the second factor, which would be to solve important evolving weed problems using economically justifiable practices.

Magnitude of Potential Impacts on Resources

APHIS identified changes in management practices that could cause impacts on physical and biological resources. If approved for use, the degree to which the DAS-81910-7 cotton variety is adopted will determine the magnitude of the impacts of the associated new management practices. Therefore, APHIS reviewed and analyzed here the range of possible management practices and their impacts. Because APHIS does not regulate production or management practices, the Agency can reasonably foresee practices likely to be taken up, but cannot channel the choices growers make.

5.2.2 Assumptions: Past, Existing and Reasonably Foreseeable Actions

A summary of the assumptions made for the analyses included in this section follow:

- The APHIS PPRA did not identify any changes in DAS-81910-7 cotton that would directly or indirectly affect physical or biological resources. These plants are compositionally similar to other cotton plants. The growth habit of the plants is also similar to other cotton plants. APHIS assumes that growers will choose management practices appropriate for the crops planted. APHIS used information available from extension services, trade journals, scientific journals, and public comments for petitions to identify common practices.

- GE 2,4-D HR cotton, corn and soybean varieties will be planted, as will other existing non-2,4-D HR cotton varieties. Most of the U.S. cotton acreage is currently planted in GE HR varieties.

- Following a determination of nonregulated status for DAS-81910-7 cotton, this Enlist crop could be crossed with any currently available cotton variety, including GE varieties no longer regulated by APHIS.

- APHIS assumes that all herbicide applications will conform to the EPA-registered uses for cotton that are summarized in the petition for nonregulated status (DAS, 2013b).

- In addition to cotton, APHIS assumes that growers will conform to EPA-registration requirements for all other approved 2,4-D uses (e.g. on pastures, wheat, oats, barley, millet, rye, sorghum, rice, cotton, sugarcane, almonds, apples, apricots, cherries, citrus, hazelnuts, nectarines, peaches, pears, pecans, plums, walnuts).

- APHIS assumes that drift from 2,4-D and other pesticide applications will be mitigated to an acceptable level by the registration requirements established by the EPA.

- APHIS assumes that all 2,4-D treatments made to DAS-81910-7 cotton will also include glyphosate because stewardship agreements between Dow and growers will stipulate that Enlist Duo (a premix of glyphosate and 2,4-D) be used on all Enlist crops.

- Under the Preferred Alternative, Dow's herbicide use estimates for 2,4-D-resistant cotton are for initially less than 20% of the cotton seed market (2 million acres) reflecting Dow's present market share, but rising to 45% given licensing agreements with other cotton seed producers in 5-10 years or to 62% reflecting seed sales for all acres predicted to have GR weeds by 2020 (see Scenario 1 in Appendix 3 of this EA). While this product may generate more market share for Dow, another synthetic auxin-resistant cotton, dicamba-resistant cotton, is expected to present competition in the cotton market. For 2,4-D-resistant corn and soybean acreage, the use potential has been analyzed in a preceding FEIS (USDA-APHIS, 2014c), and these are no longer regulated by APHIS. The estimates were based on the assumption that 2,4-D crop uses will increase, while 2,4-D uses on turf, range, pasture, and industrial management will not change.

- APHIS acknowledges that the future availability of dicamba-resistant cotton varieties on the market is reasonably foreseeable. 2,4-D and dicamba are both synthetic auxins with similar activities. They are not likely to be used simultaneously on DAS-81910-7 cotton because similar weeds may be susceptible to both 2,4-D and to dicamba. APHIS is aware of a cross licensing agreement between Dow and Monsanto for 2,4-D traits but this would not necessarily facilitate these traits being stacked together (DAS, 2013a). When APHIS estimated the upper bound of 2,4-D use on Enlist corn and soybean, it was assumed that at a maximum, HR corn (82 million acres) and 68% of the soybean acres (52 million acres) would have the dicamba resistance trait, whereas 32% of the soybean acreage would have an alternative herbicide resistance trait such as 2,4-D. Competition with soybean varieties resistant to herbicides such as dicamba, isoxaflutole, mesotrione, and glufosinate may reduce the assumed upper boundary to below 68% of the total soybean acres.

  In brief, 2,4-D use is expected to increase under the No Action and Action Alternatives because EPA has approved the new use of 2,4-D on Dow's Enlist corn and soybean varieties (US-EPA, 2014). Under the No Action Alternative, 2,4-D use is expected to be up to 300 percent greater as a result of adoption of Enlist corn and soybean (as noted in the APHIS 2,4-D FEIS (2014c)). Under the Preferred Alternative in this EA, an increase in 2,4-D use on cotton is also expected. Use is predicted to occur on 15-45% of cotton acres within ten years, using Dow's estimate of a 5.7-fold increase in 2,4-D, based mainly on market share and potential for cross-licensing of the trait (see Scenario 2, Appendix 3, of this EA).

- APHIS does not anticipate that nonregulated status of DAS-81910-7 cotton and EPA approval of Enlist Duo for use on Enlist cotton will change the use of glyphosate; however, uncertainty exists because future grower choices are unknown. APHIS in the 2,4-D-Resistant Corn and Soybean FEIS (2014) also concluded that uses of glyphosate on corn and soybean would not increase. Enlist cotton, which will contain a GR trait, will likely replace existing GR cotton varieties (see section 5.4.5 Weed Management). Since Enlist Duo contains half the amount of glyphosate per application (of the current glyphosate-only rate), adoption of DAS-81910-7 cotton could potentially decrease the rate of glyphosate use, although the overall applications of glyphosate + 2,4-D herbicides with the Enlist system compared to glyphosate-only applications could increase. APHIS does not have sufficient information for a more detailed forecast (see Section 5.4.5, Weed Management). As cited in the No Action and Preferred Alternatives, based on 2011 data, 90 percent of the corn acres and 96 percent of the soybean acres are presently treated with glyphosate, so the market is already saturated.

- Glufosinate use is not expected to increase as much under the Preferred Alternative relative to the No Action Alternative, based on the expectation that 2,4-D is considered a more efficacious option for GR weed control compared to glufosinate, with a greater weed control spectrum, and at less cost. However, as discussed later in this section, the use of glufosinate on certain GR weeds is being recommended by weed scientists.

Preferred Alternative: Cumulative Impact

- Production of DAS-81910-7 cotton would not affect physical or biological resources directly, but rather the agricultural management practices (e.g., pesticide applications) associated with cultivation of these crops and its potential impact on physical and biological resources. Cultural and mechanical practices affect agricultural and physical resources; these practices include crop rotations, sequences of crops, selections of varieties and traits, and tillage practices. Pest control practices are also relevant and include patterns, numbers and specific choices of applied herbicides or other pesticides as well as mechanical and cultural controls. These management practices all accumulate specific outcomes for crop yield, and soil, water, or air impacts. Other consequences may include development of problem or HR weeds, or adverse effects on successive crops planted on the same land. APHIS will discuss those selected issues which may potentially impact these agricultural and physical resources in the context of the Cumulative Impacts section, since as noted, the EPA approval of the new use of 2,4-D on DAS-81910-7 cotton is a foreseeable event.

5.3 Areas and Acres of Cotton Production

Cotton acreage was expected to have increased another 1 million acres in 2014, with subsequent moderate growth in future years, reflecting falling values for other crops. Cotton acreage will compete for land use with other crops including soybean acreage (which is predicted to remain around 78 million acres until 2023), and with moderate growth of acreage of corn production to meet export markets and domestic uses (USDA-OCE, 2014).

An APHIS determination of nonregulated status of DAS-81910-7 cotton and the EPA registration of the new use of 2,4-D are not anticipated to change cotton acreage because other factors such as cotton price have a greater influence on planting decisions. Cotton acreage is not likely to change unless crop strategy for weed control in DAS-81910-7 cotton reduces costs compared to those under the No Action Alternative. If the cost of production is sufficiently reduced to allow the net returns from growing 2,4-D-resistant cotton to exceed that of other crops, growers may choose to plant more cotton in these areas under this Alternative. Other factors such as changes in price of commodities and input costs are also variable and affect planting decisions. One of these is the pricing of seed with new traits, and the utility to growers of purchasing DAS-81910-7 cotton seeds. APHIS does not interpret the 2,4-D-resistance trait as having any potential for changing the economics of cotton production in the United States, and so DAS-81910 cotton is not likely to increase production acreage of either of these crops.

5.4 Agronomic Practices in Cotton Production

5.4.1 Tillage

No-till farming practices are centered on effective herbicide-based weed control. Under the No Action Alternative, increased or more extensive tillage is occurring in certain areas where HR weeds are no longer effectively controlled by currently-registered herbicides. More aggressive tillage is one effective weed control option.

> **USDA-APHIS 2,4-D-Resistant Corn and Soybeans FEIS**: Possible cumulative impacts on tillage practices for problem weed control by other likely users of 2,4-D on non-cotton agricultural crops were assessed in the 2014 FEIS (USDA-APHIS, 2014c). To evaluate the current trends for weed control in these cotton growing regions concurrent with soybean regions, APHIS tiers its analysis to this EIS. The increasing tillage needed by growers because of inadequate herbicide control of problem weeds was documented by several authors.

As noted in section 5.2.1.2 of this EA (Current Tillage Patterns), a survey of regional tillage patterns and expert assessments suggest that problem weeds were at least partially responsible for increases in conventional tillage and declines in conservation tillage (Monsanto, 2013c); these conclusions were especially applicable in the Mid-South states. To some extent the results of the survey were similar to other regions that showed declines in no-till practices, although these were accompanied with increases in reduced till practices. Between-row cotton cultivation has also increased from virtually none with early era GR crops to 30 to 40 percent of cotton acres in 2009 to 2011 (UGA Extension, 2014). Sosnokie and Culpepper (2014) in a survey of Georgia cotton growers, indicate that 44 percent of acres are now subjected to between-row cultivation. APHIS suggests that adoption of DAS-81910-7 cotton may reverse this trend of increasing tillage that is occurring under the No Action Alternative.

Under the Preferred Alternative, adoption of DAS-81910-7 cotton and the EPA registration of new 2,4-D uses on this crop is expected to improve the control of GR weeds, decreasing tillage intensity when compared to the No Action Alternative. This potential reduction in tillage is most likely to occur with the use of DAS-81910-7 cotton because the increase in the use of tillage for weed management has occurred particularly in the management of Palmer amaranth in cotton. In the absence of new herbicides, cotton "researchers recognize that integrated weed management (IWM) strategies that include tillage may be necessary" to control this GR weed (Shaw et al., 2012). Under the Preferred Alternative, APHIS concludes that control of such GR weeds would improve in cotton production, since a 2,4-D-based herbicide strategy using DAS-81910-7 cotton would make effective use of 2,4-D and provide needed herbicide diversity.

APHIS also concludes that while short term weed control efficacy may be improved, and additional tilling deterred, the potential exists for new weed resistance to herbicides to develop. However, APHIS anticipates that growers who practice good stewardship of this technology, including adoption of best management practices and diversifying weed control methods, will attain the extended usefulness of DAS-81910-7 cotton. If 2,4-D-resistant weeds develop, growers might at some future time again consider increased tillage as one possible remedy. Weed management alternatives will eventually be needed, and thus additional effective herbicide strategies may need to be developed. New or historical cultural or mechanical practices may also need to be adopted.

5.4.2 Crop Rotation

Under the Preferred Alternative, adoption of DAS-81910-7 cotton and EPA registration for the new formulation of 2,4-D for DAS-81910-7 cotton is not expected to change cotton crop rotational practices, since growers will be substituting one set of herbicides for another. While some concerns have been expressed that crops sensitive to 2,4-D may be impacted from drift or volatilization, as APHIS notes in the analysis of impacts on Plant Communities, the new 2,4-D choline salt formulation is expected to decrease the potential for impacts compared to current 2,4-D formulations. The impacts of applied herbicides on non-targeted crop plants is an issue that is important under the No Action Alternative. State extension officials remind growers to use commonsense and available tools, to work with their neighbors to lay out current rotations to avoid possible drift damage (Fishel and Ferrell, 2010; Thompson, 2014). Anyone applying herbicides needs to pay attention to neighboring crops, weather patterns, and appropriate equipment to minimize herbicide drift (Fishel and Ferrell, 2010), and if it does occur, to provide financial relief in cases of misapplication (Zollinger, 2012). As Georgia state extension agronomist S. Culpepper notes, new application technologies (such as Enlist with new low volatilization formulations, presumably) should reduce off-target movement (Thompson, 2014).

One additional consideration is that 2,4-D-resistant weeds may reduce the cost effectiveness of growing certain cotton rotation crops. For example, corn, wheat, soybean and sorghum are sometimes rotated with cotton, along with other minor crops (Table 27). Some growers rely on 2,4-D for inexpensive weed control including growers of wheat (30-60 percent of acres), corn (5-10 percent), soybean (10-15 percent) and sorghum (20-30 percent). If 2,4-D was to become ineffective on weed control in these rotation crops and the cost of alternative herbicides was too expensive, these growers may choose not to grow them. However, input costs are just one factor that determines whether a given rotation crop is grown. Other considerations for choosing a rotation crop include benefits to the soil, advantages in disease management, improved possibilities for weed control and for the economic returns. Under the Preferred Alternative, APHIS concludes that local changes to crop rotations because of weed issues in rotation crops are possible, but these changes are not different in type or scale compared to current grower practices and histories. The potential for impacts on rotation choices as economic ones related to 2,4-D use are analyzed later in the Cumulative Impacts section of this EA.

Table 27. Rotational Practices Following Cotton Production in the United States.

A	B	C	D
Total Acres Cotton Acres[1]	**Rotational Crops Following Cotton**	**Rotational Crop Acres[2]**	**% Rotational Crop of Total Cotton[3]**
United States 10,974	Cotton	5,858	53.4
	Corn	1,736	15.8
	Soybean	861	7.8
	Sorghum	836	7.6
	Wheat	1,025	9.3
	Barley	40	0.4
	Peanut	432	3.9
	Sunflower	22	0.2
	Alfalfa[8]	47	0.4
	Vegetables[9]	50	0.5
	Dry Beans	0.5	0.005
	Peppers	8	0.1
	Tomatoes	24	0.2
	Onions	6	0.06
	Tobacco		0.3
		Total: 10,974	

This table was developed by compiling the data from all four regional summaries (Tables VIII-21 through VIII-24 of Monsanto Petition for Dicamba Cotton). All acreages are expressed as 1000s of acres.
NL indicates not labeled for use.
1 Cotton acreage based on 2010 planting data (USDA-ERS, 2012c; USDA-NASS, 2014d).
2 Column C is obtained by compiling the data from the four regional summaries.
3 Column D is obtained by dividing Column C by Column A.
8 Newly seeded alfalfa.
9 Vegetables: Cauliflower (37k acres), lettuce (271 k acres), and broccoli (124k acres) (USDA-ERS, 2012c).
10 Totals may not be exact due to rounding

5.4.3 Nutrition and Fertilizer Use

Adoption of DAS-81910-7 cotton is not expected to change the general agronomic inputs associated with cotton production, except to increase 2,4-D usage. Fertilizer, fungicide, and water use are expected to remain unchanged from the No Action Alternative.

5.4.4 Insect and Pest Management

No changes are expected in insect management, except for the mandated boll weevil control programs, as noted earlier. Volunteer cotton control in the early season already has several available choices, and combinations of these may offer some possibilities in controlling late season persisting plants as well. Another HR cotton will become available, for dicamba, which is another auxin type herbicide; the trait has partial resistance to 2,4-D. Thus, another cotton variety will have reduced potential for control of post-harvest cotton using 2,4-D. Additional resources for determining new herbicide alternatives may be needed for this cotton trait and Dow has been developing a protocol using existing herbicides (DAS, 2013b). APHIS also expects state extension agents to contribute to the development of additional means for control of persistent late season cotton plants in these 2,4-D-resistant and dicamba-resistant cotton varieties.

5.4.5 Weed Management

Proximity of Cotton to Other 2,4-D-Treated Crops, Including Enlist Corn and Soybean

DAS-81910-7 cotton is expected to be attractive to those cotton growers who have or anticipate weed control difficulties caused by GR weeds. In the event that DAS-81910-7 cotton becomes widely used along with Enlist corn and soybean and 2,4-D-resistant weeds become more widespread, there are two types of growers whose actions will be important to consider when analyzing possible impacts of DAS-81910-7 cotton. The first are the cotton growers who almost exclusively have adopted GR crops and are already confronted with weed control problems related to GR weeds. Until now, these growers have relied more on glyphosate than other herbicides, but are expected to adopt Enlist crops and develop a reliance on 2,4-D as a solution to the GR weed problem. The effectiveness of 2,4-D use may delay the need to adopt a more diversified weed management program for these growers. If 2,4-D-resistant weeds became prevalent, these growers would have to become less reliant on 2,4-D and diversify their management programs in ways that would be similar to that described in the No Action Alternative.

The second type are growers who already rely on 2,4-D for weed control in applications that do not involve GR crops, growers of certain small grains being one example. These growers are more reliant on 2,4-D than glyphosate for weed control and may not currently be faced with the same degree of weed control problems as the first group. The development of 2,4-D-resistant weeds resulting from reliance of the Enlist crop adopters on 2,4-D would render the herbicide less effective to those who were already using it on other crops. This could necessitate adopting potentially more costly and somewhat less environmentally beneficial weed management practices than are currently in use. These issues are analyzed in the *Socioeconomics* section of this Cumulative Impacts analysis.

Changes in 2,4-D Use

2,4-D is currently registered for use on various crops at application rates similar to or lower than those proposed for DAS-81910-7 cotton (see Table 28). However, the proposed EPA Enlist Duo label for DAS-81910-7 cotton would allow for 2,4-D applications at burndown without the waiting period currently required before planting cotton, and also allow late applications to cotton (see Table 29).

Table 28. Present Rates of 2,4-D Application (2,4-D-Ester).

Crop	Maximum Rate (lb ae/acre)	Time of Application
Corn	3.0	1 lb ae/acre Preplant, 0.5 lb ae/acre Postemergence, 1.5 lb ae/acre Preharvest
Fallow	2.0	N/A
Sugarcane	2.0	2 lb ae/acre Preemergence, 2 lb ae/acre Postemergence
Wheat	1.3	1.25 lb ae/acre Postemergence 0.5 lb ae/acre Preharvest

Table 29. Proposed Rate of Application of 2,4-D to Enlist Cotton.

Crop	Maximum Rate (lb ae/acre)	Time of Application
Enlist Cotton	3.0	1 lb ae/acre Preemergence 1 or 2 Postemergence Applications @ 0.5-1.0 lb ae/acre

Enlist cotton may be planted more frequently in states where GR weed pressure is highest. No-till cotton acres may potentially be sprayed as many as three times in West Texas, Arizona, Oklahoma, New Mexico, and Kansas and conventional till acres sprayed two times, since the plains states, especially Texas, have had increasing Palmer amaranth problems (Bunge, 2014; Peter, 2015). Recent experience indicated that two POST glyphosate + 2,4-D applications were needed for Palmer amaranth control on Enlist cotton (aad-1 trait) and this also required a PRE application of a residual such as pendimethalin or fomesafen(Merchant et al., 2014a). In addition, current late season applications now done by hooded sprayers or layby applications could be replaced by an over-the-top application of Enlist. The Texas Department of Agriculture recently requested that EPA grant emergency exemptions for use of propazine (Bunge, 2014) for control of this weed. Since the exemption was not granted, under the Proposed Alternative there will likely be an increased need to use 2,4-D for postemergence control of this pigweed (Merchant et al., 2014a). In Georgia all counties have GR Palmer amaranth to some degree (Sosnoskie and Culpepper, 2014). In all other cotton growing regions, Enlist no-till cotton may potentially be sprayed twice and conventional till once in these areas (since Enlist will not be needed before seeding); Dow estimated the future national usage of Enlist Duo on cotton as 1.54 applications per season (DAS, 2014). There are other treatment protocols currently recommended in the absence of 2,4-D- or dicamba-resistant cotton crops (Cahoon et al., 2014), so the likely future combination of these with 2,4-D use is not clear. One commenter on the Monsanto Dicamba-Resistant Soybean and Cotton DEIS (CFS Science Comment I, 2014) noted that because GR Palmer amaranth weeds were common in the Delta and Southeast regions that an additional application of the auxinic herbicide dicamba would be needed in these states. However, the study to which it referred actually showed that a second herbicide chemistry was needed for Palmer control, but not necessarily a second application of an auxin class herbicide (Merchant et al., 2013).

In a recent public comment on the DEIS for 2,4-D-Resistant Corn and Soybeans, a weed scientist noted the use of non-glyphosate herbicides on cotton has increased 2.5-fold (Culpepper public comment APHIS-2013-0042-1911). The contributions of DAS-81910-7 cotton he noted, will include reductions in herbicide uses, since "programs developed by the University of Georgia for 2,4-D or dicamba technologies [that] suggest the pounds of herbicide active ingredient may be able to be reduced by at least 30% while actually providing better weed control; similar results are also noted in other areas across the Cotton Belt (Edwards et al., 2013; Merchant et al., 2013; Smith and Hagood, 2013)." Replacement of non-glyphosate PRE herbicides (applied prior to planting the crop through planting of the crop, but before crop emergence) by 2,4-D choline salt (formulated as Enlist Duo) under the Proposed Alternative will likely occur on many cotton acres, and replacement of POST herbicides (applied after crop emergence) also on those cotton acres planted with Enlist seed. Similar expectations have been described for use of non-glyphosate herbicides with dicamba-resistant cotton (USDA-APHIS, 2014d). APHIS concludes that reductions of other herbicides are likely but that precise expectations for that cannot be determined.

If the Preferred Alternative is chosen by APHIS and the EPA approves the new uses of 2,4-D for DAS-81910-7 cotton, the increase in 2,4-D use on cotton acres with respect to the present use of 2,4-D on cotton would be an increase beyond that expected under the No Action Alternative. 2,4-D at present can mainly be used as a pre-plant on cotton (if the maximum application rate is used), and the planting can only come at greater than 15-30 days after application (depends on total application). 2,4-D is also used to control post-harvest cotton in those states requiring cotton plant removal for boll weevil control programs. Dow estimates that the increase may reach between 6.2 and 9.3 million pounds, assuming 0.875 lb per acre applied. As noted, APHIS does not evaluate the environmental impacts of this or any herbicide, since herbicide use is regulated and evaluated by EPA; APHIS can only cite likely trends of potential changes in herbicide applications to crops, since so many choices are available to manage weeds.

<u>Changes in Glufosinate Use</u>

Glufosinate use is expected to increase under the No Action Alternative as growers continue to increase their adoption of glufosinate-resistant crops. Under the Preferred Alternative, APHIS notes that glufosinate increases the control of several cotton problem weeds, including Palmer amaranth and Benghal dayflower (Merchant et al., 2014b; Merchant et al., 2013) Use of glufosinate-resistant cotton is already high in five states (USDA-AMS in (York, 2012) where 39-67% glufosinate tolerant varieties were planted in 2011 in North Carolina, Virginia, South Carolina, Georgia, Tennessee). Glufosinate (Liberty) can be used on Bayer Liberty Link varieties, and is commonly used off-label on Dow Phytogen Widestrike lines. Glufosinate applied together with 2,4-D may be more efficacious than either singly when controlling taller Palmer amaranth (Merchant et al., 2014b), so in situations where this applies, glufosinate use may increase when DAS-81910-7 cotton has nonregulated status. APHIS concludes that 2,4-D- and glufosinate-resistant varieties would at least replace some of these glufosinate-resistant-only varieties, and, if both herbicides were needed together for control of certain GR weeds, it may result in some additional glufosinate applications.

Changes in Glyphosate Use

Glyphosate use on cotton is not expected to increase under the No Action or Preferred Alternatives because of market saturation; between 2011 and 2013, GR cotton was planted on 73 to 82 percent of total acres (USDA-ERS, 2014a). As of 2010, 98 percent of the corn acres, 99 percent of the cotton acres, and 98 percent of the soybean acres are treated with herbicides (with glyphosate being the most commonly used) (USDA-NASS, 2011b; USDA-NASS, 2013a).

Changes in Non-Glyphosate Herbicide Use

Cotton Herbicide Trends. In Georgia, with the second highest acreage for US cotton production, a recent trend analysis for herbicide use showed an increase in one of two preplant and PRE herbicides (pendimethalin), a large increase in preplant flumioxazin use, and a large increase in fomesafen use from 2006-2010 compared to the six year period preceding (Sosnoskie and Culpepper, 2014). POST herbicide use in that comparison period showed a large increase in glufosinate with a decline in glyphosate use. A pattern of increasing use of non-glyphosate herbicides on cotton can also be discerned from larger grower surveys conducted by a contracting company on behalf of Monsanto in 2012 (see Table A-37 to A-39 (Monsanto, 2013a)).

PRE Emergent Herbicide Use. Over the period 2002 to 2009 an increase was noted in PRE herbicides of about 15%, with growers notably using 2,4-D and paraquat for burndown, fomesafen, trifluralin and flumioxazin as preplants with activity extending into post emergent growth, and pendimethalin as a preemergent (Appendix 2). Between 2009 and 2011, PRE non-glyphosate herbicide use in cotton increased more sharply, rising 113% (Appendix 2). To some extent, the totals reflect a decline in total cotton acres from 2002 and 2003 compared to 2009, and an increase in cotton acreage again by 2011 (Appendix 2).

POST Emergent Non-glyphosate Herbicide Use. On GR cotton, a pattern of stasis and slight decline was seen between 2002 and 2009 based on the same grower survey data (Appendix 2). For 2009 to 2011, the total acreage treated with POST non-glyphosate herbicides increased 220%. Just as was observed in the case of PRE herbicides, the amount of increased herbicide application was far greater than that caused by the large increase in planted GR cotton acres. Again, management of existing weed resistance, and actions taken to avoid future weed resistance seemed the likely cause of the observed increases (Appendix 2).

Frequency of Herbicide Application. From 2002-2011, applications of glyphosate both PRE and POST per year remained relatively stable, about 1.2 for PRE and about 1.7 for POST applications (Appendix 2). However, applications of non-glyphosate herbicides to cotton from 2009-2011, both PRE and POST applications, began rising from about 1.5 per season to around 2.2 (Appendix 2). GR cotton plantings declined 24 percent from 2002 to 2009, then increased to 68 percent from 2009 to 2011. The much larger increase in non-glyphosate herbicides applied was not correlated with GR cotton plantings, but with a rise in GR weed development, and correlates well with the recommendations by weed scientists and extension personnel. Generally, the recommendations of these advisers are that growers should employ diversity in weed management practices and multiple effective herbicides to counteract the pattern of resistant weed development (Culpepper et al., 2014). Apparently at 2011 levels of GR weeds overall, 4.4 herbicide applications (PRE and POST) were used for the production of cotton (See Appendix 2). Ranges of recommendations for conservation tillage with Roundup Ready crops that may or may not include GR weeds can include a minimum of eight applications (Clemson-University-Extension, 2012) or seven to nine applications (Scott and Smith, 2014). When prompted for the suggested practice for a cotton field near Amarillo, an automated website sensitive to grower location recommended a minimum of five herbicides PPI (pre-plant incorporated), PRE and POST, and that was without a layby or hooded application of two to three herbicides if needed for additional late season problem weeds (Monsanto, 2015). However, it should be noted that when faced with problem weeds such as Palmer amaranth, recommendations for the total numbers of applied herbicides may be larger. When Roundup Ready crops include these weeds, 10 applications were recommended in Georgia (University of Georgia, 2014).

Overall Changes in Herbicide Use. A 250% increase in non-glyphosate herbicide applications occurred between 2003 (30.2%) and 2011 (75.8%) when expressed as ratios of non-glyphosate herbicide-treated cotton acres to total planted cotton acres (Table 30). APHIS concludes that the increasing herbicide applications reflect limited responsiveness of some GR weeds to existing herbicides. HR DAS-81910-7 cotton allows a new use of 2,4-D for cotton, and would both facilitate replacement of some herbicides by a more effective one (2,4-D), but also facilitate the preservation of existing efficacious herbicides and of the protocols employing them.

Table 30. Acres and Percentages of Cotton Acres Treated with Non-Glyphosate Herbicides.

Acreage (x1,000)	Year				
	2003	2005	2007	2009	2011
Total Area Treated - Non-Glyphosate Herbicides	4,119	4,625	2,941	3,734	11,018
Total Planted Cotton Acres	13,626	14,024	10,732	9,042	14,533
Ratio of Treated Acres to Total Acres	30.2%	33.0%	27.4%	41.3%	75.8%

Data from ER, Appendix Table A-39 (Monsanto, 2013a).

Possible Herbicide Replacements on Enlist Cotton Crops. Among the herbicides that may be replaced by use of a synthetic auxin (such as 2,4-D) on cotton (Monsanto, 2013a), several can be used as both PRE residuals, and POST directed-spray herbicides, such as fluometuron, prometryn, and diuron (Steckel, 2014). Directed-spray herbicides would be rapidly replaced by availability of 2,4-D as an over-the-top POST alternative. Under the Preferred Alternative, Enlist crops employing 2,4-D can be used to prolong the useful activities of other effective herbicides, mainly by providing a means for overlapping herbicidal control of problem and resistant weeds. It is more likely that weed resistance using multiply effective herbicides will not develop as quickly as it would under the No Action alternative. Under the Preferred Alternative, with this HR crop available, growers will be offered the choice of several herbicide crop resistance systems among which to alternate such as glufosinate-, dicamba-, and HPPD-inhibitor resistant corn, soybean and cotton, (as they become available) in successive seasons.

APHIS concludes that under the Preferred Alternative the determination of nonregulated status for the DAS-81910-7 cotton will likely have impacts on existing herbicide use as Enlist herbicide becomes available for use on Enlist crops. Regional-specific patterns of applications will likely remain the same, with differences between no-till and conventional tillage for herbicide treatments. Consequently, uses of 2,4-D will likely increase, glyphosate not change, glufosinate possibly increase slightly and other herbicides for cotton may be replaced with Enlist when producing 2,4-D resistant- (that is, Enlist) cotton and thus at least stabilize potential increases in non-glyphosate herbicide use.

2,4-D Resistance in Cotton and Interference with Boll Weevil Eradication

One present use of 2,4-D may likely decline in relevance if DAS-81910-7 is no longer regulated by APHIS. As noted earlier in the Environmental Consequences Section, *Plant Communities*, the auxinic herbicide 2,4-D is used extensively to eliminate persistent post-harvest cotton or germination from spilled seeds. These cotton removals are mandated, in many cases by law, as part of Boll Weevil Eradication programs. When the cotton plant removals are not accomplished by shredding, herbicides must be used, and sometimes both methods are employed together. The most effective stalk herbicide is 2,4-D (Greenberg et al., 2007; Lemon et al., 2003) and DAS-81910-7 cotton has resistance to 2,4-D, so 2,4-D is not usable for this practice. Monsanto's dicamba-resistant cotton has some minor resistance to 2,4-D (Feng and Brinker, 2010) and so these cotton plants may not be eliminated by 2,4-D application. If either DAS-81910-7 cotton or this second auxinic-resistant variety is grown (Monsanto's dicamba-resistant cotton), then both may need similar (or possibly even different) methods for their post-harvest control. These will necessarily require additional herbicide protocols to destroy these late season post-harvest HR cotton varieties, since appreciable amounts of no-till cotton is grown; USDA-ERS estimated that up to 24% of U.S. cotton is produced under no-till conditions (Horowitz et al., 2010) Several herbicide choices have been shown to control cotton volunteers when applied in the spring before planting (Morgan et al., 2011b). However, effective herbicide protocols for immediate post-season stalk devitalization of 2,4-D-resistant cotton using dicamba + 2,4-DP or dicamba + diflufenzopyr herbicides have recently been documented (Lassiter et al., 2014). APHIS is expecting that the appropriate post-harvest control for re-sprouting cotton will be found, and that it is not likely that any cumulative effects from commercial availability of the two auxin-resistant cotton varieties will be of concern.

5.5 Biological Resources

5.5.1 Animal Communities

As described in the No Action Alternative, agricultural practices can affect wildlife in and around agricultural fields. Wildlife commonly found in each region is described in the Affected Environment, Section 3. As discussed in Section 4, DAS-81910-7 cotton will not directly or indirectly impact wildlife any differently under the No Action Alternative which considers those cotton varieties that are currently available. If direct impacts from the changes in herbicide use associated with Enlist Duo could affect certain cotton-associated wildlife, the EPA environmental analyses will disclose these, and they are outside the scope of this EA.

The EPA considers impacts on wildlife as part of its evaluation of the new label. 2,4-D has an extensive history of safe and effective use. It has been thoroughly reviewed and reregistered by all major regulatory agencies in the world within the last ten years. In 2012, the EPA denied a petition to cancel tolerances and registrations for 2,4-D based on toxicological hazard. The Agency affirmed that 2,4-D posed no unreasonable risk when used as directed. Therefore, cumulative impacts on animal resources are not expected to differ under the No Action or Preferred Alternatives.

5.5.2 Plant Communities

A variety of plants may be potentially impacted by DAS-8910-7 cotton, including not only those in proximity to DAS-81910-7 cotton because they are incidentally present in agroecosystems, but also because they were planted as crops. To be considered is whether the potential impacts of new usage patterns of herbicides after they are brought into commercial deployment are any different from the impacts of usage of current herbicides. APHIS considered three estimates of 2,4-D herbicide use on Enlist cotton made by Dow in Appendix 3. From recent trends, 2,4-D use on crops is expected to increase under the No Action Alternative. Under the Preferred Alternative, 2,4-D use on cotton will increase from 700,000 pounds to between 6.2 and 9.3 million pounds by 2020 depending upon grower adoption rates of Enlist cotton. The increased use of this herbicide under both the No Action and Action Alternatives is expected to result in increased selection pressure for 2,4-D-resistant weeds. One issue, the potential for resistance to develop or to make future management practice more complex or costly, is analyzed in this section.

Herbicide –Resistant Weeds

USDA-APHIS Dicamba-Resistant Soybean and Cotton FEIS: Possible cumulative impacts following availability and planting of dicamba-resistant cotton were assessed in the USDA APHIS 2014 FEIS (USDA-APHIS, 2014d). Weed resistance to herbicides has occurred in response to use of many agricultural chemicals with differing modes of action, accompanied by failure to use best management practices and diverse weed control methods. The potential for new resistant weeds ensuing after new use of 2,4-D on cotton would be similar the potential after the upcoming use of dicamba on cotton, and USDA-APHIS tiers the analysis of dicamba impacts on cotton production to 2,4-D use and potential impacts on cotton.

First, the extent of selection pressure on weeds when using the new herbicide and the practices surrounding its use should be considered. Selection pressure is influenced by factors other than the volume of herbicide applied. The selection pressure is strongly related to the repeated use of one or a limited number of herbicides (Duke, 2005; Durgan and Gunsolus, 2003). It is also a function of the diversity of management practices employed (Vencill et al., 2012). The greater the diversity of management practices, the smaller the selection pressure for resistant weeds.

A second issue is that the likelihood that problem weeds in cotton, (i.e., those weeds that are actively managed in this crop), will become more resistant to 2,4-D. Table 11 lists the problem weeds of cotton by region and those that have HR biotypes are described in Table A-9 in Appendix 4. The analysis focuses on weeds that are actively managed in cotton fields and addresses which of these have developed herbicide resistance to the major herbicides used in cotton.

USDA-APHIS concluded (USDA-APHIS, 2014d) that appropriate weed management requires much more than the application of herbicides. Rotation of herbicides with alternative sites of action is one method (DAS, 2010a) but other management practices are also relevant (Beckie and Hall, 2014; Norsworthy et al., 2012). Alternative sites of action refer to herbicides that have different modes of action. Some common sites of herbicide action which show increasing use in cotton (2007-2010) include PPO inhibitors (fomesafen, 400%), Photosystem II inhibitors (fluometuron, 33%), auxin growth regulators (2,4-D 33%), microtubule inhibitor (dinitroanilines; trifluralin, 10%), and lipid biosynthesis inhibitors (S-metolachlor, 83%) (Ross and Childs, 2011) (and Appendix 1). APHIS concludes that the practice of using additional herbicides with alternative sites of action could potentially help diminish the populations of GR weeds and reduce the likelihood for the development of new HR weed populations (DAS, 2010a; Dill et al., 2008; Duke and Powles, 2008; Duke and Powles, 2009; Owen, 2008).

Managing-Glyphosate Resistant Weeds

USDA-APHIS Dicamba-Resistant Soybean and Cotton FEIS: Possible cumulative impacts following availability and planting of dicamba-resistant cotton on GR weed management was assessed in the USDA-APHIS 2014 FEIS (USDA-APHIS, 2014d) and findings for 2,4-D use and dicamba are similar. Because of increasing populations of GR weeds, growers have needed to adapt to the presence of these weeds with additional chemical and non-chemical control strategies; USDA-APHIS tiers our analysis of herbicide use on GR weeds in 2,4-D-resistant cotton to that of herbicide use on weeds in dicamba-resistant cotton.

Southeastern cotton growers who have adopted no-till production are now including more aggressive tillage in their management programs. In Georgia, heavily infested fields are being hand-weeded at a cost of up to $57 per hectare, for 52% of cotton acreage (Sosnoskie and Culpepper, 2014). Also in Georgia in-crop cultivation is frequently practiced (42% of acres), tillage is used to incorporate pre-plant herbicides (20% acres) and deep-turning is more frequent (19% of acres every three years) (Sosnoskie and Culpepper, 2014). They are also applying herbicides with different modes of action, and adopting other stewardship practices and BMPs recommended by on-line resources about herbicide resistance, lesson modules, fact sheets and general principles identified by the Weed Science Society of America (WSSA, 2015). Growers are also using residual herbicides more frequently (Sosnoskie and Culpepper, 2014). They also are choosing to apply multiple herbicides more frequently during different crop development times, including late postemergent laybys (herbicides applied to soil) and late directed sprays over the course of the growing season, as noted by a NC weed scientist (Shepard, 2015). Weed scientists encourage growers to apply herbicides with several different sites of action at different times over the course of the season to manage weeds, including some HR biotypes (Dotray and Keeling, 2014; UGA Extension, 2014). While these changes are positive ones in that they diversify herbicide-based weed control, the potential for high cost of current protocols and then new practices poses a potential challenge for the increasing costs of future cotton production using current strategies, and in the regions identified within the Affected Environment section. As noted, a replacement herbicide and an additional tool represented by 2,4-D resistant cotton can potentially provide economic benefits to growers, especially if the option deters more costly mechanical controls for problem weeds.

Under the No Action Alternative, GR weeds are likely to be an increasingly frequent issue in most regions of cotton production. Under the No Action Alternative, many growers would first try to use additional herbicides to control these weeds. However, growers are expected to become less reliant on glyphosate for weed control as it loses effectiveness. Instead, they are expected to depend on additional chemical and non-chemical methods. Changes in management practices may include diversifying the mode of action of herbicides applied to cotton and making adjustments to crop rotation and tillage or cultivation practices (Wilson et al., 2011). Herbicide use may increase to meet the need for additional integrated weed management tactics to mitigate HR weeds in different cropping systems (Culpepper et al., 2008; Owen and Zelaya, 2005; Owen, 2008). Among the herbicides that are predicted to increase in use under the No Action Alternative to control GR weeds are 2,4-D, the chloroacetamides, and glufosinate. There is a trend of increased use in cotton of PPO inhibitors (6 and 10-fold (Sosnoskie and Culpepper, 2012)), PSII inhibitors (e.g. diuron 3.2 fold 2003-2010 (USDA-NASS, 2014d), lipid biosynthesis inhibitors (chloracetamides) and microtubule inhibitors/dintroanilines (Appendix 1). Selection of weeds resistant to all these herbicides is expected to continue. At present, glufosinate resistance is only represented by one species, Italian ryegrass, in the United States (Heap, 2014d).

Under the Preferred Alternative, 2,4-D use is expected to increase relative to the No Action Alternative. Under the No Action Alternative, increased use of other herbicides such as chloroacetamides, glufosinate, ALS inhibitors, PPO inhibitors, and PSII inhibitors are expected. Because Enlist crops are expected to be adopted under the Preferred Alternative, this increase in usage of other herbicides may be diminished because 2,4-D is effective against GR weeds. The availability of inexpensive and effective herbicides combined with Enlist cotton may delay the adoption of non-chemical management strategies under the Preferred Alternative. Fewer growers would be expected to adopt aggressive tillage when herbicides remain effective for weed control. Selection of weeds resistant to glyphosate, auxins, chloroacetamides, ALS inhibitors, and glufosinate will still occur under the Preferred Alternative. However, because 2,4-D will replace some of these others that are frequently used, selection of some resistant weeds may be reduced. The magnitude of the selection pressure for HR weeds under the Preferred Alternative relative to the No Action Alternative will depend on the management practices employed under each Alternative and cannot be predicted. More diversified weed management practices will result in less selective pressure for resistance to any given herbicide or management technique.

Likelihood That Use of Enlist Duo Will Select for 2,4-D-Resistant Weeds

The relative risk that a resistant biotype will be selected for a particular herbicide is highly correlated to the herbicide mechanism of action (Sammons et al., 2007). Herbicide families have been classified according to their risk of resistant weed development. Beckie (Beckie, 2006) lists ALS- and ACCase-inhibiting herbicides as high risk for selection of resistant biotypes, while glyphosate and auxin type herbicides are considered low risk. For ALS inhibitors, 151 species have herbicide resistance, and to ACCase inhibitors 46 species (Heap, 2013b). Weeds resistant to auxin herbicides are much more limited but have been slowly accumulating over the past seventy years. None have become particularly problematic. As of 2013, there are only nine synthetic auxin-resistant species located in the United States (see Table 31) (Heap, 2013b). Of the 30 species found world-wide, 17 are resistant to 2,4-D. Of these, only five are found within the United States. Of the cotton infesting weeds, only waterhemp has 2,4-D resistance coupled with a GR biotype. Thus, at the present time, the combination of glyphosate and 2,4-D, as in Enlist, controls a wide range of problem weeds in the United States (Robinson et al., 2012) and cross resistance to multiple auxinic herbicides has a limited number of examples.

USDA-APHIS Dicamba-Resistant Soybean and Cotton FEIS: Possible cumulative impacts following availability and planting of dicamba-resistant cotton was assessed in the USDA-APHIS 2014 FEIS (USDA-APHIS, 2014d) and the potential for resistance to dicamba is likely similar to that for 2,4-D, since they are both synthetic auxin-type herbicides. The section, Weed Resistance to Auxin Class Herbicides, in the Dicamba-Resistant Soybean and Cotton FEIS, explains this more limited potential based on past experience with the development of auxin class resistant weeds, but nevertheless notes that weed resistance depends on whether growers will employ good stewardship of available herbicides.

Table 31. World and U.S. Auxin-Resistant Weeds.

	Species	Year/Location	Auxin	Situation	GR/GT
1	*Amaranthus tuberculatus Ameranthsyn. rudis)*	2009 - USA (Nebraska)	2,4-D	Pasture	+
	Common Waterhemp				
2	*Carduus nutans*	1981 - New Zealand	2,4-D	Pasture	
	Musk Thistle				
3	*Carduus pycnocephalus*	1997 - New Zealand	2,4-D, MCPA, MCPB	Pasture	
	Italian Thistle				
4	*Centaurea cyanus*	2012 – Poland	Dicamba	Winter wheat	
5	*Centaurea solstitialis*	1988 - USA (Washington)	Picloram	Roadsides	
	Yellow Starthistle				
5	*Chenopodium album*	2005 - New Zealand	Dicamba	Corn	
	Lambsquarters				
6	*Cirsium arvense*	1979 - Sweden	MCPA	Cropland	
	Canada thistle	1985 - Hungary	2,4-D and MCPA	Pasture	
8	*Commelina diffusa*	1957 - USA (Hawaii)	2,4-D	Sugarcane	
	Spreading Dayflower				
9	*Daucus carota*	1957 - Canada (Ontario)	2,4-D	Roadsides	
	Wild Carrot	1993 - USA (Michigan)	2,4-D	roadsides and cropland	
		1994 - USA (Ohio)	2,4-D	soybean	
10	*Descurainia sophia*	2011 - China	MCPA	winter wheat	
	Flixweed				
11	*Digitaria ischaemum*	2002 - USA (California)	quinclorac	rice	
	Smooth Crabgrass				

	Species	Year/Location	Auxin	Situation	GR/GT
12	*Echinochloa colona*	2000 - Colombia	quinclorac	rice	+
	Junglerice				
13	*Echinochloa crus-galli var crus-galli*	1998 - USA (Louisiana)	quinclorac	rice	
	Barnyardgrass	1999 - Brazil	quinclorac	rice	
		1999 - USA (Arkansas) *Multiple - 2 MOA's	propanil and quinclorac	rice	
		2000 - China	quinclorac	rice	
		2009 - Brazil *Multiple - 2 MOA's	bispyribac-sodium, imazethapyr, penoxsulam, and quinclorac	rice	
		2013 - Uruguay	quinclorac	rice	
14	*Echinochloa crus-galli var. zelayensis*	2013 - China	quinclorac	rice	
15	*Echinochloa crus-pavonis*	1999 - Brazil	quinclorac	rice	
	Gulf Cockspur				
16	*Fimbristylis miliacea*	1989 - Malaysia	2,4-D	rice	
	Globe Fringerush				
17	*Galeopsis tetrahit*	1998 - Canada (Alberta)	dicamba, fluroxypyr, and MCPA	barley, cereals, cropland, wheat	
	Common Hempnettle				
18	*Galium spurium*	1996 - Canada (Alberta) *Multiple - 2 MOA's	imazethapyr, metsulfuron-methyl, quinclorac, sulfometuron-methyl, thifensulfuron-methyl, triasulfuron, and tribenuron-methyl	cereals and wheat	
	False Cleavers				
19	*Kochia scoparia*	1995 - USA (Montana)	dicamba and fluroxypyr	cropland and wheat	+
	Kochia	1995 - USA (ND)	dicamba	wheat	
		1997 - USA (Idaho)	dicamba	roadsides	
		1999- USA (Colorado)	dicamba	corn	
		2010 - USA (Nebraska)	dicamba	corn	
20	*Lactuca serriola*	2007 - USA (Washington)	2,4-D, dicamba, MCPA	cereals	
	Prickly Lettuce				
21	*Limnocharis flava*	1995 - Indonesia	2,4-D	rice	
	Yellow bur-head	1998 - Malaysia *Multiple - 2 MOA's	2,4-D and bensulfuron-methyl	rice	
22	*Limnophila erecta*	2002 - Malaysia *Multiple - 2 MOA's	2,4-D, cinosulfuron, mesosulfuron-methyl, and pyrazosulfuron-	rice	

	Species	Year/Location	Auxin	Situation	GR/GT
			ethyl		
	Marshweed				
23	*Papaver rhoeas*	1993 - Spain *Multiple - 2 MOA's	2,4-D and tribenuron-methyl	cereals and wheat	
	Corn Poppy	1998 - Italy *Multiple - 2 MOA's	2,4-D, iodosulfuron-methyl-sodium, and tribenuron-methyl	wheat	
		1998 - Italy	2,4-D	wheat	
24	*Ranunculus acris*	1988 - New Zealand	MCPA	Pastures	
	Tall Buttercup				
25	*Raphanus raphanistrum*	1999 - Australia (Western Australia)	2,4-D	cereals	+
	Wild Radish	2006 - Australia (South Australia) *Multiple - 3 MOA's	2,4-D, diflufenican, MCPA, and triasulfuron	cereals	
		2009 - Australia (Victoria) *Multiple - 2 MOA's	2,4-D, chlorsulfuron, and metosulam	barley and wheat	
		2010 - Australia (Western Australia) *Multiple - 4 MOA's	2,4-D, chlorsulfuron, diflufenican, glyphosate, imazethapyr, MCPA, metosulam, and sulfometuron-methyl	Fallow	
		2011 - Australia (Victoria)	2,4-D	Barley and Wheat	
		2013 - Australia (New South Wales)	2,4-D	Barley, Oats, and Wheat	
26	*Sinapis arvensis*	1990 - Canada (Manitoba)	2,4-D, dicamba, dichlorprop, MCPA, mecoprop, and picloram	barley, cropland, and wheat	
	Wild Mustard	2008 - Turkey *Multiple - 2 MOA's	dicamba, propoxycarbazone-sodium, thifensulfuron-methyl, triasulfuron, and tribenuron-methyl	not specified	
27	*Sisymbrium orientale*	2005 - Australia (South Australia) *Multiple - 2 MOA's	2,4-D, imazethapyr, MCPA, metosulam, and metsulfuron-methyl	cereals	
	Indian Hedge Mustard		dicamba, propoxycarbazone-sodium, thifensulfuron-methyl, triasulfuron, and tribenuron-methyl		

	Species	Year/Location	Auxin	Situation	GR/GT
28	*Soliva sessilis*	1999 - New Zealand	clopyralid, picloram, and triclopyr	Golf courses	
	Carpet Burweed				
29	*Sphenoclea zeylanica*	1983 - Philippines	2,4-D	rice	
	Gooseweed	1995 - Malaysia	2,4-D	rice	
		2000 - Thailand	2,4-D	rice	
30	*Stellaria media*	1985 - United Kingdom	mecoprop	cereals and wheat	
	Common Chickweed	2010 - China	fluroxypyr and MCPA	winter wheat	
31	*Tripleurospermum perforatum (=T. inodorum)*	1975 – France	2,4-D	cereals	
	Scentless Chamomile	1975 – United Kingdom	2,4-D	cereals	

Heap (Heap, 2014b)

The likelihood of actual selection of 2,4-D-resistant weeds becomes greater as the selection pressure for resistance increases. Under the Preferred Alternative, selection pressure is expected to be greater than under the No Action Alternative because 2,4-D use is expected to be higher by 5.7- to 8.6-fold on cotton (Appendix 3). To mitigate the increased selection pressure associated with the increased use of 2,4-D, Dow (DAS, 2012) recommends the following practices for herbicide selection:

- Rotate the use of Enlist Duo Herbicide with non-auxin (non-Group 4) and non-glycine (Group 9) herbicides;
- Use a broad spectrum soil-applied herbicide as a foundation treatment;
- Use herbicides with alternative modes of action;
- Avoid using more than two applications of a Group 4 herbicide within a single growing season unless mixed with another mode of action herbicide with overlapping spectrum; and
- Apply labeled rates of Enlist Duo herbicide at the specified time (correct weed size) to minimize escapes of resistant weeds.

The advice growers receive is an important driver of best management practices. Cotton growers are currently receiving recommendations from State extension services for use of additional sites of action for cotton production, without a predominant focus on glyphosate usage. Recommendations for burndown for example, may include flumioxazin, paraquat, and direx in Georgia (UGA Extension, 2014) or thifensulfuron + tribenuron, carfentrazone and combinations with auxinics or glyphosate in the Texas Plains (Dotray and Keeling, 2014). Whether growers will employ these recommendations if the Preferred Alternative is selected is unknown. APHIS cannot rule out the possibility that some growers will use Enlist cotton and may rely predominantly on glufosinate, glyphosate and 2,4-D for weed control, contrary to recommendations to include additional herbicide chemistries. However, third party proprietary data summarized in the USDA-APHIS FEIS for dicamba-resistant soybean and cotton ((USDA-APHIS, 2014d), Appendix 4, Figure 4.3 and Figure 4.4) indicate a clear trend of growers following these recommended practices.

Modeling studies suggest that exclusive use of an herbicide can select for HR weeds in as little as five years (Neve et al., 2011). Because growers who adopt Enlist crops are expected to be those who have had the most difficulty with GR weeds, the selection of biotypes exhibiting multiple resistance to both glyphosate and 2,4-D may be related to the probability of selecting resistance to just 2,4-D and not the product of selecting resistance to both sites of action. Thus, resistance could appear within five years if glyphosate and 2,4-D are used exclusively. The southeast is expected to be a region of concern because GR weeds are already reported to be present in greater than 90 percent of cropland (Farm-Industry-News, 2013). In this region, Palmer amaranth can no longer be controlled with glyphosate and would be at potential risk for the selection of multiple resistant biotypes. APHIS however, notes that active stewardship of 2,4-D will be overseen by EPA, based on recent herbicide registration decisions (based on concern for increased HR weeds, including 2,4-D). Dow will also begin to provide grower instruction for best management practices and the use of 2,4-D will be promoted along with use of additional and alternative chemicals (see discussion in section 5.4.5 Weed Management and DAS' stated approach in this section). In addition, standard state weed recommendations for cotton production now include as many as seven to nine separate herbicides (section 5.4.5 Weed Management, Frequency of Herbicide Application).

APHIS concludes that cumulative impacts of DAS-81910-7 cotton will be minimized because EPA regulation of herbicide usages has become weed-resistance focused, and seed providers of the trait technologies are now motivated by that new EPA oversight. Those who professionally educate cotton producers have already shown by the complexity of recommended herbicide and non-herbicide control programs in cotton that the importance of diversity of weed management to reduce weed herbicide resistance has been recognized and will be a continuing effort. Growers have seen what can happen with the incidence of weed resistance when best management practices are not followed; they are now seeing the agricultural community coming together to deal with the threat. APHIS concludes that good management practices are being recognized as more necessary by growers now than they were at the beginning of the era of HR trait expression for commodity crops, and worst-case outcomes are not expected.

5.5.3 Biodiversity

Growers have the opportunity to choose many different practices to manage their operations. As described in the No Action Alternative, agricultural practices can affect biodiversity in and around agricultural fields.

Agricultural practices have the potential to impact diversity at the farm level by affecting a farm's biota, including birds, wildlife, invertebrates, soil microorganisms, and weed populations. Conservation tillage leaves a higher rate of plant residue and increases soil organic matter (Hussain et al., 1999). This benefits soil biota by providing additional food sources (energy) (USDA-NRCS, 1996) and increasing the diversity of soil microorganisms. It also benefits invertebrate detritivores, their predators, and ultimately, birds and other wildlife higher in the food chain (Carpenter, 2011a; Towery and Werblow, 2010a). Ground-nesting and seed-eating birds, in particular, have been found to benefit from greater food and cover associated with conservation tillage (SOWAP, 2007).

Herbicide use in agricultural fields can impact biodiversity by decreasing weed quantities or causing a shift in weed species. This can affect insects, birds, and mammals that use these weeds. The quantity and type of herbicide use associated with conventional and GE crops depends on many variables, including cropping systems, type and abundance of weeds, production practices, and individual grower decisions. An issue of importance to biodiversity is that of herbicide drift, and 2,4-D and glyphosate have been implicated as contributors to impacts on other crops through drift or volatilization; if other commercial crops are impacted, then so also may be plant diversity and plant related animal diversity. From historical metastudies of 2,4-D effects on cotton and soybean, dosage and stage of the exposed plant were relevant parameters that affected yield, but environmental conditions at time of spraying were also important (Egan et al., 2014a). This study established when cotton and soybean were most sensitive to drift of 2,4-D and dicamba, which can be used by growers to appropriately time herbicide applications. Since more than one-half of all cotton is planted after a previous-season cotton crop (Table 27), a high percentage of cotton will be planted near other cotton, including DAS-81910-7. Because such growers will be conscious of neighboring growers' cotton sensitivities, cautious observation of EPA rules for safe application of 2,4-D to DAS-81910 cotton will be likely.

Some studies have looked at such drift-related impacts of dicamba, another auxinic-type herbicide. Declines of plant forb populations were detected, with some changes in insect populations, both increases and declines, at treated field margins. Old plant successions showed only changes in a key flowering species. The possible impacts on nontarget plants in field edge versus mature succession plants were difficult to discern because of non-comparability of successional stage of treated and untreated areas and of differences in water stress levels in these experiments (Egan et al., 2014b).

APHIS reiterates that EPA has responsibility for assessing the potential of herbicide applications, to make impacts on the environment. For the use of Enlist Duo on corn and soybean, the EPA registration specifies application conditions that are protective of sensitive species. They determined that "in cases where the wind is blowing towards a sensitive area, a 30-foot in-field buffer must be implemented. The 30-foot buffer strip may be sprayed at a later time when the wind direction has shifted and is no longer blowing towards the sensitive area. EPA determined that by using this approach, any spray drift from 2,4-D choline salt remains on the corn or soybean field that is being treated (US-EPA, 2014d)."

Under the Preferred Alternative, the overall 2,4-D use on crops is estimated to increase 5.7 to 7.9 times more than that under the No Action Alternative for cotton applications (see Appendix 3). Unlike the No Action Alternative, the incremental increase in 2,4-D use is expected to be of the choline salt (Enlist Duo) formulation. This formulation is 50 times less volatile than dimethylamine (DMA) and 500 times less volatile than ester formulations (see Appendix 7 of the FEIS for Enlist crops). An independent trial by the University of Georgia extension has corroborated the conclusion that off-target movement is less likely with the 2,4-D choline salt formulations compared to the ester and dimethylamine formulations (public comment APHIS-2013-0042-1911-A2). The expected increase in 2,4-D use under the Preferred Alternative is not likely to result in more off-target effects because under the Preferred Alternative it will be applied as the choline salt formulation. This formulation is also likely to replace some current uses of the DMA and ester formulations on other crops (because growers appreciate reduced drift and volatility potential), so the overall use of more volatile 2,4-D formulations are expected to be less under the Preferred Alternative than under the No Action Alternative.

Though injurious off-target pesticide movement is expected to be lower for the Preferred Alternative (with 2,4-D choline salt) than for the No Action Alternative, the new use of 2,4-D on DAS-81910-7 cotton may occur over a longer season under the Preferred Alternative. This could increase exposure to sensitive plants later in the season. However, EPA has made a determination (for Enlist corn and soybean with Enlist Duo) that by using the specified herbicide application borders, and taking wind speed into account, impacts on sensitive plants would not "exceed[ed] the level of concern for spray drift as established by the Agency" (US-EPA, 2014d). In their assessments, EPA has taken into account less volatile formulations and the imposed tactics to limit exposures, to predict low risk potential from 2,4-D drift damage.

Both tillage and herbicide use patterns influence biodiversity. If DAS-81910-7 cotton is approved, APHIS concluded that it is likely that use of no-till management will be maintained or will further increase. Therefore, use of these products is likely to improve or stabilize biodiversity in fields where tillage is used currently to control GR weeds. In many regions tillage is used for purposes other than weed control so in these areas only the changes in herbicide use patterns may influence biodiversity. Because many management choices affect farm level biodiversity, the magnitude of this impact on biodiversity is uncertain.

Habitat loss is the greatest direct impact agriculture has on biodiversity (Ammann, 2005). Therefore, methods that increase crop yields have the potential to reduce impacts to biodiversity by reducing the amount of land converted to agriculture (Carpenter, 2011a). Gains in yields have not consistently been obtained from HR cotton cultivars unless higher yielding ones are modified to incorporate an HR trait (NRC, 2010). APHIS concludes, based on the low volatilizing formulation of Enlist Duo, combined with required EPA practices likely to be imposed to limit drift as well as how impacts are avoidable and controllable, that 2,4-D (as Enlist Duo) is expected to have minimal overall effects on biodiversity in the Affected Environment. Similar constraints and their effects apply also to use of dicamba in crop production; this is another auxinic herbicide whose impacts will be regulated by EPA through required application practices. APHIS also concludes that there are likely to be no other past, present or future actions that will cause any substantially increased impacts associated with Enlist cotton on biodiversity compared to current use of 2,4-D on other agricultural crops.

5.6 Physical Environment

Under the cumulative impacts of the Preferred Alternative, there is an expectation that the use of 2,4-D will increase. This increase in 2,4-D use has the potential to impact physical resources. APHIS does not regulate the use of 2,4-D. The direct and indirect impacts which may arise from this increased use are the result of the action that EPA is taking with respect to approving the use of Enlist Duo for use on Enlist cotton. EPA has recently registered Enlist Duo for use on the Enlist corn and soybean events that were the subject of three petitions considered by an APHIS FEIS and no longer regulated by APHIS. APHIS has considered the cumulative impacts on physical resources from changes in production practices that may derive from an increase in 2,4-D-resistant weeds.

5.6.1 Soil Quality

The major cotton regions in the U.S. also include some areas where soil erosion exceeds replacement (see Affected Environment). In some of these areas conservation tillage has been adopted as part of the management plan for controlling erosion.

If conventional tillage increases to control GR and other HR weeds, there may be an impact on soil quality. Residue management that employs intensive tillage and leaves low amounts of crop residue on the surface results in greater losses of soil organic matter (USDA-NRCS, 1996). The total acreage that may be impacted by such an increase in tillage would be based on the extent of resistant weeds present in a field and the weed management strategy chosen by a grower. Adoption of DAS-81910-7 cotton can provide growers with an alternative herbicide to glyphosate and glufosinate.

Based on individual grower needs, DAS-81910-7 cotton could provide growers with an alternative to intensive tillage practices that may be used to address herbicide resistance issues. This in turn could reduce the potential loss of soil organic matter and soil erosion that may result when more aggressive tillage practices are used to manage HR weeds under the No Action Alternative. However, the selection of weeds resistant to glyphosate, 2,4-D, and glufosinate will limit the use of this product and benefits to soil that may arise. The magnitude of potential benefits is uncertain because decisions on soil management are made by individual growers.

5.6.2 Water Quality

Under the No Action Alternative, increasing tillage to manage GR weeds may be needed and lead to increasing soil erosion and decreasing water quality from increasing sedimentation. Under the Preferred Alternative, use of Enlist Duo and Enlist crops may help to preserve gains in conservation tillage in the short term. In the long term, selection of 2,4-D-resistant weeds may result in similar aggressive tillage practices that are expected to occur under the No Action Alternative, unless growers choose those practices that will deter weeds from developing future herbicide resistance. APHIS concludes, however, that growers who have current problems with GR weeds will choose those management practices that will minimize development of 2,4-D-resistant weeds, preserving the opportunity for continued use of these crops for cotton production.

5.6.3 Air Quality

When considering cumulative impacts under the No Action Alternative, increased tillage to manage GR weeds may occur and lead to decreased air quality from increased air particulates and exhaust from farm equipment. Under the Preferred Alternative, Enlist cropping systems for cotton may help to preserve gains in conservation tillage and benefit air quality in the short term. In the long term, if growers follow best management practices, selection of 2,4-D-resistant weeds may be averted. Given that the growers acknowledge the presence of GR weeds, they also understand the adverse consequences of not deterring resistance to new types of HR weeds. APHIS concludes that aggressive tillage practices can be obviated and that growers will choose those practices that support the continued use of 2,4-D as a herbicide and component of Enlist.

5.6.4 Climate Change

Under the No Action Alternative when considering cumulative impacts, there is a potential impact leading to climate change from increased herbicide use and more aggressive tillage regimes to control HR weeds. Burning additional fossil fuels will increase the release of GHG and result in soil disruption from tillage that releases sequestered carbon as GHGs. Under the Preferred Alternative, the use of Enlist Duo and cotton may help to preserve gains in conservation tillage and reduce GHG contributions to climate change in the short term. In the long term, deterring selection of 2,4-D resistant weeds can avert the need to use aggressive tillage practices that are occurring under the No Action Alternative. The benefits cited above under the Preferred Alternative can be attained by growers choosing best management practices. APHIS concludes that there are no additional past, present or future actions that when considered with the present lack of impacts, will increase the total impacts from production of DAS-81910-7 cotton.

5.7 Socioeconomics

5.7.1 Alternatives Available for 2,4-D-Resistant Weed Control

A potential cumulative impact could occur following introduction of Enlist cotton if 2,4-D-resistant weeds were to arise in typical rotation crops of cotton. This impact could occur for growers of these crops that typically use 2,4-D for weed control. The potential for economic impact on rotation crops, based on available alternative practices, was analyzed.

USDA-APHIS 2,4-D-Resistant Corn and Soybeans FEIS: Possible cumulative impacts on rotation crops and among other agricultural users of 2,4-D were assessed in the 2014 FEIS (USDA-APHIS, 2014c). To evaluate how crops that currently use 2,4-D for weed control might be impacted if 2,4-D-resistant weeds become more prevalent in cotton, APHIS cites the management options and costs for weed control in the same rotation crops as in the FEIS for 2,4-D-Resistant Corn and Soybeans (DAS, 2010a; DAS, 2011). Weed control programs vary by crop, weed problem, geography, and cropping system (e.g., no-till, conventional-till, etc.). In those crops for which 2,4-D is labeled for use, 2,4-D is usually just one part of a much broader weed management strategy. Many growers use a combination of weed control techniques including cultural, mechanical, and chemical. From the EPA Screening Level Estimates of Agricultural Uses of 2,4-D (US-EPA, 2012a), APHIS identified 23 crops where as much as 10 percent of the crop is treated with 2,4-D (see EA Table 25). Many of these are managed similarly and were considered together in the FEIS analysis. For tree crops, total 2,4-D use is low, and rotation is not at issue, so they were excluded from the analysis. For each crop, or group of similar crops, APHIS considered the types and cost of herbicides that are used for broadleaf weed control. APHIS focused on post-emergence, broadleaf weed control as this is the primary use of 2,4-D in these crops. Table 32 presents a brief summary of these findings from the 2,4-D FEIS.

USDA-APHIS 2,4-D-Resistant Corn and Soybeans FEIS*: Corn and Soybean as Cotton Rotation Crops*. APHIS determined that based on expected licensing of technology to corn breeders, 30-40% of corn acreage may express the Dow 2,4-D-resistance trait, and a maximum of 68% of soybean acreage may express the trait by 2020. Both crops will most likely be major users of the 2,4-D-resistance technology, and together would include about 93.7 million acres of crops using 2,4-D at the predicted rate. Therefore, corn and soybean will themselves be potential sources of 2,4-D-resistant weeds. The maximum expected rate of 2,4-D-resistant cotton adoption in all states would produce, at most, 6.9 million acres. However, typical rotation crops of cotton include corn or soybean in cotton-growing regions at less than 50% of cotton acres. Enlist cotton can be alternated with various non-Enlist corn and soybean choices; these include selection of new HR corn and soybean options, such as dicamba-resistant soybean, HPPD-resistant corn, and glufosinate-resistant corn and soybean. The EPA has required Dow to educate growers choosing Enlist corn and soybean about negative consequences of growing 2,4-D-resistant crops in sequential years (APHIS expects the same requirement for Enlist cotton). Dow is also required to track weed resistance to Enlist use, and provide remediation as needed (US-EPA, 2014).

Table 32. Alternatives to 2,4-D for Cotton Rotation Crops and Other Agricultural Users of 2,4-D.

Rotation Crop or Usage Type	Herbicide Alternatives	Other Alternatives and Possible Impacts
Pasture and Rangeland	Alternative herbicides are available, and effective cultural controls are currently used as well	Most pasture and rangeland is not treated with herbicides. Cost increases, if any, would be small
Small Grains	Several alternative herbicides available but slightly more expensive. Others, such as pyraflufen, are cost effective but have use restrictions. Various herbicide combinations effective, at higher cost.	Crop rotation where practiced is effective. Alternative herbicides may have an increased cost, but at only marginally greater costs. These others may control key weeds that 2,4-D does not. Winter wheat usually outcompetes weeds.
Fallow and Burndown	Used with glyphosate to complement weed activity spectrum; other herbicides may be moderately more expensive or may have undesired residual activity	The 2,4-D-Resistant Corn and Soybean FEIS notes that the principle cost increases would be on weeds of cotton, corn and soybean; however, Enlist corn and soybean in rotations are already nonregulated and will themselves be a potential source for selection of 2,4-D-resistant weed selection; these varieties should be planted in non-sequential years to reduce potentials for new

Rotation Crop or Usage Type	Herbicide Alternatives	Other Alternatives and Possible Impacts
		weed resistance
Sorghum	Low priced atrazine and carfentrazone are good substitutes and are currently used by growers	Weeds that are currently controlled with the substitutes have some biotypes resistant to ALS and atrazine. Mechanical means are alternatives: preplant harrowing costs about $8/acre and inter row cultivation can be used, but may cost an additional $7-8/acre
Corn and Soybean (non-Enlist Varieties)	For soybean, preponderant use of 2,4-D is for burndown, and is covered above. For corn, post emergent use is currently 5% (or less) of acres on average, and numerous herbicide options for weed control and problem weeds are available.	Potential development of resistant weeds will likely be deterred by EPA-required Dow training of growers (in registration requirements) that enjoins sequential planting of Enlist crops (i.e., corn and soybean) with Enlist cotton. If non-2,4-D-resistant corn and soybean alternates with Enlist cotton, different herbicides used on these crops will deter continuous single herbicide selection for new resistant weeds.

Although the potential socioeconomic impacts for cotton rotation crops and other important agricultural users can be described, alternative herbicide uses for weed management may be numerous as may be the alternative management practices. In some cases, various mechanical or harrowing options may be useful; cultural controls, such as appropriate crop rotations can be observed and all of these may already be part of current best management practices. In other cases, alternative herbicides to 2,4-D are available, some only slightly more costly, but sometimes more effectual in some geographic areas because 2,4-D alone fails to control key weeds. APHIS concludes that as with any weed issue, if new 2,4-D resistance should arise in weeds of cotton, approved and successful alternatives for weed control in the rotation crop are available, some better, others possibly less effective than 2,4-D; resistant weed control with alternative weed management practices is clearly possible, and any socioeconomic impacts are likely to be marginal or avoidable.

New resistant weed development should be limited because growers will avoid frequent use of the same herbicide on the same acreage, since recent adverse consequences of glyphosate misuse are now well known. Consequently, APHIS concludes that rotating 2,4-D-resistant cotton with these other 2,4-D-resistant Enlist crops will likely result initially in only low levels of new weed resistance. The risk for development of resistance in these Enlist crops will likely be similar to that for such development in cotton crops; growers of Enlist corn and soybean following the EPA approved label recognize that certain management practices, such as continuous use of this system and no diversification of herbicides or of best management practices will lead to unsustainable herbicide use and to their economic detriment over the longer term.

USDA has begun several initiatives to help growers with strategies to integrate practices for managing herbicide resistant weeds(USDA-Office-of-Communications, 2014). USDA-NRCS is soliciting proposals under a grant program to address herbicide resistant weeds using novel conservation systems. USDA-APHIS will begin recommending BMPs for field trials of herbicide resistant crops. USDA is partnering with the WSSA for education and then funding for outreach materials on herbicide resistant weeds. The USDA Office of Pest Management Policy worked with EPA to address the issue of herbicide resistance through appropriate label language that will require registrants to develop a stewardship program for new uses of herbicides on resistant crops. Other efforts include producing training materials for diverse weed management practices, for investigating nonperformance of herbicides and for implementing responses to suspected herbicide resistant weeds. USDA in recent years has also worked with the WSSA to both identify BMPs for weeds, and to assess any issues that interfere with adopting those practices. While both weed management and developing strategies that will avert new resistant weed development are a focus for state extension efforts, for seed development companies and private consultants, the USDA is also making efforts to participate in both these grower goals.

6 THREATENED AND ENDANGERED SPECIES

The Endangered Species Act (ESA) of 1973, as amended, is one of the most far-reaching wildlife conservation laws ever enacted by any nation. Congress passed the ESA to prevent extinctions facing many species of fish, wildlife and plants. The purpose of the ESA is to conserve endangered and threatened species and the ecosystems on which they depend as key components of America’s heritage. To implement the ESA, the U.S. Fish & Wildlife Service (USFWS) works in cooperation with the National Marine Fisheries Service (NMFS), other Federal, State, and local agencies, Tribes, non-governmental organizations, and private citizens. Before a plant or animal species can receive the protection provided by the ESA, it must first be added to the Federal list of threatened and endangered wildlife and plants.

A species is added to the list when it is determined by the USFWS/NMFS to be endangered or threatened because of any of the following factors:

- The present or threatened destruction, modification, or curtailment of its habitat or range;
- Overutilization for commercial, recreational, scientific, or educational purposes;
- Disease or predation;
- The inadequacy of existing regulatory mechanisms; and
- The natural or manmade factors affecting its survival.

Once an animal or plant is added to the list, protective measures apply to the species and its habitat. These measures include protection from adverse effects of federal activities.

Section 7 (a)(2) of the ESA requires that federal agencies, in consultation with USFWS and/or the NMFS, ensure that any action they authorize, fund, or carry out is "not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated critical habitat." It is the responsibility of the federal agency taking the action to assess the effects of their action and to consult with the USFWS and NMFS if it is determined that the action "may affect" listed species or designated critical habitat. To facilitate their ESA consultation requirements, APHIS met with the USFWS from 1999 to 2003 to discuss factors relevant to APHIS' regulatory authority and effects analysis for petitions for nonregulated status and developed a process for conducting an effects determination consistent with the Plant Protection Act (PPA) of 2000 (Title IV of Public Law 106-224). APHIS uses this process to help fulfill its obligations and responsibilities under Section 7 of the ESA for biotechnology regulatory actions.

APHIS met with USFWS officials on June 15, 2011, to discuss whether APHIS has any obligations under the ESA regarding analyzing the effects on TES that may occur from use of pesticides associated with GE crops. As a result of these joint discussions, USFWS and APHIS have agreed that it is not necessary for APHIS to perform an ESA effects analysis on herbicide use associated with GE crops because EPA has both regulatory authority over the labeling of pesticides under FIFRA, and the necessary technical expertise to assess pesticide effects on the environment. APHIS has no statutory authority to authorize or regulate the use of 2,4-D, glufosinate, or any other herbicide, by cotton growers. Under APHIS' current Part 340 regulations, APHIS only has the authority to regulate DAS-81910-7 cotton or any GE organism as long as APHIS believes they may pose a plant pest risk (7 CFR § 340.1). APHIS has no regulatory jurisdiction over any other risks associated with GE organisms including risks resulting from the use of herbicides or other pesticides on those organisms.

After completing a plant pest risk analysis, if APHIS determines that DAS-81910-7 cotton seeds, plants, or parts thereof do not pose a plant pest risk, then these articles would no longer be subject to the plant pest provisions of the PPA or to the regulatory requirements of 7 CFR Part 340, and therefore, APHIS must reach a determination that these articles are no longer regulated. As part of its EA analysis, APHIS is analyzing the potential effects of DAS-81910-7 cotton on the environment including, as required by the ESA, any potential effects to threatened and endangered species and critical habitat. As part of this process, APHIS thoroughly reviews the GE product information and data related to the organism (generally a plant species, but may also be other genetically engineered organisms). For each transgene/transgenic plant, APHIS considers the following:

- A review of the biology and taxonomy of the crop plant and its sexually compatible relatives;
- Characterization of each transgene with respect to its structure and function and the nature of the organism from which it was obtained;
- A determination of where the new transgene and its products (if any) are produced in the plant and their quantity;

- A review of the agronomic performance of the plant, including disease and pest susceptibilities, weediness potential, and agronomic and environmental impacts;
- Determination of the concentrations of known plant toxicants (if any are known in the plant);
- Analysis to determine if the transgenic plant is sexually compatible with any threatened or endangered species (TES) of plants or a host of any TES; and
- Any other information that may inform the potential for an organism to pose a plant pest risk.

In following this review process, APHIS, as described below, has evaluated the potential effects that a determination of nonregulated status of DAS-81910-7 cotton may have, if any, on federally-listed TES species and species proposed for listing, as well as designated critical habitat and habitat proposed for designation. Based upon the scope of the EA and production areas identified in the Affected Environment section of the EA, APHIS reviewed the USFWS list of TES species (listed and proposed) for each state where cotton is commercially produced (USFWS, 2014a).

Prior to this review, APHIS considered the potential for DAS-81910-7 cotton to extend the range of cotton production and also the potential to extend agricultural production into new natural areas. APHIS has determined that agronomic characteristics and cultivation practices required for DAS-81910-7 cotton are essentially indistinguishable from practices used to grow other cotton varieties, including other herbicide-tolerant varieties (DAS, 2013b; USDA-APHIS, 2014f). Although DAS-81910-7 cotton may be expected to replace other varieties of cotton currently cultivated, APHIS does not expect the introduction of DAS-81910-7 cotton to result in new cotton acres or to be planted in areas that are not already devoted to agriculture. Accordingly, the issues discussed herein focus on the potential environmental consequences of the determination of nonregulated status DAS-81910-7 cotton on TES species in the areas where cotton is currently grown (USFWS, 2014a).

For its analysis on TES plants and critical habitat, APHIS focused on the agronomic differences between the regulated articles and cotton varieties currently grown; the potential for increased weediness; and the potential for gene movement to native plants, listed species, and species proposed for listing.

For its analysis of effects on TES animals, APHIS focused on the implications of exposure to the novel proteins expressed in the plants as a result of the transformation, and the ability of the plants to serve as a host for a TES. The novel proteins associated with DAS-81910-7 cotton are listed in Table 33.

Table 33. Novel Proteins Associated with DAS-81910-7 Cotton.

Regulated Article	Protein	Phenotypic Effects
DAS-81910-7 cotton	aryloxyalkanoate dioxygenase-12 (AAD-12)	Resistance to 2,4-D
	phosphinothricin acetyltransferase (PAT)	Resistance to glufosinate

Source: (DAS, 2013b).

6.1 Potential Effects of DAS-81910-7 Cotton on TES and Critical Habitat

6.1.1 Threatened and Endangered Plant Species and Critical Habitat

Upland cotton (*G. hirsutum*) possesses few of the characteristics common to plants that are successful weeds (Baker, 1965; Keeler, 1989) and is not considered to be a serious or common weed in the United States. It is not listed as a weed in the major weed references (Crockett, 1977; Holm LG et al., 1979), nor is it present on Federal or State lists of noxious weed species (USDA-APHIS, 2012; USDA-NRCS, 2012f). Modern Upland cotton is a domesticated perennial grown as an annual crop that is not generally persistent in unmanaged or undisturbed environments without human intervention. Modern cultivars are not frost tolerant and do not survive freezing winter conditions, do not produce abundant or long-lived seeds that can persist or lie dormant in soil, do not exhibit vegetative propagation or rapid vegetative growth, and do not compete effectively with other cultivated plants (OECD, 2008). In areas where winter temperatures are mild and freezing does not occur, cotton plants can occur as volunteers in the following growing season. These volunteers can be easily controlled by herbicides or mechanical means. Excepting 2,4-D and glufosinate, DAS-81910-7 cotton is expected to be sensitive to the same herbicides as other cotton varieties (DAS, 2013b). Cotton can become locally feral or naturalized in suitable areas, such as southern Florida, Hawaii, and Puerto Rico (Coile and Garland, 2003; Fryxell 1984; USDA-NRCS, 2012e; Wunderlin and Hansen, 2008).

The agronomic and morphologic characteristics data provided by Dow were used in the APHIS analysis of the weediness potential for DAS-81910-7 cotton, and evaluated for the potential to impact TES and critical habitat. Agronomic studies conducted by Dow tested the hypothesis that the weediness potential of DAS-81910-7 cotton is unchanged with respect to conventional cotton (DAS, 2013b). Dow conducted field trials during the 2012 growing season across eight locations representative of the major cotton-growing areas of the United States to evaluate phenotypic, agronomic and ecological characteristics (DAS, 2013b). DAS-81910-7, seven near isogenic nontransgenic lines, and reference variety plants were grown under conditions of no herbicide applications and sprayed with 2,4-D plus glufosinate (DAS, 2013b). Dow evaluated seven agronomic characteristics: early population, seedling vigor, flower initiation, nodes above first white flower, plant height, percent open bolls and lint yield; and disease and insect pressure (DAS, 2013b). Analyses of these field data revealed no statistically significant differences between non-sprayed DAS-81910-7 cotton and the isoline (control). In addition, mean results for non-sprayed DAS-81910-7 cotton entries fell within the reference variety ranges (DAS, 2013b). Therefore, non-sprayed DAS-81910-7 cotton was found to be agronomically equivalent to the isoline (control). The comparisons of agronomic characteristics between DAS-81910-7 cotton sprayed with 2,4-D plus glufosinate and non-sprayed DAS-81910-7 cotton were not statistically significant. The relative magnitudes of the differences between the mean values for non-sprayed DAS-81910-7 cotton vs. sprayed DAS-81910-7 cotton for the combined site analysis were small (-3.45%) (DAS, 2013b). In addition, mean results for DAS-81910-7 cotton sprayed with 2,4-D plus glufosinate fell within the reference variety ranges (DAS, 2013b). This leads to the conclusion that the agronomic characteristics of DAS-81910-7 cotton sprayed with 2,4-D plus glufosinate are equivalent to non-sprayed DAS-81910-7 cotton. Seed dormancy is a characteristic that is often associated with plants that are considered weeds. Lab studies found no significant differences in germination (as an indicator of dormancy) of DAS-81910-7 cottonseed compared with nontransgenic control cottonseed (98M-2983XCoker310) under warm (30ºC) and cool conditions (18ºC) (DAS, 2013b). In summary, no differences were detected between DAS-81910-7 cotton and nontransgenic cotton in growth, reproduction, or interactions with pests and diseases, other than the intended effect of tolerance to the two herbicides (DAS, 2013b; USDA-APHIS, 2014f).

Based on the agronomic field and laboratory data, and literature survey concerning weediness potential of cotton, DAS-81910-7 cotton is unlikely to persist as a troublesome weed or to have a significant impact on current weed management practices (USDA-APHIS, 2014f). DAS-81910-7 cotton volunteers and feral populations can be managed using a variety of currently available methods and alternative herbicides (DAS, 2013b; Keeling, 2009; Morgan, 2010 ; Morgan et al., 2011a; Morgan et al., 2011b; Thompson, 2008; York et al., 2004). Furthermore, extensive post-harvest monitoring of field trial plots planted with DAS-81910-7 cotton under USDA-APHIS notifications and permits and field data reports did not reveal any differences in survivability or persistence relative to other varieties of the same crop currently being grown (USDA-APHIS, 2014f). These data suggest that DAS-81910-7 cotton is no more likely to become a weed than conventional varieties of cotton.

As part of its analysis of effects on species and habitat, APHIS evaluated the potential of DAS-81910-7 cotton to cross with wild relatives. Cultivated *G. barbadense* (Pima or Egyptian cotton), is grown in Arizona, California, New Mexico, and Texas (Pleasants and Wendell, 2005; USDA-NASS, 2012b). Naturalized populations of *G. barbadense* grow in Puerto Rico, the Virgin Islands and most of the major Hawaiian Islands (Bates, 1990; Fryxell 1984; USDA-NRCS, 2012d). Two wild species of cotton are native to the United States, *G. thurberi* and *G. tomentosum*, and grow in Arizona and Hawaii respectively (Fryxell 1984; USDA-NRCS, 2012d). G. hirsutum is tetraploid and thus effectively incompatible with diploid species such as *G. thurberi*. Plants from these two groups do not normally hybridize spontaneously and produce fertile offspring, and experimental crosses are difficult (OECD, 2008). In contrast, G. *hirsutum* is sexually compatible with the tetraploids *G. barbadense* (cultivated Pima or Egyptian cotton) and *G. tomentosum* and can form viable and fertile progeny with both species (Brubaker CL et al., 1993; OECD, 2008; Saha et al., 2006). Thus, unassisted outcrossing and gene introgression could potentially occur in areas where these species are co-located (USDA-APHIS, 2014f).

For transgene introgression from DAS-81910-7 cotton to occur there would have to be spatial proximity between DAS-81910-7 cotton and the recipient variety or species; overlap in their flowering period; and because cotton is insect pollinated, they must share similar pollinators (Pleasants and Wendell, 2005). Published studies report that there has been relatively little gene introgression from *G. hirsutum* into native or naturalized *G. barbadense* in Mesoamerica and the Caribbean, despite the fact that *G. barbadense* has been grown in the presence of the predominant *G. hirsutum* since prehistoric times (Brubaker CL et al., 1993; Wendel et al., 1992). In contrast, introgression from *G. barbadense* to native or naturalized *G. hirsutum* in these areas has been relatively common (Brubaker CL et al., 1993; Wendel et al., 1992). Various mechanisms have been suggested to account for this difference (Brubaker CL et al., 1993; Jiang and PW Chee, 2000; OGTR, 2008; Percy and Wendel., 1990). While none of these mechanisms leads to complete isolation between the two species, the reported asymmetry in gene flow suggests that gene introgression from cultivated *G. hirsutum* varieties such as DAS-81910-7 cotton to native or naturalized *G. barbadense* should be rare (USDA-APHIS, 2014f).

Natural populations of *G. tomentosum* are found on all Hawaiian Islands except Kauai and Hawaii. Populations are located on the drier, leeward coastal plains of the islands at low elevations, which are also the areas that are primarily used for agriculture (Pleasants and Wendell, 2005). As discussed further in the PPRA, there is overlap in the timing of flowering (both in time of year and time of day), and potential pollinators with *G. hirsutum* (USDA-APHIS, 2014f). However, *G. hirsutum* has not been grown as an agricultural commodity in Hawaii for decades, and to the best of APHIS' knowledge, seed companies no longer use the Hawaiian Islands as a winter nursery for cotton (Grace, 2012; USDA-APHIS, 2014f). Even if gene introgression into wild relatives were to occur, expression of the AAD-12 and PAT proteins does not cause any major changes in the phenotype of cotton plants other than to confer resistance to the herbicides 2,4-D and glufosinate (DAS, 2013b; USDA-APHIS, 2014f). In the absence of treatment with these herbicides, the transgenic material in DAS-81910-7 cotton is unlikely to confer a selective advantage on any hybrid progeny that may result from outcrossing (USDA-APHIS, 2014f).

None of the relatives of cotton are Federally listed (or proposed) as endangered or threatened species (USFWS, 2014b). In the State of Florida wild populations of upland cotton, *G. hirsutum*, have been listed as endangered by the state (Coile and Garland, 2003). However, wild *G. hirsutum* is not present in the northwestern panhandle where cotton cultivation occurs, and cultivation of cotton is prohibited by the EPA in those areas of southern Florida where it is found (Coile and Garland, 2003; US-EPA, 2001; Wunderlin and Hansen, 2008). Thus, outcrossing from DAS-81910-7 cotton to naturalized *G. hirsutum* in Florida is highly unlikely. Accordingly, a determination of nonregulated status of DAS-81910-7 cotton is not expected to impact state endangered feral cotton populations.

Based on agronomic field data, literature surveyed on cotton weediness potential, the biology of cotton, and no sexually compatibility of TES with cotton in areas where cotton is commercially grown, APHIS has concluded that DAS-81910-7 cotton will have no effect on threatened or endangered plant species or on critical habitat.

6.1.2 Threatened and Endangered Animal Species

Threatened and endangered animal species that may be exposed to the gene products in DAS-81910-7 cotton would be those TES that inhabit cotton fields and potentially feed on DAS-81910-7 cotton. To identify potential effects on threatened and endangered animal species, APHIS evaluated the risks to threatened and endangered animals from consuming DAS-81910-7 cotton.

Cotton plants contain the antinutrient gossypol that plays a role in defense of cotton against insect pests (Chan et al., 1978; Kong et al., 2010). Gossypol is a yellow polyphenolic pigment found in the cotton plant and in the small pigment glands in the seed (Ely and Guthrie, 2012). Studies indicate that on cotton bollworm (*Helicoverpa armigera*) higher levels of gossypol were fatal although lower levels were found to be beneficial to growth (Paz Celorio-Mancera et al., 2011). Gossypol is harmful to monogastrics such as chickens, swine, and young ruminants (Ely and Guthrie, 2012). This defense seems to have little effect in reducing feeding by adult ruminants. In the North Carolina, 92% of cotton growers surveyed reported damage from white-tailed deer (NCDA&CS, 2010). Whole cottonseed is often used by deer managers as a supplemental feed because it is cheaper than protein pellets and feral hogs and raccoons will not consume it (DeYoung, 2005); (Taylor et al., 2013). When doing so, managers generally stop feeding in June to allow time for plasma gossypol levels to reduce prior to entering the breeding season. Although feeding studies of whole cottonseed to whitetails is lacking, there is a general belief that feeding high concentrations, especially during breeding season, may reduce breeding success (Bullock et al., 2010). Studies on European red deer indicate that bucks fed whole cottonseed had negative response in regard to body weight and antler growth (Brown et al., 2002). In studies of fallow deer, feeding whole cottonseed to bucks resulted in decreased body weight, body condition score, antler growth, and plasma testosterone concentration (Mapel, 2004).

Whole cottonseed is commonly used as a supplemental protein feed for cattle (Ely and Guthrie, 2012). However, care must be taken to not overfeed because of the possibility of gossypol toxicity. If fed too much whole cottonseed, even mature dairy cows have been known to become ill and fatalities have occurred when it was the sole diet (Ely and Guthrie, 2012). Other domestic ruminants such as goats have also shown negative effects from consumption of whole cottonseed feed. However, some of the detrimental effects were attributed to the increased dietary intake of ether extract and neutral detergent fiber rather than gossypol (Luginbuhl et al., 2000). One study indicated that whole cottonseed introduced as 15 percent of the diet to Nubian buck kids had positive results in growth, but at 30 percent had increased red blood cell fragility and reduced reproductive performance (Solaiman, 2007).

Perhaps partly because of the toxic effects of gossypol in cotton plants, especially in non-ruminants, information on wildlife depredation of cotton other than whitetail deer is lacking. However, wildlife may use cotton fields as a food source, consuming the insects that live on and among the plants. Quail and some other birds are known to nest in grassy strips on the edge of cotton fields and will enter the fields to obtain food or grit (Palmer and Bromley, NoDate). However, TES generally are found outside of agricultural fields in natural settings. Few if any TES are likely to use cotton fields because they do not provide suitable habitat. Only whooping crane (*Grus americana*), Mississippi sandhill crane (*Grus canadensis pulla*), piping plover (*Charadrius melodus*), interior least tern (*Sterna antillarum*), and Sprague's pipit (*Anthus spragueii;* a candidate species) occasionally feed in farmed sites (USFWS, 2011). These bird species may visit cotton fields during migratory periods, but would not be present during normal farming operations (Krapu et al., 2004; USFWS, 2011);.

Dow carried out a compositional assessment of DAS-81910-7 cotton by comparing DAS-81910-7 cottonseed to seed from conventional control varieties using the principles outlined in the OECD consensus document of the compositional considerations for cotton (Herman, 2013;

OECD, 2009). The samples for compositional assessment were collected from eight locations in 2012, chosen to represent typical cotton growing regions in the United States (DAS, 2013b). To provide a range of values of the normal variability of commercial cotton lines, the ranges in natural variation of the analytes was obtained from planting six commercial nontransgenic cotton reference lines as reference varieties, along with values provided from published literature ranges (DAS, 2013b). Compositional analyses of cotton seed samples included: nine proximates and fiber, twelve minerals, eighteen amino acids, twenty-two fatty acids, seven vitamins and five anti-nutrients (DAS, 2013b). Of the 73 analytes tested, 14 were excluded from the combined site analysis because more than 50% of the results were below the limit of quantification (LOQ). Overall, a comprehensive evaluation of event DAS-81910-7 cottonseed and the controls showed no biologically meaningful differences for seed composition for either major nutrients or key anti-nutrients in cotton seed. The few detected differences were small in number, and were less than the values found in the reference varieties and/or the literature ranges (DAS, 2013b). Based on these results, it can be concluded that cottonseed from DAS-81910-7 can be considered compositionally and nutritionally equivalent to those derived from convention cotton with the exception of the expression of AAD-12 and PAT proteins (USDA-APHIS, 2014f).

APHIS considered the potential for the expressed AAD-12 and PAT proteins in DAS-81910-7 cotton to impact other organisms. The AAD-12 protein is expressed in a variety of plant tissues in DAS-81910-7 cotton with average expression values ranging from 10.74 nanograms (ng)/mg dry weight in roots at plant maturity to 71.17 ng/mg dry weight in leaves at the 4-leaf stage of growth (DAS, 2013b). Similarly, the PAT protein is expressed throughout the plant during multiple growing stages with average values from 0.11 ng/mg dry weight in pollen at the early bloom stage to 13.29 ng/mg in leaves at the 4-leaf stage of growth (DAS, 2013b). AAD-12 and PAT expression values were similar for sprayed treatments as well as for plots sprayed and unsprayed with 2,4-D (DAS, 2013b). The AAD-12 protein does not share any meaningful amino acid sequence similarities with known toxins (DAS, 2013b). AAD-12 amino acid sequence similarities were evaluated using BLASTp search algorithm against the GenBank non-redundant protein dataset. The only significant similarities identified were grouped into 10 categories: 2,4-D/alpha-ketoglutarate dioxygenase, putative alkylsulfatase, alpha-ketoglutarate (dependent) dioxygenase, alphaketoglutarate-dependent sulfonate dioxygenase, taurine catabolism dioxygenase, taurine dioxygenase, dioxygenase, oxidoreductase, pyoverdine biosynthesis protein, and hypothetical (putative) or unnamed proteins. Dow reported that none of the similar proteins returned by the search identified any safety concerns that might arise from the expression of AAD-12 protein in cotton. Bioinformatic analyses demonstrated that the PAT protein does not share amino acid sequence similarity with known protein toxins that would present any safety concerns. In addition, acute oral toxicity studies have indicated that the AAD-12 and PAT proteins have no adverse effects in mice at the highest dose tested (DAS, 2013b). The lack of known toxicity of ADD-12 and PAT proteins suggests no potential for deleterious effects on organisms that may contact or consume DAS-81910-7 cotton.

The PAT enzyme present in DAS-81910-7 cotton is analogous to the PAT proteins in commercially available glufosinate-tolerant products in several crops including cotton, corn, soybean, and canola (USDA-APHIS, 2014f). OECD recognizes PAT proteins produced from different genes to be equivalent with regard to function and safety (OECD, 1999). PAT proteins are structurally similar only to other acetyltransferases known to not cause adverse effects after consumption (Herouet et al., 2005). In 1997, a tolerance exemption was issued for PAT proteins by the EPA (40 CFR part 180, 1997; 40 CFR Part 180, 2005).

The donor organism for the *aad-12* gene, *Delftia acidovorans* (formerly designated as *Pseudomonas acidovorans* (1926-1987) and *Comamonas acidovorans* (1987-1999) is widely distributed in nature (soil, water) and has been infrequently isolated from humans and animals (von Graevenitz, 1985; Wen, 1999). The PAT protein was derived from *Streptomyces viridochromogenes*, a gram-positive soil bacterium (OECD, 1999). *D. acidovorans* and *S. viridochromogenes* are neither plant pests nor known pests of organisms beneficial to agriculture (USDA-APHIS, 2014f).

The *aad-12* and *pat* expression cassettes introduced into DAS-81910-7 cotton are the same as those introduced into DAS-68416-4 soybean (USDA Petition 09-349-01p) and DAS-44406-6 soybean (USDA Petition 11-234-01p), both of which were granted non-regulatory status on September 22, 2014 (DAS, 2010b; DAS, 2011; USDA-APHIS, 2014a; USDA-APHIS, 2014b).

The *pat* gene is also expressed in other previously deregulated GE crops, including soybean and corn (USDA-APHIS, 1996; USDA-APHIS, 2001; USDA-APHIS, 2005) and the PAT protein has been the subject of numerous safety reviews (Herouet et al., 2005; OECD, 1999; US-EPA, 2008a).

On June 26, 2013, Dow submitted a safety and nutritional assessment summary document to the FDA to initiate a consultation on the food and feed safety and compositional assessment of DAS-81910-7 cotton which expresses the same the AAD-12 protein as DAS-68416-4 and DAS-44406-6 soybean. Dow received a completed consultation letter from the FDA on November 14, 2014. FDA concluded: “food and feed derived from DAS-81910-7 cotton are not materially different in composition, safety, and other relevant parameters from cottonseed-derived food and feed currently on the market, and that genetically engineered DAS-81910-7 cotton does not raise issues that would require premarket review or approval by FDA.”

In summary, all indications are that contact and ingestion of the plant or plant parts is unlikely to affect threatened and endangered species. There is no allergenicity potential with DAS-81910-7 cotton, and no increased toxicity. Therefore, there is no increased risk of direct or indirect toxicity or allergenicity impacts to animal species or their associated biological food chain, from contacting or feeding on DAS-81910-7 cotton. Based on these analyses, APHIS concludes that, although unlikely, consumption of DAS-81910-7 cotton plant parts would have no effect on any listed threatened or endangered animal species or animal species proposed for listing.

APHIS considered the possibility that DAS-81910-7 cotton could serve as a host plant for a threatened or endangered species (i.e., a listed insect or other organism that may use the cotton plant to complete its lifecycle). A review of the species list reveals that there are none that would use cotton as a host plant (USFWS, 2014a).

6.2 Conclusion

After reviewing the possible effects of allowing the environmental release of DAS-81910-7 cotton, APHIS has not identified any stressor that could affect the reproduction, numbers, or distribution of a listed TES or species proposed for listing. As a result, a detailed exposure analysis for individual species is not necessary. APHIS also considered the potential effect of a determination of nonregulated status of DAS-81910-7 cotton on designated critical habitat or habitat proposed for designation, and could identify no differences from effects that would occur from the production of other cotton varieties. Cotton is not considered a particularly competitive plant species and has been selected for domestication and cultivation under conditions not normally found in natural settings. Cotton is not sexually compatible with, or serves as a host species for, any listed species or species proposed for listing. Consumption of DAS-81910-7 cotton by any listed species or species proposed for listing will not result in an allergic reaction or increase the risk of a toxic reaction. Based on these factors, APHIS has concluded that a determination of nonregulated status of DAS-81910-7 cotton, and the corresponding environmental release of this cotton variety will have no effect on listed species or species proposed for listing, and would not affect designated habitat or habitat proposed for designation. Because of this no-effect determination, consultation under Section 7(a)(2) of the Act or the concurrence of the USFWS or NMFS is not required.

7 CONSIDERATION OF EXECUTIVE ORDERS, STANDARDS, AND TREATIES RELATING TO ENVIRONMENTAL IMPACTS

7.1 Executive Orders with Domestic Implications

The following executive orders (EOs) require consideration of the potential impacts of the Federal action to various segments of the population.

EO 12898 (US-NRA, 2014)"Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," requires Federal agencies to conduct their programs, policies, and activities that substantially affect human health or the environment in a manner so as not to exclude persons and populations from participation in or benefiting from such programs. It also enforces existing statutes to prevent minority and low-income communities from being subjected to disproportionately high and adverse human health or environmental impacts.

EO 13045, "Protection of Children from Environmental Health Risks and Safety Risks," acknowledges that children may suffer disproportionately from environmental health and safety risks because of their developmental stage, greater metabolic activity levels, and behavior patterns, as compared to adults. The EO (to the extent permitted by law and consistent with the Agency's mission) requires each Federal agency to identify, assess, and address environmental health risks and safety risks that may disproportionately affect children.

The No Action and Preferred Alternatives were analyzed with respect to EO 12898 and EO 13045. Neither of the alternatives is expected to have a disproportionate adverse impact on minorities, low-income populations, or children.

FDA completed new protein and biotechnology consultations with Dow on DAS-81910-7 cotton (US-FDA, 2014a). As part of the evaluations for this event, FDA reviewed the safety and nutritional assessments submitted by Dow concluding that food and feed derived from DAS-81910-7 cotton are not materially different in composition, safety, and other relevant parameters from cotton and cotton-derived food and feed currently on the market.

Dow conducted compositional analyses to establish the nutritional adequacy of cottonseed-derived products from DAS-81910-7 cotton in comparison to conventional counterparts. The studies compared data on key nutrients, secondary metabolites, and antinutrients for DAS-81910-7 cotton cottonseed samples and the conventional variety controls. According to Dow, the measured parameters were within the combined literature range for cottonseed and the comparisons indicated no biologically meaningful differences for food and feed safety and nutrition (US-FDA, 2014a).

Both AAD-12 and PAT proteins were investigated for their potential to be a toxin or allergen. Bioinformatics studies confirmed the absence of any biologically statistically significant amino acid sequence similarity to known protein toxins or allergens. No meaningful homologies to known or reputed allergens or toxins were identified. Digestibility studies demonstrated that these proteins would be rapidly degraded following ingestion, similar to other dietary proteins. Enzymatic activity of the AAD-1 and AAD-12 proteins was shown to be eliminated under all heating conditions (US-FDA, 2014a).

Acute oral mouse toxicity studies were performed for the AAD-1 and AAD-12 proteins, as ingestion represents the most likely route of human exposure to these proteins. No clinical signs of toxicity were observed in any of the test animals.

Dow indicated in their submission to FDA that the AAD-1 and AAD-12 proteins in DAS-81910-7 cotton was shown to be equivalent to that produced in other transgenic crops and previous assessments have shown it is non-toxic to mammals and does not exhibit any potential to be allergenic to humans. A biotechnology consultation on cotton lines containing the PAT protein was completed on June 5, 2003 (US-FDA, 2003b) and also was evaluated as part of the consultation on DAS-81910-7 cotton completed in 2014 (US-FDA, 2014a). EPA has previously reviewed data on the acute toxicity and digestibility of the PAT protein and concluded that there is a reasonable certainty that no harm will result from aggregate exposure to the U.S. population, including infants and children, to the PAT protein (US-EPA, 1997a).

Based on the information submitted by the applicant and reviewed by APHIS, DAS-81910-7 cotton is agronomically, phenotypically, and biochemically comparable to conventional cotton and cotton grown, marketed, and consumed except for the inserted proteins. The results of available mammalian toxicity studies associated with the AAD-12 and PAT proteins establish the safety of DAS-81910-7 cotton, and associated products to humans, including minorities, low-income populations, and children who might be exposed to them through agricultural production and/or processing. No additional safety precautions would need to be taken with nonregulated DAS-81910-7 cotton. Based on these factors, a determination of nonregulated status of DAS-81910-7 cotton is not expected to have a disproportionate adverse impact on minorities, low-income populations, or children.

Agricultural workers, which may include children, minorities, and low-income populations, could come into contact with the deregulated DAS-81910-7 cotton being grown. Common agricultural practices that would be used with the DAS-81910-7 cotton are no different than those utilized on current conventional and GE crops. If EPA approves the additional new uses of 2,4-D on DAS-81910-7 cotton, 2,4-D use patterns on this cotton variety would be different than is currently allowed. As a result, the use of 2,4-D is expected to increase.

Currently, the EPA is proposing to revise the existing Worker Protection Standard (WPS) at 40 CFR part 170 to reduce the incidence of occupational pesticide exposure and related illness among agricultural workers (workers) and pesticide handlers (handlers) covered by the rule. EPA is proposing to strengthen the protections provided to agricultural workers and handlers under the WPS by improving elements of the existing regulation, such as training, notification, communication materials, use of personal protective equipment, and decontamination supplies. The EPA expects the revisions, once final, to prevent unreasonable adverse effects from exposure to pesticides among agricultural workers and pesticide handlers; vulnerable groups, such as minority and low-income populations, child farmworkers, and farmworker families; and the general public. This regulation, in combination with other components of EPA's pesticide regulatory program, is intended to prevent unreasonable adverse effects of pesticides among pesticide applicators, workers, handlers, the general public, and vulnerable groups, such as minority and low-income populations.

Further, the increased cost of seed for HR crops, such as DAS-81910-7 cotton, relative to conventional seeds is not a barrier to low income producers, since net returns for HR corn were in the aggregate no different (Fernandez-Cornejo et al., 2014b). Regardless of seed premiums charged for GE seeds, such as DAS-81910-7 cotton, growers select GE HR seeds because they are associated with certain conveniences in the production of the crop, such simplifying herbicide practices and gaining ability to spray herbicides at different times in the developmental stages of the crop.

The following executive order addresses Federal responsibilities regarding the introduction and effects of invasive species:

EO 1311 (US-NARA, 2010), "Invasive Species," states that Federal agencies take action to prevent the introduction of invasive species, to provide for their control, and to minimize the economic, ecological, and human health impacts that invasive species cause.

Cotton is not listed in the United States as a noxious weed specie by the Federal government (USDA-NRCS, 2010c), nor is these crop listed as invasive species by major invasive plant data bases (GRN, 2012; University of Georgia and USDOI-NPS, 2009).

While pollen-mediated gene transfer can occur, there are no differences in the potential for gene flow and weediness from conventional or other GE varieties. Outcrossing and weediness are addressed in the PPRA (USDA-APHIS, 2014f) and DAS-81910-7 cotton is similar to other HR-cotton or HR-cotton varieties. The risk of gene flow and weediness of DAS-81910-7 cotton is no greater than that of other nonregulated, HR cotton or cotton varieties.

The following executive order requires the protection of migratory bird populations:

EO 13186 (US-NARA, 2010), "Responsibilities of Federal Agencies to Protect Migratory Birds," states that federal agencies taking actions that have, or are likely to have, a measurable negative impacts on migratory bird populations are directed to develop and implement, within two years, a Memorandum of Understanding (MOU) with the Fish and Wildlife Service that shall promote the conservation of migratory bird populations.

Data submitted by the applicant has shown no substantial difference in compositional and nutritional quality of DAS-81910-7compared with other GE or non-GE cotton, apart from the presence of the AAD-12 protein. Similarly, except for the presence of the inserted proteins, DAS-81910-7 cotton has been found to be compositionally and nutritionally comparable to other GE or non-GE cotton varieties. Additionally, the PAT protein has been cultivated in a wide variety of commercial cotton strains since 1995. The migratory birds that forage in cotton fields are unlikely to be affected adversely by ingesting DAS-81910-7 cotton and associated products.

EPA considers the toxicity of pesticides to birds in its pesticide registration and registration reviews.

7.2 International Implications

EO 12114 (US-NARA, 2010), "Environmental Effects Abroad of Major Federal Actions" requires federal officials to take into consideration any potential environmental impacts outside the United States, its territories, and possessions that result from actions being taken.

APHIS has given this EO careful consideration and does not expect any major environmental impact outside the United States in the event of a determination of nonregulated status of DAS-81910-7 cotton. All existing national and international regulatory authorities and phytosanitary regimes that currently apply to introductions of new cotton and cotton cultivars internationally apply equally to those covered by an APHIS determination of nonregulated status under 7 CFR part 340.

Any international trade of DAS-81910-7 cotton subsequent to a determination of nonregulated status of the product would be fully subject to national phytosanitary requirements and be in accordance with phytosanitary standards developed under the International Plant Protection Convention (IPPC, 2010). The purpose of the IPPC "is to secure a common and effective action to prevent the spread and introduction of pests of plants and plant products and to promote appropriate measures for their control" (IPPC, 2010). The protection it affords extends to natural flora and plant products and includes both direct and indirect damage by pests, including weeds.

The IPPC establishes a standard for the reciprocal acceptance of phytosanitary certification among the nations that have signed or acceded to the Convention (172 countries as of March 2010). In April 2004, a standard for pest risk analysis of living modified organisms (LMOs) was adopted at a meeting of the governing body of the IPPC as a supplement to an existing standard, International Standard for Phytosanitary Measures No. 11 (ISPM-11, Pest Risk Analysis for Quarantine Pests). The standard acknowledges that all LMOs will not present a pest risk and that a determination needs to be made early in the pest risk analysis for importation as to whether the LMO poses a potential pest risk resulting from the genetic modification. APHIS pest risk assessment procedures for GE organisms are consistent with the guidance developed under the IPPC. In addition, issues that may relate to commercialization and transboundary movement of particular agricultural commodities produced through biotechnology are being addressed in other international forums and through national regulations.

The *Cartagena Protocol on Biosafety* is a treaty under the United Nations Convention on Biological Diversity that established a framework for the safe transboundary movement, with respect to the environment and biodiversity, of LMOs, which include those modified through biotechnology. The Protocol came into force on September 11, 2003, and 160 countries are Parties to it as of December 2010 (CBD, 2010). Although the U.S. is not a party to the Convention on Biological Diversity, and thus not a party to the Cartagena Protocol on Biosafety, U.S. exporters will still need to comply with those regulations that importing countries which are Parties to the Protocol have promulgated to comply with their obligations. The first intentional transboundary movement of LMOs intended for environmental release (field trials or commercial planting) will require consent from the importing country under an advanced informed agreement (AIA) provision, which includes a requirement for a risk assessment consistent with Annex III of the Protocol and the required documentation.

LMOs imported for food, feed, or processing are exempt from the AIA procedure and are covered under Article 11 and Annex II of the Protocol. Under Article 11, Parties must post decisions to the Biosafety Clearinghouse database on domestic use of LMOs for food, feed, or processing that may be subject to transboundary movement. To facilitate compliance with obligations to this protocol, the U.S. Government has developed a website that provides the status of all regulatory reviews completed for different uses of bioengineered products (NBII, 2010). These data will be available to the CropLife website's Biotrade Status database (http://www.biotradestatus.com).

APHIS continues to work toward harmonization of biosafety and biotechnology consensus documents, guidelines, and regulations, within the North American Plant Protection Organization (NAPPO), which includes Mexico, Canada, and the U.S., and within the OECD. NAPPO has completed three modules of the Regional Standards for Phytosanitary Measures (RSPM) No. 14, *Importation and Release into the Environment of Transgenic Plants in NAPPO Member Countries* (NAPPO, 2009).

APHIS also participates in the *North American Biotechnology Initiative (NABI)*, a forum for information exchange and cooperation on agricultural biotechnology issues for the U.S., Mexico, and Canada. In addition, bilateral discussions on biotechnology regulatory issues are held regularly with other countries including Argentina, Brazil, Japan, China, and Korea.

7.3 Compliance with Clean Water Act and Clean Air Act

This EA evaluated the potential changes in cotton and cotton production associated with approving the petition for a determination of nonregulated status to DAS-81910-7 cotton and determined that the cultivation of DAS-81910-7 cotton would not lead to the increase in or expand the area of cotton and cotton production that could impact water resources or air quality any differently than currently cultivated cotton and cotton varieties. The herbicide resistance conferred by the genetic modification of DAS-81910-7 cotton is not expected to result in any changes in water usage for cultivation compared to current cotton and cotton production. Based on these analyses, APHIS concludes that an extension of a determination of nonregulated status to DAS-81910-7 cotton would comply with the Clean Water Act and the Clean Air Act.

7.4 Impacts on Unique Characteristics of Geographic Areas

Approving the petition for a determination of nonregulated status to DAS-81910-7 cotton is not expected to impact unique characteristics of geographic areas such as parklands, prime farmlands, wetlands, wild and scenic areas, or ecologically critical areas.

Dow has presented results of agronomic field trials for DAS-81910-7 cotton that demonstrate there are no differences in agronomic practices between DAS-81910-7 and currently available HR-cotton varieties. The common agricultural practices that would be carried out in the cultivation of DAS-81910-7 cotton are not expected to deviate from current practices. The product is expected to be cultivated by growers on agricultural land currently suitable for production of cotton and is not anticipated to expand the cultivation of cotton to new, natural areas.

The Preferred Alternative for DAS-81910-7 cotton does not propose major ground disturbances or new physical destruction or damage to property, or any alterations of property, wildlife habitat, or landscapes. Likewise, no prescribed sale, lease, or transfer of ownership of any property is expected as a direct result of a determination of nonregulated status for DAS-81910-7 cotton. This action would not convert land use to nonagricultural use and, therefore, would have no adverse impact on prime farmland. Standard agricultural practices for land preparation, planting, irrigation, and harvesting of plants would be used on agricultural lands planted to DAS-81910-7 cotton, including the use of EPA-registered pesticides.

APHIS assumes that EPA's pesticide label use restrictions for the DAS-81910-7 cotton will protect agricultural ecology and geographic areas surrounding farms. Furthermore, it is assumed that those label use restrictions will be adhered to by growers. Based on APHIS conclusions, approving the petition for a determination of nonregulated status to DAS-81910-7 cotton is not expected to impact unique characteristics of geographic areas such as park lands, prime farm lands, wetlands, wild and scenic areas, or ecologically critical areas any differently than cotton varieties already in commercial agriculture.

7.5 National Historic Preservation Act (NHPA) of 1966 as Amended

National Historic Preservation Act (NHPA; Public Law 89-665; 16 U.S.C. 470 et seq.) designates federal agencies that are proposing federally funded or permitted projects on historic properties (buildings, archaeological sites, etc.) to consider the impacts using the required Section 106 Review process.

The NHPA of 1966 and its implementing regulations (36 CFR 800) require Federal agencies to: 1) determine whether activities they propose constitute "undertakings" that have the potential to cause impacts on historic properties; 2) if so, to evaluate the impacts of such undertakings on such historic resources and consult with the Advisory Council on Historic Preservation (i.e., State Historic Preservation Office, Tribal Historic Preservation Officers), as appropriate.

A determination of nonregulated status of DAS-81910-7 cotton would have no impact on districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places, nor would they likely cause any loss or destruction of important scientific, cultural, or historic resources. Standard agricultural practices for land preparation, planting, irrigation, and harvesting of plants would be used on these agricultural lands, including the use of EPA-registered pesticides. Adherence to the EPA label use restrictions for pesticides will mitigate impacts to the human environment. In general, common agricultural activities conducted under this action do not have the potential to introduce visual, atmospheric, or audible elements to areas in which they are used that could results in impacts on the character or use of historic properties.

The APHIS proposed action is not an undertaking that may directly or indirectly cause alteration in the character or use of historic properties protected under the NHPA. In general, common agricultural activities conducted under this action do not have the potential to introduce visual, atmospheric, or noise elements to areas in which they are used that could result in impacts on the character or use of historic properties. For example, there is potential for increased noise on the use and enjoyment of a historic property during the operation of tractors and other mechanical equipment close to such sites. A built-in mitigating factor for this issue is that virtually all of the methods involved would only have temporary impacts on the audible nature of a site and can be ended at any time to restore the audible qualities of such sites to their original condition with no further impacts. These cultivation practices are already being conducted throughout the cotton production regions. The cultivation of DAS-81910-7 cotton is not expected to change any of these agronomic practices that could result in an adverse impact under the NHPA.

7.6 Consultation with Tribal Groups

EO 13175, "Consultation and Coordination with Indian Tribal Governments," pledges agency communication and collaboration with tribal officials when proposed Federal actions have potential tribal implications.

A determination of nonregulated status of DAS-81910-7 cotton is not expected to adversely impact cultural resources on tribal properties. Prior to the publication of this EA, APHIS sent a letter to tribal leaders in the continental United States on May 3, 2013. This letter contained information regarding DAS-81910-7 cotton and asked tribal leaders to contact APHIS if they believed that there were potentially significant impacts to tribal lands or resources that should be considered. No responses were received by APHIS from tribal leaders regarding DAS-81910-7 cotton. Any farming activities by farmers on tribal lands are only conducted at a tribe's request; thus, tribes have control over any potential conflict with cultural resources on tribal properties. Thus, the tribes would have control over any potential conflict with cultural resources on tribal properties. The proposed action, a determination of nonregulated status of DAS-81910-7 cotton, is not expected to adversely impact cultural resources on tribal properties.

8 BIBLIOGRAPHY

Phosphinothricin Acetyltransferase and the Genetic Material Necessary for Its Production in All Plants; Exemption From the Requirement of a Tolerance On All Raw Agricultural Commodities. 40 CFR part 180.

180.1151 - Phosphinothricin Acetyltransferase (PAT) and the genetic material necessary for its production all plants; exemption from the requirement of a tolerance. 40 CFR Part 180. http://www.gpo.gov/fdsys/pkg/CFR-2005-title40-vol23/xml/CFR-2005-title40-vol23-sec180-1151.xml.

Adler, P., S. Del Grosso, and W. Parton. 2007. Life-cycle assessment of net greenhouse-gas flux for bioenergy cropping systems. *Ecological Applications*. 17:675-691.

AgWatch. 2011. Cotton growers look at late-season burndown options. AgWatch Network. http://www.agwatchnetwork.com/newsView.cfm/uuid/03358CBB-9B9F-47AC-B8172EF5AA0426F2

Albers, D.W., and D.L. Reinbott. 1994. Cotton tillage and planting guidelines. University of Missouri Extension. http://extension.missouri.edu/p/G4270

Altieri, M.A. 1999. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems & Environment*. 74:19-31.

Ammann, K. 2005. Effects of biotechnology on biodiversity: herbicide-tolerant and insect-resistant GM crops. *TRENDS in Biotechnology*. 23:388-394.

Aneja, V.P., W.H. Schlesinger, and J.W. Erisman. 2009. Effects of agriculture upon the air quality and climate: Research, policy, and regulations. *Environmental Science and Technology*. 43:4234-4240.

AOCS. 2009. Cellulose yield pressure-cook method. *In* Method Bb 3-47. American Oil Chemists' Society, Champaign, Illinois

Arbuckle, J., J.G. , and P. Lasley. Iowa Farm and Rural Life Poll.   2013 Summary Report. https://store.extension.iastate.edu/Product/Iowa-Farm-and-Rural-Life-Poll-2013-Summary-Report.

Arle, F., and H.C. Hamilton. 1973. Hith population Cotton flat plant - 16 inch rows.

Ashigh, J., M. Mosheni-Moghadam, J. Idowu, and C. Hamilton. 2012. Weed Management in Cotton.

Aumaitre, A., K. Aulrich, A. Chesson, G. Flachowsky, and G. Piva. 2002. New feeds from genetically modified plants: substantial equivalence, nutritional equivalence, digestibility, and safety for animals and the food chain. *Livestock Production Science*. 74:223-238.

Babu, K., M. Selvadass, and R. Somaskekar. 2013. Characterization of the Conventional and Organic Cotton Fibres. *The Journal of the Textile Institute*. 104:1101-1112.

Baker, H. 1965. Characteristics and modes of origins of weeds *In* The Genetics of Colonizing Species. Acedemic Press, London. 147-168.

Baker, J.B., R.J. Southard, and J.P. Mitchell. 2005. Agricultural dust production in standard and conservation tillage systems in the San Joaquin Valley. *Journal of Environment Quality*. 34:1260-1269.

Bates, D.M. 1990. Malvaceae: Mallow family: Manual of the flowering plants of Hawaii. *In* Manual of the Flowering Plants of Hawai'i. University of Hawai'i Press, Honolulu, Hawai'i. 868-903.

Beckie, H.J. 2006. Herbicide-resistant weeds: Management tactics and practices. *Weed Technology*. 20:793-814.

Beckie, H.J., and L.M. Hall. 2014. Genetically-modified herbicide-resistant (GMHR) crops a two-edged sword? An Americas perspective on development and effect on weed management. *Crop Protection*. 66:40-45.

Beckie, H.J., and M.D.K. Owen. 2007. Herbicide-resistant crops as weeds in North America. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*. 2.

Beckie, H.J., and X. Reboud. 2009. Selecting for weed resistance: Herbicide rotation and mixture. *Weed Technology*. 23:363-370.

Benedict, J.H., K.M. El-Zik, L.R. Oliver, P.A. Roberts, and L.T. Wilson. 1989. Economic injury levels and thresholds for pests of cotton. *In* Integrated pest management systems and cotton production. R.E. Frisbie, K.M. El-Zik, and L.T. Wilson, editors. John Wiley and Sons, Inc., New York. 437.

Berglund, D.R., and T.C. Helms. 2003. Soybean Production. North Dakota Extension Service, Fargo. 12.

Blasi, D.A., and J. Drouillard. 2002. Composition and feeding value of cottonseed feed products for beef cattle. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan, Kansas

Bohmfalk, G.T., R.E. Frisbie, W.L. Sterling, R.B. Metzer, and A.E. Knutson. 2011. Identification, Biology and Sampling of Cotton Insects Texas AgriLife Extension Service http://www.soilcropandmore.info/crops/CottonInformation/insect/B-933/b-933.htm.

Boyd, M.L., B.J. Phipps, and J.A. Wrather. 2004. Integrated Pest Management: Cotton Pests Scouting and Management. Missouri University Extension. http://ipm.missouri.edu/ipm_pubs/ipm1025.pdf. February 24, 2014.

Brookes, G., and P. Barfoot. 2012. Global impact of biotech crops: Environmental effects, 1996–2010. *GM Crops and Food: Biotechnology in Agriculture and the Food Chain*. 3:129-137.

Brouwer, C., and M. Heibloem. 1986. Irrigation Water Management: Irrigation Water Needs. FAO

Brown, C., D.A. Neuendorff, T.A. Strauch, A.W. Lewis, M.L. Wade, R.D. Randel, B.C. Baldwin, and M.C. Calhoun. 2002. Consumption of Whole Cottonseed and Easiflo™ Cottonseed Affect Growth in Red Deer Stags. Texas A&M University. http://articlesearchdatabase.tamu.edu/tmppdfs/viewpdf_171_15607.pdf?CFID=8846169&CFTOKEN=c2a5e52163e05456-9EB710F4-01BE-CF23-86A04F804A5BC6C4&jsessionid=a030bf41bc30acc06ae5202a2a6449395d62. March 27, 2014.

Brubaker CL, JA Koontz, and J. Wendell. 1993. Bidirectional Cytoplasmic and Nuclear Introgression in the New World Cottons, Gossypium barbadense and G. hirsutum (Malvaceae). . *American Journal of Botany*. 80:1203-1208.

Buckley, D.H., and T.M. Schmidt. 2001. The structure of microbial communities in soil and the lasting impact of cultivation. *Microbial Ecology*. 42:11-21.

Buckley, D.H., and T.M. Schmidt. 2003. Diversity and dynamics of microbial communities in soils from agro-ecosystems. *Environmental Microbiology*. 5:441-452.

Bullock, S., D.G. Hewitt, R.L. Stanko, M.K. Dowd, J. Rutledge, and D.A. Draeger. 2010. Plasma gossypol dynamics in white-tailed deer: Implications for whole cottonseed as a supplemental feed. *Small Ruminant Research*. 93:165-170.

Bunge, J. 2014. EPA Denies Texas Emergency Weedkiller Request. http://www.wsj.com/articles/epa-denies-texas-emergency-weedkiller-request-1406053913.

Burgos, N., S. Culpepper, P. Dotray, J.A. Kendig, J. Wilcut, and R. Nichols. 2006. Managing Herbicide Resistance in Cotton Cropping Systems. Cotton Incorporated. http://cotton.tamu.edu/Weeds/ManagingHerbicideResistance.pdf.

Butcher, G.S., D.K. Niven, and T. Present. 2007. Status and Trends of Waterbirds in High-Intensity Agricultural Areas of the United States. *Technical Report of the National Audubon Society*:52.

Cahoon, C.W., A.C. York, D.L. Jordan, W.J. Everman, and R.W. Seagroves. 2014. An Alternative to Multiple Protoporphyrinogen Oxidase Inhibitor Applications in No-Till Cotton. *Weed Technology*. 28:58-71.

Calhoun, M.C. 2011. Cottonseed meal and whole cottonseed: Optimizing their use in dairy cattle rations. Texas Agricultural Experiment Station, Texas A&M University System, San Angelo, Texas

Cambra-Lopez, M., A.J.A. Aarmoml, Y. Zhao, and S. Calvert. 2010. Airborne particulate matter from livestock production systems: A review of an air pollution problem. *Environmental Pollution*. 158:1-17.

Cao, J., J.-P. Blond, and J. Bézard. 1993. Inhibition of fatty acid Δ^6- and Δ^5-desaturation by cyclopropene fatty acids in rat liver microsomes. *Biochimica et Biophysica Acta*. 1210:27-34.

Carpenter, J. 2011a. Impact of GM Crops on Biodiversity. *GM Crops*. 2:7-23.

Carpenter, J.E. 2011b. Impacts of GM Crops on Biodiversity. *ISB News Report*.

CAST. 2009. U.S. Soybean Production: A Comparison of Sustainable Production Systems for Conventional, Biotech, and Organic Soybeans. Council for Agricultural Science and Technology. http://www.soyconnection.com/pdf/9001_USB_CAST_V1r1May11.pdf

Catchot, A., B. Layton, and S.D. Stewart. 2008. Common Beneficial Arthropods Found in Field Crops. *Mississippi State Univeristy Extention*.

CBD. 2010. The Cartegena Protocol on Biosafety Convention on Biological Diversity. http://www.cbd.int/biosafety/

CDC. 2013. NIOSH pocket guide to chemical hazards. Appendix C - Supplementary exposure limits. http://www.cdc.gov/niosh/npg/nengapdxc.html. internal-pdf://0701464761/CDC 2013 pocket guide chem hazards.pdf. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

Chan, B., A. Waiss Jr., R. Binder, and C. Elliger. 1978. Inhibition of lepidopterous larval growth by cotton constituents. *Entomologia Experimentalis et Applicata* 24:294-300.

Charles, G., G. Roberts, S. Kerlin, and M. Hickman. 2013. CONTROLLING VOLUNTEER COTTON.

Cherry, J.P. 1983. Cottonseed oil. *Journal of the American Oil Chemists' Society*. 60:360-367.

Clemson-University-Extension. 2012. 2012 HERBICIDE PROGRAMS FOR WEED CONTROL IN COTTON. Mike Marshall, Extension Weed Specialist. http://www.clemson.edu/extension/county/hampton/programs/row_crops/Cotton/mikemarshall.pdf.

Coble, H.D., and J.D. Byrd. 1992. Chapter 4: Interference of Weeds With Cotton. *In* WEEDS OF COTTON: Characterization and Control. C.G. McWhorter and J.R. Abernathy, editors. Cotton Foundation 631.

Coile, N., and Garland. 2003. Notes on Florida's Endangered and Threatened Plants. Florida Department of Agriculture and Consumer Services. http://www.virtualherbarium.org/EPAC/Notes2003.pdf. November 5, 2012.

Cook, E., P. Bartlein, N. Diffenbaugh, R. Seager, B. Shuman, R. Webb, J. Williams, and C. Woodhouse. 2008. Hydrological Variability and Change. The U.S. Climate Change Science Program

Cotton-Inc. 2014. Cottonseed Production Projected Up, with Strong Prices. Whole cottonseed packs a triple punch of fiber, protein and energy. Cottonseed News. http://www.wholecottonseed.com/news/2014/05/28/cottonseed-production-projected-up-with-strong-prices/.

Crockett, L.J. 1977. Wildly Successful Plants: A Handbook of North American Weeds. University of Hawaii Press, Honolulu. 609 pp.

Culpepper, A., T. Grey, W. Vencill, J. Kichler, T. Webster, S. Brown, A. York, J. Davis, and W. Hanna. 2006. Glyphosate-resistant Palmer (*Amaranthus palmeri*) confirmed in Georgia. *Weed Technology*. 54:620-626.

Culpepper, A.S., J. Kichler, and A.C. York. 2014. UGA Programs for Controlling Glyphosate-Resistant Palmer Amaranth in 2014 Cotton. Cooperative Extension. The University of Georgia College of Agricultural and Environmental Sciences. http://www.gaweed.com/HomepageFiles/2014Palmerhandout-finaljan2.pdf.

Culpepper, A.S., J.R. Whitaker, A.W. MacRae, and A.C. York. 2008. Distribution of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) in Georgia and North Carolina during 2005 and 2006. *Journal of Cotton Science*. 12:306-310.

Culpepper, A.S., A.C. York, and L.E. Steckel. 2011. Glyphosate-resistant Palmer amaranth management in cotton. San Juan, Puerto Rico.

DAS. 2010a. Petition for Determination of Nonregulated Status for Herbicide Tolerant DAS-40278-9 Corn. Company Full Na me. 212. R.L. L. Tagliani, Regulatory Sciences & Government Affairs.

DAS. 2010b. Petition for Determination of Nonregulated Status for Herbicide Tolerant DAS-68416-4 Soybean. Company Full Na me. 1150. S.K. Mark.

DAS. 2011. Petition for Determination of Nonregulated Status for Herbicide Tolerant DAS-44406-6 Soybean. USDA APHIS petition number 11-234-01p. Company Full Na me. 1068.

DAS. 2012. Dow AgroSciences comments to docket APHIS-2012-0012. Re: Preliminary Plant Pest Risk Assessment and Draft Environmental Assessment for Determination of Nonregulated Status of DAS-68416-4 Soybean Genetically Engineered for Herbicide Tolerance (DAS Comment Part 1 of 3). Dow AgroSciences LLC.

DAS. 2013a. Dow AgroSciences, Monsanto Cross-License Advanced Corn Trait Technology, Designed to Provide Exceptional New Tools for Weed and Insect Management. http://newsroom.dowagro.com/press-release/dow-agrosciences-monsanto-cross-license-advanced-corn-trait-technology-designed-provid.

DAS. 2013b. Petition for Determination of Nonregulated Status for Herbicide Tolerant DAS-8191Ø-7 Cotton. OECD Unique Identifier: DAS-8191Ø-7. Company Full Na me. 215. G. Rudgers.

DAS. 2014. Estimate of Possible Herbicide Increase upon Introduction of DAS-8191Ø-7 Cotton Dow AgroSciences.

DAS. 2015. Personal Communication.

Del Grosso, S., D. Ojima, W. Parton, A. Mosier, G. Peterson, and D. Schimel. 2002. Simulated effects of dryland cropping intensification on soil organic matter and greenhouse gas exchanges using the DAYCENT ecosystem model. *Environmental Pollution*. 116:S75-S83.

DeYoung, C. 2005. Feeding Cottonseed to Deer. *Inside Deer Research*. 2:4.

Diggle, A.J., P.B. Neve, and F.P. Smith. 2003. Herbicides used in combination can reduce the probability of herbicide resistance in finite weed populations. *Weed Research*. 43:371-382.

Dill, G.M., C. CaJacob, and S. Padgette. 2008. Glyphosate-resistant crops: Adoption, use and future considerations. *Pest Management Science*. 64:326-331.

Dively, G.P., and R. R. 2003. Effects of Bt Transgenic and Conventional Insecticide Control on the Non-Target Natural Enemy Communtiy in Sweet Corn. Presented at 1st International Symposium on Biological Control of Arthropods.

Donegan, K.K., and R.J. Seidler. 1999. Effects of Transgenic Plants on Soil and Plant Microorganisms. US Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Western Ecology Division., Oregon. 415-424 pp.

Doran, J.W., M. Sarrantonio, and M.A. Liebig. 1996. Soil Health and Sustainability. 56:1-54.

Dotray, P., and W. Keeling. 2014. Cotton Weed Management on the Texas Southern High Plains. Preplant Burndown Options Texas A&M AgriLife Extension. http://agrilife.org/yoakumterryipm/?p=691.

Duffy, M. 2011. Estimated Cost of Crop Production in Iowa-2011. Iowa State University http://www.extension.iastate.edu/agdm/crops/pdf/a1-20.pdf.

Duke, S. 2005. Taking stock of herbicide-resistant crops ten years after introduction. *Pest Management Science*. 61:211-218.

Duke, S.O., and S.B. Powles. 2008. Glyphosate: A once-in-a-century herbicide. *Pest Management Science*. 64:319-325.

Duke, S.O., and S.B. Powles. 2009. Glyphosate-resistant crops and weeds: Now and in the future. *AgBioForum*. 12:346-357.

Durgan, B.R., and J.L. Gunsolus. 2003. Developing Weed Management Strategies that Address Weed Species Shifts and Herbicide Resistant Weeds. Department of Agronomy and Plant Genetics University of Minnesota. http://appliedweeds.cfans.umn.edu/pubs/03pub01.pdf.

Edwards, R., D. Reynolds, J. Bond, and D. Dodds. 2013. Glyphosate-resistant Palmer amaranth control in cotton with the Enlist weed control system. http://www.swss.ws/wp-content/uploads/2013/09/Proceedings-of-the-2013-Southern-Weed-Science-Society-Meeting-revised.pdf.

Egan, J.F., K.M. Barlow, and D.A. Mortensen. 2014a. A Meta-Analysis on the Effects of 2,4-D and Dicamba Drift on Soybean and Cotton. *Weed Science*. 62:193-206.

Egan, J.F., E. Bohnenblust, S. Goslee, Mortensen, D., , and J. Tooker. 2014b. Herbicide drift can affect plant and arthropod communities *Ecosystems and Environment* 185:77-87.

El-Zik, K.M., D.W. Grimes, and P.M. Thaxton. 1989. Cultural Management and Pest Suppression. John Wiley and Sons, Inc., New York.

Ellington, J.J., T. Carrillo, J. McCauley, D. McWilliams, J. Lillywhite, J. Pierce, and J. Drake. 2007. Precision Cotton Production. New Mexico State University Cooperative Extension. http://aces.nmsu.edu/pubs/_circulars/CR-629.pdf.

Ely, L., and L. Guthrie. 2012. Feeding Whole Cottonseed to Dairy Cows and Replacements. University of Georgia, College of Agriculture and Environmental Services. http://www.caes.uga.edu/publications/pubDetail.cfm?pk_id=7752

EOP-OSTP. 1986. Coordinated Framework for Regulation of Biotechnology. *51 Federal Register 23302, June 26, 2006*:Executive Office of the President, Office of Science and Technology Policy.

European Commission. 2010. A Decade of EU-Funded GMO Research (2001-2010), Luxembourg. 268.

Evett, S.R., R.L. Baumhardt, T.A. Howell, N.M. Ibragimov, and D.J. Hunsaker. 2011. Cotton.

FAO. 2009. Codex Alimentarius, Foods Derived from Modern Biotechnology, 2nd Edition. World Health Organization, Food and Agriculture Organization of the United Nations, Rome. 85 pp.

Farm-Industry-News. 2013. Glyphosate-resistant weed problem extends to more species, more farms. http://farmindustrynews.com/ag-technology-solution-center/glyphosate-resistant-weed-problem-extends-more-species-more-farms.

Farnham, D. 2001. Corn Planting. Cooperative Extension Service, Iowa State University of Science and Technology. http://www.extension.iastate.edu/publications/pm1885.pdf. April 6, 2011.

Faust, M.A. 2002. New feeds from genetically modified plants: The US approach to safety for animals and the food chain. *Livestock Production Science*. 74:239-254.

Felsot, A.S. 2005. Evaluation and mitigation of spray drift. Proceedings of the International Workshop on Crop Protection Chemistry in Latin America. San Jose, Coasta Rica. http://feql.wsu.edu/esrp531/fall05/felsotcostaricadrift.pdf. March 11, 2014.

Feng, P.C.C., and R.J. Brinker. 2010. Methods for weed control using plants having dicamba-degrading enzymatic activity. US 7,855,326 B2. http://www.google.com/patents/US7855326.

Fernandez-Cornejo, J., R. Nehring, C. Osteen, S.J. Wechsler, A. Martin, and A. Vialou. 2014a. Pesticide Use in U.S. Agriculture: 21 Selected Crops, 1960-2008. E.R.S. U.S. Department of Agriculture. http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib124.aspx.

Fernandez-Cornejo, J., S.J. Wechsler, M. Livingston, and L. Mitchell. 2014b. Genetically Engineered Crops in the United States. USDA-ERS. February Economic Research Report No. (ERR-162) 60 pp. http://www.ers.usda.gov/publications/err-economic-research-report/err162.aspx. Economic Research Service.

Field to Market. 2012. Environmental and Socioeconomic Indicators for Measuring Outcomes of On-Farm Agricultural Production in the United States: Second Report. http://www.fieldtomarket.org/report/national-2/PNT_NatReport_A30.pdf

Fishel, F.M., and J.A. Ferrell. 2010. Managing Pesticide Drift University of Florida IFAS Extension. https://edis.ifas.ufl.edu/pi232.

Fleskes, J.P., R.L. Jarvis, and D.S. Gilmer. 2003. Selection of flooded agricultural fields and other landscapes by female northern pintails wintering in Tulare Basin, California. *Wildlife Society Bulletin*. 31:793-803.

FOCUS. 2008. Pesticides in Air: Considerations for Exposure Assessment. European Commission Forum for Coordination of Pesticide Fate Models and Their Use Working Group on Pesticides in Air. http://focus.jrc.ec.europa.eu/ai/docs/FOCUS_AIR_GROUP_REPORT-FINAL.pdf.

Frans, R.E., and J.M. Chandler. 1989. Strategies and tactics for weed management. *In* Integrated pest management systems and cotton production. R.E. Frisbie, K.M. El-Zik, and L.T. Wilson, editors. John Wiley and Sons, Inc, New York. 437.

Frisvold, G.B., T.M. Hurley, and P.D. Mitchell. 2009. Adoption of best management practices to control weed resistance by corn, cotton, and soybean growers. *AgBioForum*. 12:370-381.

Fromme, D., G. Morgan, P. Baumann, B. Bean, and J. Grichar. 2011. Control of Volunteer Cotton in Corn. Texas Agrilife Extension Service. http://agrilifecdn.tamu.edu/coastalbend/files/2011/09/10finalcornboardreport.pdf.

Fryxell , P.A. 1984. Taxonomy and Germplasm Resources. *In* In: RJ Kohel and CF Lewis (Eds) Cotton, Agronomy Monograph 24. ASA-CSSA-SSA, Madison, WI. 27-57.

FSANZ. 2014. Food derived from Herbicide-tolerant Cotton Line DAS-81910-7. F.S.A.N.Z. (FSANZ). internal-pdf://1844004951/FSANZ-2014.docx.

Funtanilla, M., C. Lyford, and C. Wang. 2009. An Evaluation of the Organic Cotton Marketing Opportunity. Agricultural and Applied Economics Association's 2009 AAEA and ACCI Joint Annual Meeting. Milwaukee, WI. http://ageconsearch.umn.edu/bitstream/49359/2/2009%20aaea%20paper%2004-30-09.pdf.

Gadberry, S. 2011. Alternative feeds for beef cattle. Vol. FSA3047. University of Arkansas Division of Agriculture, Little Rock, Arkansas

Garbeva, P., J.A. van Veen, and J.D. van Elsas. 2004. Microbial diversity in soil: Selection of microbial populations by plant and soil type and implications for disease suppressiveness. *Annual Review of Phytopathology*. 42:243-270.

Genito, D., W.J. Gburek, and A.N. Sharpley. 2002. Response of stream macrionvertebrates to agricultural land cover in a small watershed. *Freshwater Ecology*. 17:109-119.

Gianesi, L.P., and J.E. Carpenter. 1999. Agricultural Biotechnology: Insect Control Benefits. National Center for Food and Agricultural Policy. http://www.iatp.org/files/Agricultural_Biotechnology_Insect_Control_Bene.htm.

Gibbs, M., R. Dufour, and M. Guerena. 2005. BASIC Cotton Manual. Practical Lessons Learned from the Sustainable Cotton Project's Biological Agriculture Systems in Cotton (BASIC) Program. Sustainable Cotton Project.

Givens, W.A., D.R. Shaw, W.G. Johnson, S.C. Weller, B. Young, R. Wilson, M.D.K. Owen, and D.L. Jordan. 2009. A grower survey of herbicide use patterns in glyphosate-resistant cropping systems. *Weed Technology*. 23:156-161.

Grace, J.K. 2012. A. Pearson. November 20, 2012.

Green, J.D., and J.R. Martin. 1996. Dealing with Perennial Broadleaf Weeds in Conservation Tillage Systems. http://www.ag.auburn.edu/auxiliary/nsdl/scasc/Proceedings/1996/Green.pdf.

Greenberg, S.M., A.N. Sparks, J.W. Norman, R. Coleman, J.M. Bradford, C. Yang, T.W. Sappington, and A. Showler. 2007. Chemical cotton stalk destruction for maintenance of host-free periods for the control of overwintering boll weevil in tropical and subtropical climates. *Pest Management Science*. 63:372-380.

Greene. 2012. Cotton Insect Management *In* South Carolina Pest Management Handbook For Field Crops - 2014.

GRN. 2012. Invasive Species. Global Restoration Network - Society for Ecological Restoration. http://www.globalrestorationnetwork.org/database/cipm-database/

GTR. 2002. The biology and ecology of cotton (Gossypium hirsutum) in Australia. *Office of the Gene Technology Registrar*.

Guerena, M., and P. Sullivan. 2003. Organic cotton production. . *Appropriate Technology Transfer for Rural Areas, National Center for Appropriate Technology, Fayetteville, Arkansas*.

Hake, K.D., D. Blasingame, C. Burmester, P.B. Goodell, and C. Stichler. 1991. Crop Rotation. Physiology Today. *Newsletter of the Cotton Physiology Education Program of the National Cotton Council*. 3:1-4.

Hake, S.J., T.A. Kerby, and K.D. Hake. 1996. Preparation for the new crop season - Fall/winter. *In* Cotton Production Manual. University of California Division of Agriculture and Natural Resources, Davis, California. 6-14.

Hammond, B.G., and J.M. Jez. 2011. Impact of food processing on the safety assessment for proteins introduced into biotechnology-derived soybean and corn crops. *Food Chem Toxicol*. 49:711-721.

Hanson, B. 2012. Off-Site Movement of Herbicides. *University of California, Davis, Dept. of Plant Sciences*.

Hanson, B.D., T.A. Rauch, and D.C. Thill. 2004. Plantback restrictions for herbicides used in the dryland wheat production areas of the Pacific Northwest. *A Pacific Northwest Extension Publication University of Idaho*

Harris, W.D. 1981. Cottonseed. *In* Encyclopedia of Chemical Processing and Design. Marcel Dekker, Inc., New York, New York. 375-391.

Heap, I. 2011. The International Survey of Herbicide Resistant Weeds. WeedScience. http://www.weedscience.org/

Heap, I. 2014a. Herbicide-Resistant Weeds by Site of Action WSSA. http://www.weedscience.com/summary/SOASummary.aspx

Heap, I. 2014b. Herbicide resistant weeds - Synthetic auxins (O/4) resistant weeds. International Survey of Herbicide Resistant Weeds. http://www.weedscience.org/Summary/MOA.aspx?MOAID=24

Heap, I. 2014c. The International Survey of Herbicide Resistant Weeds. Data Base Online Database. www.weedscience.com.

Heap, I. 2014d. International survey of herbicide resistant weeds summary. WeedScience.org, International Survey of Herbicide Resistant Weeds. http://www.weedscience.org/summary/home.aspx

Heap, I. 2015a. Weeds Resistant to EPSP synthase inhibitors (G/) by species and country. International Survey of Herbicide Resistant Weeds. http://www.weedscience.org/Summary/MOA.aspx?MOAID=12.

Heap, I. 2015b. Weeds Resistant to the Herbicide 2,4-D International Survey of Herbicide Resistant Weeds. http://www.weedscience.org/Summary/ResistByActive.aspx.

Heatherly, L., A. Dorrance, R. Hoeft, D. Onstad, J. Orf, P. Porter, S. Spurlock, and B. Young. 2009. Sustainability of U.S. Soybean Production: Conventional, Transgenic, and Organic Production Systems. Council for Agricultural Science and Technology. https://www.cast-science.org/publications/index.cfm?sustainability_of_us_soybean_production&show=product&productID=2947.

Heiniger, R.W. 2000. NC Corn Production Guide - Chapter 4 - Irrigation and Drought Management. The North Carolina Cooperative Extension Service, College of Agriculture and Life Sciences, North Carolina State University. http://www.ces.ncsu.edu/plymouth/cropsci/cornguide/Chapter4.html

Herman, R.A., Fast, B.J., Johnson, T.Y., Sabbatini, J., Rudgers, G.W., . 2013. Compositional safety of herbicide-tolerant DAS-81910‑7 cotton. . *Journal of Agricultural and Food Chemistry.* . 61:11683-11692.

Hernandez-Soriano, M.C., M.D. Mingorance, and A. Pena. 2007. Interaction of pesticides with a surfactant-modified soil interface: Effect of soil properties. *Physicochem. Eng. Aspects*. 306:49-55.

Herouet, C., D. Esdale, B. Maillyon, D. E, S. A, C. T, H. K, R. van der Klis, and R. D. 2005. Safety Evaluation of the phosphinothrin acetyltransferase proteins encoded by the pat and bar sequences that confer tolerance to glufosinate-ammonium herbicide in transgenic plants. *Regulatory Toxicology and Pharmacology*. 41:134-149.

Higgins, R. 1997. Soybean Insects-Soybean Production Handbook. Kansas State University. http://www.ksre.ksu.edu/library/crpsl2/c449.pdf.

Hoeft, R.G., E.D. Nafziger, R.R. Johnson, and S.R. Aldrich. 2000. Modern Corn and Soybean Production. MCSP Publications, Champaign, IL.

Holm LG, JV Pancho, JP Herberger, and D. Plucknett. 1979. A Geographical Atlas of World Weeds. John Wiley and Sons, New York. 391 pp.

Horowitz, J., R. Ebel, and K. Ueda. 2010. “No-Till” Farming Is a Growing Practice. Agriculture. Economic Information Bulletin Number 70. http://www.ers.usda.gov/media/135329/eib70.pdf. internal-pdf://0179083048/Horowitz 2010 USDA ERS No Till Farming.pdf. USDA-ERS.

Horowitz, J., and J. Gottlieb. 2010. The Role of Agriculture in Reducing Greenhouse Gas Emissions. U.S. Department of Agriculture–Economic Research Service. http://www.ers.usda.gov/Publications/EB15/EB15.pdf.

HRAC. 2014. Glossary. Herbicide Resistance Action Committee http://www.hracglobal.com/Education/Glossary.aspx.

Hussain, I., K. Olson, and S. Ebelhar. 1999. Impacts of tillage and no-till on production of maize and soybean on an eroded Illinois silt loam soil. *Soil and Tillage*. 52:37-49.

Iowa State University. 2003. Weeds to watch: New weed threats for corn and soybean fields. Vol. IPM 72. Iowa State University Extension, Ames, Iowa

IPM. 2007. Crop Profile for Corn in the Northern and Central Plains (KS, NE, ND, and SD),.

IPPC. 2010. Official web site for the International Plant Protection Convention: International Phytosanitary Portal International Plant Protection Convention. https://www.ippc.int/IPP/En/default.jsp

Jiang, C.-X., and X.D. PW Chee, PL Morrell, CW Smith, AH Paterson. 2000. Multilocus Interactions Restrict Gene Introgression in Interspecific Populations of Polyploid Gossypium (Cotton). . *Evolution*. 54:798-814.

Johnson, J.M., A.J. Franzluebbers, S.L. Weyers, and D.C. Reicosky. 2007. Agricultural opportunities to mitigate greenhouse gas emissions. *Environ Pollut*. 150:107-124.

Jones, C., and J. Jacobsen. 2003. Micronutrients: Cycling, Testing and Fertilizer Recommendations. Montana State University Extension. http://msuextension.org/publications/AgandNaturalResources/4449/4449_7.pdf. March 7, 2014.

Karl, T., G. Meehl, C. Miller, S. Hassol, A. Waple, and W. Murray. 2008. Weather and Climate Extremes in a Changing Climate - Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. The U.S. Climate Change Science Program. http://www.climatescience.gov/Library/sap/sap3-3/final-report/.

Keeler, K. 1989. Can Genetically Engineered Crops Become Weeds? . *Bio/Technology*. 7:1134-1139.

Keeling, J.W., Reed, J.D., Petty, D.M., Brown, B.A.,. 2009. Control of volunteer Roundup Ready Flex cotton with postemergence herbicides. . 2009 Beltwide Cotton Conferences San Antonio, Texas.

Kirkpatrick, T.L., and A.C. Thomas. Crop Rotation for Management of Nematodes in Cotton and Soybean. *University of Arkansas Cooperative Extension Service*.

Knezevic, S.Z., S.P. Evans, and M. Mainz. 2003. Yield Penalty Due to Delayed Weed Control in Corn and Soybean. *Crop Managment*.

Knutson, A., and J. Ruberson. 2005. Recognizing the Good Bugs in Cotton. Field Guide to Predators, Parasites and Pathogens Attacking Insects and Mite Pests of Cotton. *AgriLife Extension Bulletin E-357. College Station, TX. Agriculture Communications, Texas A&M University.*

Kong, G., MK Daud, and S. Zhu. 2010. .Effects of pigment glands and gossypol on growth, development and insecticide-resistance of cotton bollworm (Heliothis armigera (Hubner)). . *Crop Protection* 29:813-819.

Krapu, G.L., D.A. Brandt, and R.R. Cox Jr. 2004. Less Waste Corn, More Land in Soybeans, and the Switch to Genetically Modified Crops: Trends with Important Implications for Wildlife Management. *Wildlife Society Bulletin, 2004*. 32:127 - 136.

Krieger, M.S. 2008. Early Food Safety Evaluation for Aryloxyalkanoate Dioxygenase-12 (AAD-12) Protein. DowAgroSciences. http://www.fda.gov/downloads/Food/Biotechnology/Submissions/UCM222238.pdf

Langemeier, L. 1997. Profit Prospects-Soybean Production Handbook. Kansas State University. http://www.ksre.ksu.edu/library/crpsl2/c449.pdf.

Lassiter, R.B., J.A. Lee, B.B. Braxton, and M.A. Peterson. 2014. Investigation Into Post-Harvest Control of 2,4-D Tolerant Cotton. *In* Procedings Beltwide Cotton Conference 2014. National Cotton COuncil. Dow AgroSciences LLC

Lemieux, P.M., C.C. Lutes, and D.A. Santoianni. 2004. Emissions of organic air toxics from open burning: a comprehensive review. *Progress in Energy and Combustion Science*. 30:1-32.

Lemon, R., C. Stickler, and J. Norman, John. 2003. Cotton Stalk Destruction With Herbicides. *Texas Cooperative Extension-Texas A&M University System* 2.

Lenat, D.R., and J.K. Crawford. 1994. Effects of land use on water quality and aquatic biota of three North Carolina piedmont streams. *Hydrobiologia*. 294:185-199.

Leonard, B.R. 2007. Cotton Aphid Population Dynamics and Control Strategies in Conservation Tillage Cotton Fields. 2007 Conservation Tillage Conference Proceedings. http://www.cottoninc.com/fiber/Agricultural-Research/Agricultural-Meetings-Conferences/Conservation-Tillage-Conferences/2007-Presentations/Cotton%20Aphid%20Population%20Dynamics%20And%20Control%20Strategies.pdf March 5, 2014.

Lordelo, M.M., M.C. Calhoun, N.M. Dale, M.K. Dowd, and A.J. Davis. 2007. Relative toxicity of gossypol enantiomers in laying and broiler breeder hens. *Poultry Science*. 86:582-590.

Loux, M.M., D. Doohan, A.F. Dobbels, W.G. Johnson, and T.R. Legleiter. 2013. Weed Control Guide for Ohio, Indiana, and Illinois.

Lovett, S., P. Price, and J. Lovett. 2003. Managing Riparian Lands in the Cotton Industry. Cotton Research and Development Corporation. http://live.greeningaustralia.org.au/nativevegetation/pages/pdf/Authors%20L/18_Lovett_Price.pdf.

Luginbuhl, J., M. Poore, and A. Conrad. 2000. Effect of Level of Whole Cottonseed on Intake, Digestibility, and Performance of Growing Male Goats Fed Hay-based Diets. 78:1677-1683.

Madden, N.M., R.J. Southard, and J.P. Mitchell. 2009. Soil Water Content and Soil Disaggregation by Disking Affects PM10 Emissions. University of California-Davis.

Mapel, S.L. 2004. Effect of Cottonseed Meal Consumption on Performance of Female Fallow Deer. Texas A&M University. 1200. http://repository.tamu.edu/bitstream/handle/1969.1/325/etd-tamu-2004A-ANSC-Mapel-1.pdf?sequence=1.

McClelland, M.R., K.L. Smith, and J.K. Norsworthy. 2006. Managing glyphosate-resistant horseweed in conservation-tillage cotton production: Final summary and recommendations. Vol. AAES Research Series 552. University of Arkansas Agricultural Experiment Station, Fayetteville, Arkansas

McCray, K. 2009. Ground water: Out of sight, but not out of mind. National Ground Water Association. http://www.fb.org/newsroom/focus/fo2012/fo0312.html

Merchant, R.M., A.S. Culpepper, P.M. Eure, J.S. Richburg, and L.B. Braxton. 2014a. Controlling Glyphosate-Resistant Palmer Amaranth (Amaranthus palmeri) in Cotton with Resistance to Glyphosate, 2,4-D, and Glufosinate. *Weed Technology*. 28:291-297.

Merchant, R.M., A.S. Culpepper, P.M. Eure, J.S. Richburg, and L.B. Braxton. 2014b. Salvage Palmer Amaranth Programs Can Be Effective in Cotton Resistant to Glyphosate, 2,4-D, and Glufosinate. *Weed Technology*. 28:316-322.

Merchant, R.M., L.M. Sosnoskie, A.S. Culpepper, L.E. Steckel, A.C. York, L.B. Braxton, and J.C. Ford. 2013. Weed response to 2,4-D, 2,4-DB, and dicamba applied alone or with glufosinate. *Journal of Cotton Science*. 17:212-218.

Meyer, L., S. MacDonald, and L. Foreman. 2007. Cotton backgrounder. http://www.ers.usda.gov/publications/cws/2007/03Mar/CWS07B01/CWS07B01.pdf. U.S. Department of Agriculture, Economic Research Service.

Mississippi-State-University. 2010. Chemical-resistant weeds challenge state row crops. MSU Ag Communications--Bonnie Coblentz. http://msucares.com/news/print/agnews/an10/100805crop.html.

Mitchell, J.P., L. Carter, D.S. Munk, K.M. Klonsky, R.B. Hutmacher, A. Shrestha, R. DeMoura, and J.F. Wroble. 2012. Conservation tillage systems for cotton advance in the San Joaquin Valley. *California Agriculture*. 66:108-115.

Monaco, T.J., S.C. Weller, and F.M. Ashton. 2002. Weed Science: Principles and Practices Johns Wiley & Sons Inc., New York. 128-138 pp.

Monsanto. 2012a. Petition for the Determination of Nonregulated Status for Dicamba and Glufosinate-Tolerant Cotton MON 88701. Company Full Na me. 423. Marianne Malven.

Monsanto. 2012b. Unpublished grower survey data performed by a contracting agency. Monsanto Company, St. Louis, Missouri

Monsanto. 2012c. Unpublished grower survey data performed by a contracting agency. Monsanto Company.

Monsanto. 2013a. Petitioner's Environmental Report for Dicamba-Tolerant Soybean MON 88708 and Dicamba- and Glufosinate-Tolerant Cotton MON 88701. Monsanto. http://www.regulations.gov/#!documentDetail;D=APHIS-2013-0043-0071.

Monsanto. 2013b. Supplemental Document for the analysis of Environmental Report.

Monsanto. 2013c. Supplemental Information to Support the NEPA Analysis for the Determination of Nonregulated Status of Dicamba-Tolerant Soybean MON 87708 and Dicamba- and Glufosinate-Tolerant Cotton MON 88701. Information regarding trends in tillage practices in corn, cotton and soybean. Monsanto Company. For OECD Unique Identifiers: MON-877Ø8-9 (soybean) and MON-887Ø1-3 (cotton).

Monsanto. 2014. Petitioner's Environmental Report for Dicamba-Tolerant Soybean MON 87708 and Dicamba- and Glufosinate-Tolerant Cotton MON 88701. Information regarding trends in tillage practices in corn, cotton and soybean

Monsanto. 2015. Crop PhD. Roundup Ready Plus. Crop Management Solutions. Data Base Online Database. http://www.roundupreadyplus.com/cropphd?zip=39701&crop=cotton. 1-30-15.

Mora, M.A. 1997. Feeding flights of cattle egrets nesting in an agricultural ecosystem. *Southwestern Naturalist*. 42:52-58.

Morgan, G.D. 2010 Producers battling volunteer cotton in corn, sorghum fields. . *Texas AgriLife.* .

Morgan, G.D., D.A. Fromme, P.A. Baumann, J. Grichar, B. Bean, M.E. Matocha, and D.A. Mott. 2011a. Managing Volunteer Cotton in Grain Crops (Corn, Sorghum, Soybean, and Wheat). Texas AgriLife Extension Service. http://publications.tamu.edu/COTTON/PUB_cotton_Managing%20Volunteer%20Cotton%20in%20Grain%20Crops.pdf.

Morgan, G.D., J.W. Keeling, P.A. Baumann, and P.A. Dotray. 2011b. Managing Volunteer Cotton in

Cotton. http://publications.tamu.edu/COTTON/PUB_cotton_Managing%20Volunteer%20Cotton%20in%20Cotton.pdf.

NAPPO. 2009. NAPPO approved standards http://www.nappo.org/Standards/Std-e.html

Naranjo, S.E. 2009. Impacts of Bt crops on non-target invertebrates and insecticide use patterns. CAB Review: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural. http://naldc.nal.usda.gov/catalog/48264.

NBII. 2010. United States Regulatory Agencies Unified Biotechnology Website http://usbiotechreg.nbii.gov/

NCCA. 2007. The first 40 days: The most critical period in cotton production. National Cotton Council of America, The Cotton Foundation, Atlanta, Georgia

NCCA. 2015. Pink Bollworm Eradication: Proposal and Current Status. National Cotton Council of America. http://www.cotton.org/tech/pest/bollworm/

NCDA&CS. 2010. Wildlife damage to N.C. field crops totals $29.4 million. North Carolina Department of Agriculture and Consumer Services. http://www.ncagr.gov/paffairs/release/2010/3-10wildlifedamage.htm

NCGA. 2007. Sustainability - Conserving and Preserving: Soil Management and Tillage. National Corn Growers Association. http://www.ncga.com/uploads/useruploads/conservingpreservingsoilmanagement.pdf September 13, 2013.

NCPA. 1993. Cottonseed oil. National Cottonseed Products Association, Inc. and The Cotton Foundation, Memphis, Tennessee.

NCPA. 2002a. Cottonseed and its Products. National Cottonseed Producers Association. http://www.cottonseed.com/publications/cottonseedanditsproducts.asp.

NCPA. 2002b. Cottonseed feed products guide. National Cottonseed Products Association. http://www.cottonseed.com/publications/feedproductsguide.asp

NCPA. 2002c. Cottonseed Feed Products Guide. National Cottonseed Products Association (NCPA). http://www.cottonseed.com/publications/feedproductsguide.asp

Neve, P., J.K. Norsworthy, K.L. Smith, and I.A. Zelaya. 2011. Modelling evolution and management of glyphosate resistance in Amaranthus palmeri. *Weed Research*. 51:99-112.

New, L., and G. Fipps. 2000. Center Pivot Irrigation. *In* Irrigation Training Program South Texas Edition. D. Porter, editor. Texas Water Resources Institute, College Station, TX. 35-41.

Nida, D.L., S. Patzer, P. Harvey, R. Stipanovic, R. Wood, and R.L. Fuchs. 1996. Glyphosate-tolerant cotton: The composition of the cottonseed is equivalent to that of conventional cottonseed. *Journal of Agricultural and Food Chemistry*. 44:1967-1974.

Norsworthy, J.K., S.M. Ward, D.R. Shaw, R.S. Llewellyn, R.L. Nichols, T.M. Webster, K.W. Bradley, G. Frisvold, S.B. Powles, N.R. Burgos, W.W. Witt, and M. Barrett. 2012. Reducing the Risks of Herbicide Resistance: Best Management Practices and Recommendations. *Weed Science*. 12:32.

Norwine, J., J.R. Giardino, and S. Krishnamurthy. 2005. Water for Texas Texas A&M University Press. 271 pp.

NRC. 2004. New approaches for identifying unintended changes in food composition. *In* Safety of Genetically Engineered Foods: Approaches to Assessing Unintended Health Effects. Institute of Medicine and National Research Council, National Academies Press, Washington, D.C. 73-102.

NRC. 2010. The Impact of Genetically Engineered Crops on Farm Sustainability in the United States. National Academies Press- The National Academies Press, Washington, D.C. 270 pp.

OECD. 1999. Consensus document on general information concerning the genes and their enzymes that confer tolerance to phosphinothricin herbicide. 13. internal-pdf://1294703111/OECD 1999 PAT.pdf. Organisation for Economic Co-operation and Development,.

OECD. 2008. Consensus document on the biology of cotton (Gossypium spp.). . Organization for Economic Co-operation and Development. http://www.oecd.org/science/biosafety-biotrack/46815918.pdf. November 2, 2012.

OECD. 2009. Consensus document on the compositional considerations for new varieties of cotton (*Gossypium hirsutum* and *Gossypium barbadense*): Key food and feed nutrients and anti-nutrients. internal-pdf://3648843354/OECD_2009_cotton_comp.pdf. Organisation for Economic Co-operation and Development.

OGTR. 2008. The Biology of Gossypium hirsutum L. and Gossypium barbadense L. (cotton), version 2. . O.o.t.G.T.R. Department of Health and Ageing. http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/content/cotton-3/$FILE/biologycotton08.pdf.

OSHA. 2013. Safety and health topics: Agricultural operations - Hazards & controls. http://www.osha.gov/dsg/topics/agriculturaloperations/hazards_controls.html. internal-pdf://2662277888/OSHA agricultural operations accessed april 30.pdf. Occupational Safety & Health Administration.

OSHA. 2014. Safety and Health Topics - Cotton Dust. https://www.osha.gov/SLTC/cottondust/index.html. Occupational Safety & Health Administration.

Osteen, C., J. Gottlieb, and U. Vasavada. 2012. Agricultural Resources and Environmental Indicators, 2012. E.R.S. U.S. Department of Agriculture. EIB-98. http://www.ers.usda.gov/media/874175/eib98.pdf.

Osteen, C.D., and J. Fernandez-Cornejo. 2013. Economic and policy issues of U.S. agricultural pesticide use trends. *Pest Management Science*. 69:1001-1025.

OTA. 2010. Organic Cotton Facts. Organic Trade Association. http://www.ota.com/organic/mt/organic_cotton.html

OTA. 2014. 2012 and Preliminary 2013 U.S. Organic Cotton Production & Marketing Trends. Organic Trade Association. http://www.ota.com/pics/documents/2012-2013-Organic-Cotton-Report.pdf.

Owen, M., and I. Zelaya. 2005. Herbicide-resistant crops and weed resistance to herbicides *Pest Management Science*. 61:301-311.

Owen, M.D., B.G. Young, D.R. Shaw, R.G. Wilson, D.L. Jordan, P.M. Dixon, and S.C. Weller. 2011a. Benchmark study on glyphosate-resistant crop systems in the United States. Part 2: Perspectives. *Pest Management Science*. 67:747-757.

Owen, M.D.K. 2008. Weed species shifts in glyphosate-resistant crops. *Pest Management Science*. 64:377-387.

Owen, M.D.K., B.G. Young, D.R. Shaw, R.G. Wilson, D.L. Jordan, P.M. Dixon, and S.C. Weller. 2011b. Benchmark study on glyphosate-resistant cropping systems in the USA. II. Perspective. *Pest Management Science*. 67:747-757.

Palmer, W., and P. Bromley. NoDate. Pesticides and Wildlife - Cotton. North Carolina Cooperative Extension Service. http://ipm.ncsu.edu/wildlife/cotton_wildlife.html

Papendick, R.I., and W.C. Moldenhauer. 1995. Crop Residue Management To Reduce Erosion and Improve Soil Quality: Northwest. USDA-Agricultural Research Service. http://eprints.nwisrl.ars.usda.gov/1205/1/878.pdf.

Paz Celorio-Mancera, M.d.l., Seung-Joon Ahn, Heiko Vogel, and D.G. Heckel. 2011. Transcriptional responses underlying the hormetic and detrimental effects of the plant secondary metabolite gossypol on the generalist herbivore Helicoverpa armigera. *BMC Genomics*. 12:575.

Percy, R., and J. Wendel. 1990. Allozyme evidence for the origin and diversification of Gossypium barbadense L. . *Theoritical and Applied Genetics*. 79:529-542.

Peter, M.L. 2015. Kansas: Resistant Pigweed Requires Integrated Approach. AgFax. http://agfax.com/2014/07/21/kansas-palmer-amaranth-taking-hold-state/.

Pettigrew, W.T., W.R. Meredith, H.A. Bruns, and S.R. Stetina. 2006. Effects of a short-term corn rotation on cotton dry matter partitioning, lint yield, and fiber quality production. *J. Cotton Sci.* 10:244-251:8.

Pleasants, J., and J. Wendell. 2005. Assessment of potential for gene flow between transgenic cotton and the endemic Hawaiian cotton - Final Report. .

Powles, S.B., C. Preston, I.B. Bryan, and A.R. Jutsum. 1996. Herbicide resistance: Impact and management. *In* Advances in Agronomy. Academic Press, San Diego, California. 57-93.

Price, A.J., K.S. Balkcom, S.A. Culpepper, J.A. Kelton, R.L. Nichols, and H. Schomberg. 2011. Glyphosate-resistant Palmer amaranth: A threat to conservation tillage. *Journal of Soil and Water Conservation*. 66:265-275.

Prince, J.M., D.R. Shaw, W.A. Givens, M.E. Newman, M.D.K. Owen, S.C. Weller, B.G. Young, R.G. Wilson, and D.L. Jordan. 2011a. Benchmark study: III. Survey on changing herbicide use patterns in glyphosate-resistant cropping systems. *In* Weed Technology. Weed Science Society of America, Champaign, Illinois

Prince, J.M., D.R. Shaw, W.A. Givens, M.D.K. Owen, S.C. Weller, B.G. Young, R.G. Wilson, and D.L. Jordan. 2011b. Benchmark study: I. Introduction, weed population and management trends from the benchmark survey 2010. *In* Weed Technology. Weed Science Society of America, Champaign, Illinois

Prostko, E.P. 2013. A.K. Weissinger. 2/21/2013.

Pucci, J. 2013. Glyphosate resistance spreads in the U.S. Farm Chemicals International. http://www.farmchemicalsinternational.com/crop-inputs/herbicides/glyphosate-resistance-spreads-in-the-u-s/.

Reeves, J.B., and J.L. Weihrauch. 1979. Composition of foods. internal-pdf://3671741046/ReevesWeirauch(1979)CompositionOfFoods.pdf. U.S. Department of Agriculture.

Robertson, A., R.F. Nyvall, and C.A. Martinson. 2009. Controlling Corn Diseases in Conservation Tillage. Iowa State University, University Extension. http://www.ag-essentials.com/ControllingCornDiseasesinConservationTillage.pdf.

Robertson, B., K. Smith, B. Scott, and G. Studebaker. 2002. Cotton Comments. Options For Chemical Stalk Termination. University of Arkansas. https://www.uaex.edu/farm-ranch/crops-commercial-horticulture/cotton/Chemical%20Stalk%20Destruction.pdf.

Robertson, G., E. Paul, and R. Harwood. 2000. Greenhouse gases in intensive agriculture: Contributions of individual gases to the radiative forcing of the atmosphere. *Science*. 289:1922-1925.

Robinson, A.P., D.M. Simpson, and W.G. Johnson. 2012. Summer Annual Weed Control with 2,4-D and Glyphosate. *Weed Technology*. 26:657-660.

Rolph, C.E., R.S. Moreton, and J.L. Harwood. 1990. Control of acyl lipid desaturation in the yeast *Rhodotorula gracilis* via the use of the cyclopropenoid fatty acid, sterculate. *Applied Microbiology and Biotechnology*. 34:91-96.

Rosenzweig, C., A. Iglesias, X.B. Yang, P.R. Epstein, and E. Chivian. 2001. Climate change and extreme weather events: Implications for food production, plant diseases, and pests. *Global Change and Human Health*. 2:90-104.

Ross, M.A., and D.J. Childs. 2011. Herbicide Mode-of-Action Summary. Cooperative Extension Service, Perdue University. http://www.extension.purdue.edu/extmedia/WS/WS-23-W.html

Rude, P.A. 1984. Integrated Pest Management for Cotton in the Western Region of the United States. University of California. 143 pp.

Ruiz, N., P. Lavelle, and J. Jimenez. 2008. Soil macrofauna field manual: Technical level. ftp://ftp.fao.org/docrep/fao/011/i0211e/i0211e.pdf. Food and Agriculture Organization of the United Nations.

Saha, S., Raska DA, and S. DM. 2006. Upland Cotton (Gossypium hirsutum L.) x Hawaiian Cotton (G. tomentosum Nutt. ex Seem.) F1 Hybrid Hypoaneuploid Chromosome Substitution Series. . *Journal of Cotton Science* 10:263-272.

Salvaggio, J.E., C.E. O'Neil, and B.T. Butcher. 1986. Immunologic responses to inhaled cotton dust. *Environmental Health Perspectives*. 66:17-23.

Sammons, R.D., D.C. Heering, N. Dinicola, H. Glick, and G.A. Elmore. 2007. Sustainability and stewardship of glyphosate and glyphosate-resistant crops. *Weed Technology*. 21:347-354.

Schaible, G.D., and M.P. Aillery. 2012. Water Conservation in Irrigated Agriculture: Trends and Challenges in the Face of Emerging Demands. U.S. Department of Agriculture, Economic Research Service. http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib99.aspx.

Schmidhuber, J., and F.N. Tubiello. 2007. Global food security under climate change. *PNAS*. 104:19703-19708.

Scott, B., and K. Smith. 2014. Prevention and Control of Glyphosate Resistant Pigweed in Soybean and Cotton. University of Arizona Cooperative Extension. http://www.arkansas-crops.com/wp-content/uploads/2014/02/FSA-2152.pdf.

Sharpe, T. 2010a. Cropland Management. A Guide for Managing Wildlife on Private Lands In North Carolina. North carolina Wildlife. Data Base Online Database. http://www.ncwildlife.org/tarheelwildlife.aspx.

Sharpe, T. 2010b. Tarheel wildlife - A guide for managing wildlife on private lands in North Carolilna. North Carolina Wildlife Resources Commission, Raleigh, North Carolina

Shaw, D.R., S. Culpepper, M. Owen, A. Price, and R. Wilson. 2012. Herbicide-resistant weeds threaten soil conservation gains: finding a balance for soil and farm sustainability.

Shepard, P.R. 2015. Resistant weeds demand chemistry rotation, system approach. Delta Farm Press. http://deltafarmpress.com/cotton/resistant-weeds-demand-chemistry-rotation-system-approach?page=1.

Shrestha, A., T. Lanini, S. Wright, J. Mitchell, and R. Vargas. 2006. Conservation Tillage and Weed Management. Data Base Online Database.

Singer, J.W. 2006. Cover crops in the corn belt: Survey finds underused potential as conservation tool. Iowa State University, Leopold Center for Sustainable Agriculture, Ames, Iowa

Smith, A., and S. Hagood. 2013. 2,4-D and dicamba resistant soybean for management of glyphosate resistant common ragweed. http://www.swss.ws/wp-content/uploads/2013/09/Proceedings-of-the-2013-Southern-Weed-Science-Society-Meeting-revised.pdf.

Smith, C.W., and J.T. Cothren. 1999. Cotton: Origin, history, technology, and production. John Wiley and Sons, Inc., New York, New York.

Snell, C., A. Bernheim, J.-B. Berge, M. Kuntz, G. Pascal, A. Paris, and A.E. Ricroch. 2012. Assessment of the Health Impact of GM Plant Diets in Long-Term and Multigenerational Animal Feeding Trials: A Literature Review. Elsevier. Data Base Online Database. www.elsevier.com/locate/foodchemtox.

Solaiman, S. 2007. Feeding Value of Whole Cottonseed for Goats. Tuskeegee University. http://www.boergoats.com/clean/articles/feeding/wholecottonseed.pdf

Sosnoskie, L.M., and A.S. Culpepper. 2012. 2012: Changes in cotton weed management practices in Georgia following the development of glyphosate-resistant Palmer amaranth,. University of Georgia, Tifton, Georgia

Sosnoskie, L.M., and A.S. Culpepper. 2014. Glyphosate-resistant palmer amaranth (Amaranthus palmeri) increases herbicide use, tillage, and hand-weeding in georgia cotton. *Weed Science*. 62:393-402.

SOWAP. 2007. Impact of Conservation Tillage on Terrestrial Biodiversity. Soil and Water Protection Project. http://www.sowap.org/results/biodiversity.htm

Steckel, L. 2014. Cotton Weed Control. 2014 Weed Control Manual for Tennessee. University of Tennessee Extension. https://utextension.tennessee.edu/publications/Documents/PB1580.pdf.

Stepenuck, K.F., R.L. Crunkilton, and L. Wang. 2002. Impacts of urban land use on macroinvertebrate communities in southeastern Wisconsin streams. *American Water Resources Association*.

TAMU. 2014. Texas Water Resources Institute Irrigation Training Program. Crop-specific guidelines: cotton production. Texas A&M University. http://irrigationtraining.tamu.edu/

Taylor, B., E. Lyons, D. Rollins, C. Scott, J. Huston, and C. Taylor. 2013. Consumption of Whole Cottonseed by White Tailed Deer and Nontarget Species. *Human-Wildlife Interactions*. 7:99-106.

TDA. 1997. Tennesse Boll Weevil Eradication Program FAQ. Tennessee State Department of Agriculture. http://www.tn.gov/agriculture/publications/regulatory/bollweevilfaq.pdf

Thompson, A., Steckel, L., . 2008. Controlling volunteer cotton in soybeans. . *University of Tennesse Extension.* .

Thompson, C. 2014. Managing herbicide drift is important to the bottom line, environment. University of Georgia, College of Agricultural and Environmental Sciences http://www.caes.uga.edu/applications/gafaces/?public=viewStory&pk_id=5044.

TOCMC. 2011. About us. Texas Organic Cotton Marketing Cooperative. http://www.texasorganic.com/aboutus/aboutus.htm

TOCMC. 2014. Texas Organic Cotton Marketing Cooperative. http://www.texasorganic.com/aboutus/aboutus.htm

Towery, D., and S. Werblow. 2010a. Facilitating Conservation Farming Practices and Enhancing Environmental Sustainability with Agricultural Biotechnology. Conservation Technology Information Center,. http://www.ctic.purdue.edu/media/pdf/Biotech_Executive_Summary.pdf.

Towery, D., and S. Werblow. 2010b. Facilitating Conservation Farming Practices and Enhancing Environmental Sustainability with Agricultural Biotechnology. Conservation Technology Information Center. http://improveagriculture.com/uploads/files/BiotechFinal2.pdf

Towery, D., and S. Werblow. 2010c. Facilitating Conservation Farming Practices and Enhancing Environmental Sustainability with Agricultural Biotechnology; Exective summary. Conservation Technology Information Center,. http://www.ctic.purdue.edu/media/pdf/Biotech_Executive_Summary.pdf.

Tyler, D.D., M.G. Wagger, D.V. McCraken, and W. Hargrove. 1994. Role of Conservation Tillage in Sustainable Agriculture in the Southern United States. *In* Conservation Tillage in Temperate Agroecosystems. M.R. Carter, editor. CRC Press. 209-229.

U.S.-Organic-Trade-Association. 2011. 2011 and Preliminary 2012 US Organic Cotton Production and Marketing Trends. Cotton Incorporated. http://www.ota.com/pics/documents/OTA-2011-Organic-Cotton-Report.pdf.

UGA Extension. 2014. 2014 Georgia Cotton Production Guide. The University of Georgia Cooperative Extension http://www.ugacotton.com/production-guide/

University-of-Georgia. 2011. 2011 Georgia Cotton Production Guide. University of Georgia College of Agricultural and Environmental Sciences, Athens, Georgia.

University-of-Tennessee. 2007. 2007 Budgets. Corn, Cotton, Grain Sorghum, Soybeans, Wheat and Tobacco UTenn. http://economics.ag.utk.edu/budgets/archived/2007Budgets.pdf.

University-of-Tennessee. 2015. 2015 Non-Irrigated Cotton Budget (No-till). UTenn. http://economics.ag.utk.edu/budgets/2015/Crops/CottonNonIrrNoTill.pdf.

University of Arkansas. 2008. Corn Production Handbook. Cooperative Extension Service, University of Arkansas.

University of Georgia. 2012. 2012 Georgia cotton production guide. University of Georgia College of Agricultural and Environmental Sciences.

University of Georgia. 2014. UGA Programs for Controlling Glyphosate-Resistant Palmer Amaranth in 2014 Cotton. http://www.gaweed.com/HomepageFiles/2014Palmerhandout-finaljan2.pdf.

University of Georgia and USDOI-NPS. 2009. Invasive Plant Atlas of the United States, Grasses and Grasslike Plants. The University of Georgia - Center for Invasive Species and Ecosystem Health and the U.S. Department of the Interior - National Park Service. http://www.invasiveplantatlas.org/grass.html

US-CDC. 2013. Agricultural Water.

Phosphinothricin Acetyltransferase and the Genetic Material Necessary for Its Production in All Plants; Exemption from the Requirement of a Tolerance on all Raw Agricultural Commodities. US-EPA.

Phosphinothricin acetyltransferase and the genetic material necessary for its production in all plants; Exemption from the requirement of a tolerance on all raw agricultural commodities. US-EPA.

US-EPA. 2000. Profile of the Agricultural Crop Production Industry. U.S. Environmental Protection Agency-Office of Compliance Sector Notebook Profile. http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/agcrop.pdf.

US-EPA. 2001. Bt Plant-Incorporated Protectants October 15, 2001 Biopesticides Registration Action Document.

US-EPA. 2005a. Protecting Water Quality from Agricultural Runoff. U.S. Environmental Protection Agency. http://www.epa.gov/owow/nps/Ag_Runoff_Fact_Sheet.pdf. September 13, 2013.

US-EPA. 2005b. Reregistration Eligibility Decision for 2,4-D. EPA 738-R-05-002. http://www.epa.gov/pesticides/reregistration/REDs/24d_red.pdf.

US-EPA. 2008a. Glufosinate Summary Document, Registration Review: Initial Docket, March 2008. S.R.a.R. Division. http://www.epa.gov/oppsrrd1/registration_review/glufosinate_ammonium/.

US-EPA. 2008b. Glufosinate Summary Document. Registration Review: Initial Docket, March 2008. S.R.a.R. Division. Docket No. EPA-HQ-OPP-2008-0190. http://www.epa.gov/oppsrrd1/registration_review/glufosinate_ammonium/.

US-EPA. 2009. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2007. U.S. Environmental Protection Agency. http://www.epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Complete_Report.pdf.

US-EPA. 2010a. Pesticide Registration Manual: Chapter 11 - Tolerance Petitions. U.S. Environmental Protection Agency. http://www.epa.gov/pesticides/bluebook/chapter11.html

US-EPA. 2010b. A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: Field Volatilization of Conventional Pesticides. U.S. Environmental Protection Agency. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2009-0687-0037

US-EPA. 2011a. Agricultural Burning. U.S. Environmental Protection Agency. http://www.epa.gov/agriculture/tburn.html#Air

US-EPA. 2011b. Chapter 6: Agriculture. *In* Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. U.S. Environmental Protection Agency, Washington, DC. 6-1 through 6-40.

US-EPA. 2011c. Inventory of U.S. Greenhouse Gas Emissions And Sinks: 1990 – 2009. U.S. Environmental Protection

Agency. http://www.epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Complete_Report.pdf.

US-EPA. 2011d. Managing Nonpoint Source Pollution from Agriculture. U.S. Environmental Protection Agency. http://water.epa.gov/polwaste/nps/outreach/point6.cfm.

US-EPA. 2011e. Pesticide Tolerance. U.S. Environmental Protection Agency. http://www.epa.gov/pesticides/regulating/tolerances.htm

US-EPA. 2011f. Pesticides: Registration Review. U.S. Environmental Protection Agency. http://www.epa.gov/oppsrrd1/registration_review/index.htm

US-EPA. 2012a. 2,4-D (030001, 030004) - Screening Level Usage Analysis (SLUA). U.S. Environmental Protection Agency, Ed. Office of Chemical Safety and Pollution Prevention, Washington, D.C. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2012-0330-0007.

US-EPA. 2012b. Agricultural Burning. EPA. http://www.epa.gov/agriculture/tburn.html#Prescribed

US-EPA. 2012c. Crop Production. United States Environmental Protection Agency. http://www.epa.gov/oecaagct/ag101/printcrop.html

US-EPA. 2012d. Water Exposure Models Used by the Office of Pesticide Programss.

US-EPA. 2013a. 2,4-D. Acute and Chronic Aggregate Dietary (Food and Drinking Water) Exposure and Risk Assessment for the Section 3 Registration Action on Herbicide Tolerant Field Corn and Soybean.

US-EPA. 2013b. 2,4-D. Human Health Risk Assessment for a Proposed Use of 2,4-D Choline on Herbicide Tolerant Corn and Soybean. EPA-HQ-OPP-2014-0195-0007. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2014-0195-0007.

US-EPA. 2013c. EFED Environmental Risk Assessment of the Proposed Label for Enlist (2,4-D Choline Salt), Ne Uses on Soybean with DAS 68416-4 (2,4-D Tolerant) and Enlist (2,4-D + Glyphosate Tolerant) Corn and Field Corn. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2014-0195-0002.

US-EPA. 2014a. Ag 101: demographics. http://www.epa.gov/oecaagct/ag101/demographics.html

US-EPA. 2014b. Nonpoint Source: Introduction. Environmental Protection Agency Data Base Online Database. http://water.epa.gov/polwaste/nps/nonpoin1.cfm. 09/24/2014.

US-EPA. 2014c. Pesticide Issues in the works: pesticide volatization. Data Base Online Database. http://www.epa.gov/pesticides/about/intheworks/volatilization.htm.

US-EPA. 2014d. Response to Public Comments Received Regarding New Uses of Enlist DuoTM on Corn and Soybeans. Product Name: Enlist DuoTM EPA Registration Number: 62719-649. internal-pdf://0676831258/EPA-Response Comm Enlist Reg Doc Soy&Corn 2014.doc.

US-EPA. 2014 Final Registration of Enlist Duo Herbicide. http://www2.epa.gov/sites/production/files/2014-10/documents/final_registration_-_enlist_duo.pdf.

US-FDA. 1992. Guidance to Industry for Foods Derived from New Plant Varieties. *Federal Register*. 57:22984.

US-FDA. 1995. Completed Consultations on Foods from Genetically Engineered Plant Varieties - BNF No. 000026. US Food and Drug Administration. http://www.fda.gov/Food/FoodScienceResearch/Biotechnology/Submissions/ucm161118.htm

US-FDA. 1997. Consultation Procedures under FDA's 1992 Statement of Policy - Foods Derived from New Plant Varieties, Guidance on Consultation Procedures Foods Derived From New Plant Varieties. http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/ucm096126.htm. U.S. Food and Drug Administration.

US-FDA. 1998a. Biotechnology Consultation Agency Response Letter BNF No. 000055. U.S. Food and Drug Administration. http://www.fda.gov/Food/Biotechnology/Submissions/ucm161092.htm

US-FDA. 1998b. Biotechnology Consultation Note to the File BNF No. 000055: Glufosinate-tolerant Soybean Lines. U.S. Food and Drug Admnistration. http://www.fda.gov/Food/Biotechnology/Submissions/ucm161170.htm

US-FDA. 2003a. Completed Consultations on Bioengineered Foods BNF No.86. US Food and Drug Administration. http://www.fda.gov/Food/FoodScienceResearch/Biotechnology/Submissions/ucm155758.htm

US-FDA. 2003b. Completed Consultations on Bioengineered Foods BNF No. 86. US Food and Drug Administration. http://www.fda.gov/Food/Biotechnology/Submissions/ucm155787.htm

US-FDA. 2006. Guidance for Industry: Recommendations for the Early Food Safety Evaluation of New Non-Pesticidal Proteins Produced by New Plant Varieties Intended for Food Use. U.S. Food and Drug Administration. http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/Biotechnology/ucm096156.htm

US-FDA. 2010. NPC 000009: Agency Response Letter - Aryloxyalkanoate Dioxygenase-12 (AAD-12). U.S. Food and Drug Administration. http://www.fda.gov/Food/Biotechnology/Submissions/ucm224037.htm

US-FDA. 2013. Completed Consultations on Bioengineered Foods BFN No. 135. US Food and Drug Administration. http://www.accessdata.fda.gov/scripts/fcn/fcnDetailNavigation.cfm?rpt=bioListing&id=97

US-FDA. 2014a. Biotechnology Consultation Agency Response Letter NPC 000142 - DAS-81910-7 cotton U.S. Food and Drug Administration, CFSAN/Office of Food Additive Safety. http://www.fda.gov/Food/FoodScienceResearch/Biotechnology/Submissions/UCM427612

US-FDA. 2014b. Biotechnology Consultations on Food from GE Plant Varieties: inventory of all completed Biotechnology consultations on Genetically Engineered foods US Food and Drug Administration. http://www.accessdata.fda.gov/scripts/fdcc/?set=Biocon

US-NARA. 2010. Executive Orders disposition tables index. United States National Archives and Records Administration. http://www.archives.gov/federal-register/executive-orders/disposition.html

USDA-AMS. 2010. PDP Program Overview. U.S. Department of Agriculture–Agricultural Marketing

Service. http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?more=G.OptionalText2&template=TemplateG&navID=PDPDownloadNav2Link2&rightNav1=PDPDownloadNav2Link2&topNav=&leftNav=ScienceandLaboratories&page=PDPProgramOverview&resultType=&acct=pestcddataprg

USDA-APHIS. 1996. Availability of Determination of Nonregulatated Status for Soybeans Genetically Engineered for Glufosinate Herbicide Tolerance. USDA-APHIS. 160. Federal Register

USDA-APHIS. 1999. Mississippi Boll Weevil Cooperative Eradication Program Environmental Assessment

USDA-APHIS. 2001. Availability of Determination of Nonregulatated Status for Genetically Engineered Corn for Insect Resistance and Glufosinate Herbicide Tolerance (Corn line 1507). 157. Federal Register.

USDA-APHIS. 2005. Availability of Determination of Nonregulated Status for Genetically Engineered Corn (Corn Line DAS-59122-7). Federal Register

USDA-APHIS. 2012. United States Department of Agriculture, Animal Plant Health Inspection Service. Federal Noxious Weed List as of 2/1/2012. Data Base Online Database. http://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/weedlist.pdf. March 19, 2014.

USDA-APHIS. 2014a. Determination of Nonregulatory Status for DAS-44406-6 Soybean (Petition 11-234-01p). http://www.aphis.usda.gov/brs/aphisdocs/11_23401p_det.pdf.

USDA-APHIS. 2014b. Determination of Nonregulatory Status for DAS-68416-4 Soybean (Petition 09-349-01p). http://www.aphis.usda.gov/brs/aphisdocs/09_34901p_det.pdf.

USDA-APHIS. 2014c. Final EIS. Dow AgroSciences Petitions (09-233-01p, 09-349-01p, 11-234-01p) for Determinations of Nonregulated Status for 2,4-D Resistant Corn and Soybean Varieties

USDA-APHIS. 2014d. Final EIS. Monsanto Petitions (10-188-01p and 12-185-01p) for Determinations of Nonregulated Status for Dicamba-Resistant Soybean and Cotton Varieties

USDA-APHIS. 2014e. Petitions Tables - Determinations of Nonregulated Status. http://www.aphis.usda.gov/biotechnology/petitions_table_pending.shtml. U.S. Department of Agriculture, Animal and Plant Health Inspection Service.

USDA-APHIS. 2014f. Plant Pest Risk Assessment - Dow AgroSciences LLC Petition (13-262-01p) for Determination of Nonregulated Status of Event DAS-8191Ø-7 Cotton. USDA-APHIS. Data Base Online Database. http://www.aphis.usda.gov/biotechnology/petitions_table_pending.shtml. April 1, 2014.

USDA-ERS. 1996. The Cotton Industry in the United States. http://naldc.nal.usda.gov/naldc/download.xhtml?id=CAT10754725&content=PDF. internal-pdf://1313767387/ERS Ag Econ report 739.pdf.

USDA-ERS. 1997. Crop Residue Management. *In* Agricultural Resources and Environmental Indicators 1996-1997. U.S. Department of Agriculture–Economic Research Service, Washington. 356.

USDA-ERS. 2009. Conservation Policy: Compliance Provisions for Soil and Wetland Conservation. U.S. Department of Agriculture–Economic Research Service. http://www.ers.usda.gov/Briefing/ConservationPolicy/compliance.htm

USDA-ERS. 2010. Data sets: Organic production. http://www.ers.usda.gov/Data/organic/. U.S. Department of Agriculture, Economic Research Service.

USDA-ERS. 2011. Major Uses of Land in the United States, 2007. USDA-ERS.

USDA-ERS. 2012a. Crop production practices for cotton. *National. U.S. Department of Agriculture, Economic Research Service, Washington, D.C.*

USDA-ERS. 2012b. Crop production practices for cotton: National. U.S. Department of Agriculture, Economic Research Service.

USDA-ERS. 2012c. Crops. Agriculture. http://webarchives.cdlib.org/sw10z7207q/http://www.ers.usda.gov/Browse/view.aspx?subject=Crops.

USDA-ERS. 2013a. Cotton production costs and returns per planted acre, excluding Government payments, Prairie Gateway, 2007-2013. Agriculture, editor. Economic Research Service

USDA-ERS. 2013b. Organic Production - Table 3: Certified organic and total U.S. acreage, selected crops and livestock, 1995-2011. Vol. 2014. USDA-Economic Research Service

USDA-ERS. 2014a. Adoption of Genetically Engineered Crops in the U.S. http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx.

USDA-ERS. 2014b. Adoption of Genetically Engineered Crops in the U.S. - Recent Trends in GE Adoption. United States Department of Agriculture Economic Research Service. http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption.aspx

USDA-ERS. 2014c. Cotton and Wool Outlook. USDA-ERS

USDA-ERS. 2014d. Cotton and Wool Yearbook

USDA-ERS. 2014e. Cotton production costs and returns per planted acre, excluding Government payments, 2012-2013. Agriculture, editor

USDA-ERS. 2014f. US Cotton Supply and Use

USDA-ERS. 2015. Commodity Cost and Returns. Compiled by ERS using Agricultural Resource Management Survey data and other sources. http://www.ers.usda.gov/data-products/commodity-costs-and-returns.aspx

USDA-FAS. 2014a. Cotton: World Markets and Trade. Foreign-Agricultural-Service. http://usda.mannlib.cornell.edu/usda/fas/cotton-market//2010s/2014/cotton-market-08-12-2014.pdf

internal-pdf://1240916757/FAS 2014 world cotton-market.pdf.

USDA-FAS. 2014b. Global Trade Atlas Data Base Online Database. http://www.tradestatistics.com/gta/usda/.

USDA-FSA. 2010. Biomass Crop Assistance Program: Final Programmatic Environmental Impact Statement. United States Department of Agriculture, Farm Service Agency. http://www.fsa.usda.gov/Internet/FSA_File/bcapfinalpeis062510.pdf.

USDA-NASS. Census of Agriculture Table 26 Organic Cotton. 2008 Organic Survey. http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Organics/. internal-pdf://3422238728/Census Agri 2008 Organic Cotton.pdf.

USDA-NASS. 2009. 2007 Census Ag Atlas Map: Irrigated Cotton, Harvested Acres: 2007. United States Department of Agriculture, National Agricultural Statistics Service. http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Crops_and_Plants/Field_Crops_Harvested/07-M186-RGBDot1-largetext.pdf

USDA-NASS. 2011a. Agricultural Chemical Use - Corn, Upland Cotton, and Fall Potatoes 2010. N.A.S.S. U.S. Department of Agriculture. http://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/FieldCropChemicalUseFactSheet06.09.11.pdf.

USDA-NASS. 2011b. Agricultural Chemical Use: Corn, Upland Cotton and Fall Potatoes 2010. USDA-National Agricultural Statistics Service.

USDA-NASS. 2011c. Crop Production 2010 Summary. N.A.S.S. U.S. Department of Agriculture. Cr Pr 2-1 (11)a. http://usda.mannlib.cornell.edu/usda/nass/CropProdSu//2010s/2011/CropProdSu-01-12-2011_revision.pdf. U.S. Department of Agriculture, National Agricultural Statistics Service.

USDA-NASS. 2012a. Crop Production 2011 Summary. N.A.S.S. U.S. Department of Agriculture. U.S. Department of Agriculture, National Agricultural Statistics Service.

USDA-NASS. 2012b. United States Department of Agriculture, National Agricultural Statistics Service. Crop Production, pp. 14-15. Retrieved on November 5, 2012 from http://usda01.library.cornell.edu/usda/nass/CropProd//2010s/2012/CropProd-05-10-2012.pdf. November 5, 2012

USDA-NASS. 2013a. 2012 Agricultural Chemical Use Survey: Soybean USDA-National Agricultural Statistics Service. http://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/2012_Soybeans_Highlights/ChemUseHighlights-Soybeans-2012.pdf.

USDA-NASS. 2013b. Crop Production: 2012 summary. U.S. Department of Agriculture, National Agricultural Statistics Service.

USDA-NASS. 2013c. Crop Production: 2012 summary. January, 2013. U.S. Department of Agriculture, National Agricultural Statistics Service.

USDA-NASS. 2013d. Map: Pima Cotton 2013 Harvested Acres by County for Selected States. U.S. Department of Agriculture, National Agricultural Statistics Service.

USDA-NASS. 2013e. Map: Upland Cotton 2013 Harvested Acres by County for Selected States. http://www.nass.usda.gov/Charts_and_Maps/graphics/cotnacm.pdf. U.S. Department of Agriculture, National Agricultural Statistics Service.

USDA-NASS. 2014a. Crop Production 2013 Summary. http://usda01.library.cornell.edu/usda/current/CropProdSu/CropProdSu-01-10-2014.pdf. U.S. Department of Agriculture, National Agricultural Statistics Service.

USDA-NASS. 2014b. Crop Production (September 2014). N.A.S.S. U.S. Department of Agriculture. http://www.usda.gov/nass/PUBS/TODAYRPT/crop0914.pdf. internal-pdf://1099409928/USDA NASS 2014 Crop Production.pdf.

USDA-NASS. 2014c. Crop Production Historical Track Records. N.A.S.S. U.S. Department of Agriculture. April 2014. ISSN: 2157-8990. http://usda.mannlib.cornell.edu/usda/current/htrcp/htrcp-04-11-2014.pdf. internal-pdf://3371218251/USDA NASS htrcp-04-11-2014.pdf.

USDA-NASS. 2014d. Quick Stats. USDA. Data Base Online Database. http://www.nass.usda.gov/Quick_Stats/. 4-8-2014.

USDA-NASS. 2015a. All Cotton Yield Graph. U.S. Department of Agriculture, National Agricultural Statistical Service,

USDA-NASS. 2015b. Crop Production 2014 Summary. N.A.S.S. U.S. Department of Agriculture. January 2015. http://www.nass.usda.gov/Statistics_by_Subject/result.php?CDC03D5A-502B-344F-9014-F3F3729512C1&sector=CROPS&group=FIELD%20CROPS&comm=COTTON. internal-pdf://3927960649/2015 Cotton Production.pdf.

USDA-NRCS. 1996. Effects of Residue Management and No-Till on Soil Quality. United States Department of Agriculture, Natural Resources Conservation Service, Soil Quality Institute.

USDA-NRCS. 1999. Conservation Tillage Systems and Wildlife. United States Department of Agriculture, Natural Resources Conservation Service, Wildlife Habit Management Institue.

USDA-NRCS. Land Capability Class, by State, 1997. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/dma/?cid=nrcs143_014040. 9-27-13.

USDA-NRCS. 2004. Soil Biology and Land Management. U.S. Department of Agriculture–Natural Resources Conservation Service. http://soils.usda.gov/sqi/publications/publications.html#atn.

USDA-NRCS. 2005. Conservation Practices that Save: Crop Residue Management. U.S. Department of Agriculture–Natural Resources Conservation Service. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_023624.pdf

USDA-NRCS. 2006a. Conservation Resource Brief: Air Quality, Number 0605. National Resources Conservation Service. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_023301.pdf

USDA-NRCS. 2006b. Conservation Resource Brief: Soil Quality. U.S. Department of Agriculture–Natural Resources Conservation Service. https://prod.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_023219.pdf.

USDA-NRCS. 2010a. 2007 National resources inventory: Soil erosion on cropland. U.S. Department of Agriculture, Natural Resources Conservation Service.

USDA-NRCS. 2010b. Conservation Practice Standard, Conservation Crop Rotation (Ac.) Code 328. U.S. Department of Agriculture–Natural Resources Conservation Service. http://efotg.sc.egov.usda.gov//references/public/MN/328mn.pdf

USDA-NRCS. 2010c. Federal Noxious Weed List. U.S. Department of Agriculture - Natural Resources Conservation Service. http://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/weedlist-2010doc.pdf

USDA-NRCS. 2011. Clean Air Act Criteria Pollutants. National Resources Conservation Service. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046188.pdf

USDA-NRCS. 2012a. Agricultural Air Quality Air Conservation Measures, Reference Guide for Cropping Systems and General Land Management,. U.S. Department of Agriculture. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1049502.pdf. National Resources Conservation Service.

USDA-NRCS. 2012b. Air: Ozone Precursors. National Resources Conservation Service. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1080890.pdf

USDA-NRCS. 2012c. Air: Particulate Matter. National Resources Conservation Service. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1080891.pdf

USDA-NRCS. 2012d. Plant profile for Gossypium barbadense. The PLANTS Database. National Plant Data Team, Greensboro, NC. Data Base Online Database. http://plants.usda.gov. November 26, 2012.

USDA-NRCS. 2012e. Plant profile for Gossypium hirsutum L. . The PLANTS Database. National Plant Data Team, Greensboro, NC. Data Base Online Database. http://plants.usda.gov. November 26, 2012.

USDA-NRCS. 2012f. United States Department of Agriculture, Natural Resources Conservation Service. Invasive and Noxious Weeds. Data Base Online Database. http://plants.usda.gov/java/invasiveOne?startChar=G. March 19, 2014.

USDA-NRCS. 2014. Common Beneficial Insects and their Habitat. Plant Materials Technical Note. *Technical Note: TX-PM-14-02*.

USDA-OCE. 2014. USDA Agricultural Projections to 2023. USDA. USDA.

USDA-OCE. 2015. USDA Agricultural Projections to 2024. I.A.P. Committee. Long-term Projections Report OCE-2015-1. http://www.usda.gov/oce/commodity/projections/USDA_Agricultural_Projections_to_2024.pdf.

USDA-Office-of-Communications. 2014. News Release. USDA Announces Measures to Help Farmers Diversify Weed Control Efforts B. Mabry, editor

USFWS. 2011. Environmental Assessment - Use of Genetically Modified, Glyphosate-Tolerant Soybeans and Corn on National Wildlife Refuge Lands in the Mountain - Prairie Region (Region 6).

USFWS. 2014a. Species List for Cotton Producing States. USFWS. http://www.fws.gov/endangered/. April 1, 2014.

USFWS. 2014b. US Threatened or Endangered Species. USFWS. http://www.fws.gov/endangered/species/us-species.html

USGCRP. 2009. Agriculture. *In* Global Climate Change Impacts in the United States. U.S. Global Change Research Program. 71-78.

Van Deynze, A.E., F.J. Sundstrom, and K.J. Bradford. 2005. Pollen-mediated gene flow in California cotton depends on pollinator activity. *Crop Science*. 45:1565-1570.

Vencill, W.K., R.L. Nichols, T.M. Webster, J.K. Soteres, C. Mallory-Smith, N.R. Burgos, W.G. Johnson, and M.R. McClelland. 2012. Herbicide resistance: Toward an understanding of resistance development and the impact of herbicide-resistant crops. *Weed Science*. 60:2-30.

Vitosh, M.L. 1996. N-P-K Fertilizers. Michigan State University Extension. http://fieldcrop.msu.edu/uploads/documents/e0896.pdf. March 7, 2014.

von Graevenitz, A. 1985. Ecology, clinical significance, and antimicrobial susceptibility encountered glucose-nonfermentative gram-negative rods. . *In* Nonfermentative gram-negative rods. . Marcel Dekker, Inc., New York, NY. 181-233.

Wang, L., J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons. 2000. Watershed urbanization and changes in fish communities in southeastern Wisconsin streams. *J. American Water Resources Association*. 36:1173-1189.

Ward, C.W., O. Isengildina, A. Flanders, and F.C. White. 2002. Efficiency of Alternative Technologies and Cultural Practices for Cotton in Georgia. *The Journal of Agrobiotechnology Management and Economics*. 5:10-13.

Webster, T.M., M. Patterson, J. Everest, K. Smith, D. Oliver, J. Norsworthy, N. Burgos, B. Scott, J. Byrd, C. Fristoe, J. Ferrell, B. Brecke, P. Minogue, A.S. Culpepper, E.P. Prostko, D.

Moorhead, J.M. Moore, J.D. Green, J.R. Martin, B. Williams, D. Stephenson, D. Miller, D. Sanders, J. Griffin, K. Bradley, A. York, D. Jordan, L. Fisher, D. Murray, M. Marshall, S. Hagood, and C. Johnson. 2009. Weed survey – Southern states 2009: Broadleaf crops subsection (cotton, peanut, soybean, tobacco, and forestry). 2009 Proceedings of the Southern Weed Science Society. Las Cruces, New Mexico.

Weersink, A., M. Walker, C. Swanton, and J.E. Shaw. 1992. Costs of conventional and conservation tillage systems. *Soil and Water Conservation*. 47:328-334.

Wen, A., Fegan, M., Hayward, C., Chakrabory, S., Sly, L., . 1999. Phylogenetic relationships among members of the Comamonadaceae, and description of Delftia acidovorans (den Dooren de Jong 1926 and Tamaoka et al. 1987) gen. nov., comb. nov. . *International Journal of Systematic bacteriology* 49:567-576.

Wendel, J., Brubaker CL, and Percival AE. 1992. Genetic Diversity in Gossypium hirsutum and the Origin of Upland Cotton. . *American Journal of Botany* 79:1291-1310.

West, T., and G. Marland. 2002. A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: comparing tillage practices in the United States. *Agriculture, Ecosystems and Environment*. 91:217–232.

Western Farm Press. 2007. More D&PL cotton varieties available in San Joaquin than ever before. Western Farm Press. http://westernfarmpress.com/more-dpl-cotton-varieties-available-san-joaquin-ever-0

Wilcut, J.W., R.M. Hayes, R.L. Nichols, S.B. Clewis, J. Summerlin, D.K. Miller, A. Kendig, J.M. Chandler, D.C. Bridges, B. Brecke, C.E. Snipes, and S.M. Brown. 2003. Weed management in transgenic cotton. North Carolina State University Agricultural Research Service, Raleigh, North Carolina.

Williams, M.R. 2013. Cotton Insect Losses - 2013. Mississippi State University. Data Base Online Database. http://www.entomology.msstate.edu/resources/croplosses/2013loss.asp. January 28, 2015.

Wilson, R.G., B.G. Young, J.L. Matthews, S.C. Weller, W.G. Johnson, D.L. Jordan, M.D. Owen, P.M. Dixon, and D.R. Shaw. 2011. Benchmark study on glyphosate-resistant cropping systems in the United States. Part 4: Weed management practices and effects on weed populations and soil seedbanks. *Pest Management Science*. 67:771-780.

Wozniak, C.A. 2002. Gene Flow Assessment for Plant-Incorporated Protectants by the Biopesticide and Pollution Prevention Division, U.S. EPA. Presented at Scientific Methods Workshop: Ecological and Agronomic Consequences of Gene Flow from Transgenic Crops to Wild Relatives. Columbus, Ohio. .

Wright, D. 2013. A.K. Weissinger. 2/26/2013.

WSSA. 2015. Herbicide Resistance. Weed-Science-Society-America Data Base Online Database. http://wssa.net/weed/resistance/.

Wunderlin, R., and B. Hansen. 2008. Atlas of Florida Vascular Plants University of South Florida, Tampa, FL.

Yang, Y., and G. Sheng. 2003. Enhanced pesticide sorption by soils containing particulate matter from crop residue burns. *Environ. Sci. Technol.* 37:3636-3639.

York, A.C. 2012. Weed Control in Cotton. NC Extension Service. http://wayne.ces.ncsu.edu/files/library/96/wayne%20co.%20york%20cotton%20grower%20meetings%202012.pdf.

York, A.C., A.M. Stewart, P.R. Vidrine, and A.S. Culpepper. 2004. Control of volunteer glyphosate-resistant cotton in glyphosate-resistant soybean. *Weed Technology* 18:532-539.

Zhao, L. 2007. Understanding Air Emissions from Animal Feeding Operations. Ohio State University Extension. http://ohioline.osu.edu/aex-fact/0721.html

Zollinger, R. 2012. Documentation for Suspected Herbicide Drift Damage. WC-751. http://www.ag.ndsu.edu/pubs/plantsci/weeds/wc751.pdf. internal-pdf://1574240540/ZOllinger 2012 ND MS reqts Drift proceedings.pdf. North Dakota State University.

Zollinger, R., M. Christoffers, G. Endres, G. Gramig, K. Howatt, B. Jenks, R. Limm, J. Stachler, A. Thostenson, and H. Valenti. 2011. 2011 North Dakota Weed Control Guide W-253. North Dakota State University Extension Service and North Dakota Agricultural Experiment Station. http://www.ag.ndsu.edu/weeds/weed-control-guides/nd-weed-control-guide-1/.

Appendix 1. Herbicide Use on Cotton

The following information was presented in APHIS' FEIS for Dicamba-Tolerant Soybean MON 87708 and Dicamba- and Glufosinate-Tolerant Cotton MON 88701 (USDA-APHIS, 2014d) and derives mainly from Monsanto's *Petitioner's Environmental Report for Dicamba-Tolerant Soybean MON 87708 and Dicamba- and Glufosinate-Tolerant Cotton MON 88701* (ER). Additional information can be obtained in the ER, which was posted by USDA as supplementary information to EIS in the Federal Register docket for that EIS:

http://www.regulations.gov/#!docketDetail;D=APHIS-2013-0043

Herbicide Use – Cotton

Herbicides are used on essentially all (>99 percent) cotton acres, and in 2011 approximately 39 million pounds of herbicides were applied pre- or postemergence in cotton production (Brookes and Barfoot, 2012; Monsanto, 2012b). According to 2010 market data[13], there were approximately 46.3 million herbicide-treated cotton acres. Herbicides were applied to 21.8 million acres prior to the planting or emergence of cotton (preemergent) and to 24.5 million acres after the emergence of cotton (postemergent). For clarification, the market survey data counts one treated acre as the application of one active ingredient (a.i.) one time to an acre. If the same a.i. is applied a second time to that same acre or if two a.i.s are applied, it counts as two treated acres. USDA reports that 11.0 million acres of cotton were planted in 2010,[14] so that the 46.3 million herbicide-treated cotton acres means that on average each planted acre received at least 4 herbicide treatments. Cotton acres also received on average four treatments with herbicides during the 2011 growing season (USDA-ERS, 2012b).

Herbicide-tolerant cotton is planted on the majority of U.S. cotton acres (73 percent in 2011), which allows for the postemergence in-crop use of glyphosate for control a broad spectrum of weeds. Glyphosate is the most widely-used herbicide in cotton, applied on 91 percent of cotton acres with an average of 2.4 applications per growing season (Monsanto, 2012b). In 2010, between 49 and 76 percent of the growers who plant glyphosate-tolerant (GT) cotton applied non-glyphosate herbicides prior to planting, at planting, or postemergence. Percentages varied among cropping systems, with 76 percent of GT cotton in a rotation system with GT soybean receiving non-glyphosate herbicide applications, whereas non-glyphosate herbicides were only applied 49 percent of the time in continuous cotton cropping systems (Prince et al., 2011a).

Over 30 different herbicide active ingredients are registered and available for use by cotton growers to control weeds. Table A-1 (from Monsanto ER Table A-33 (Monsanto, 2013a)) provides a summary of the herbicide applications registered for use in cotton in 2011, demonstrating that herbicides are used on essentially all (>99%) cotton acres in the U.S (Brookes and Barfoot, 2012; Monsanto, 2012b). Approximately 39 million pounds of herbicide active ingredient were applied to cotton in 2011.

Of these treatments, 50 percent (23.3 million acres) were made with glyphosate herbicides, and the remaining 50 percent of treatments were made with more than 25 other active ingredients. The number of glyphosate applications on an average cotton acre was between 2 and 3 applications per year at an average rate of 2.0 pounds acid equivalent (a.e.) of glyphosate active ingredient per acre per crop year.

13 Monsanto Company. 2011. Farmer Survey Data. St. Louis, MO.

14 USDA Statistics for crops and geographic regions are available at http://www.nass.usda.gov/index.asp.

Approximately 53 to 64 percent of growers used a non-glyphosate herbicide in addition to glyphosate in the GT cotton systems in 2005 (Givens et al., 2009). In 2007, approximately 39 percent of the growers often or always used herbicides with different modes-of-action in the GT cotton systems (Frisvold et al., 2009).

Non-glyphosate herbicides with different modes-of-action are also frequently used to provide residual weed control, improve control on certain weed species, and extend weed control or control resistant weed species (Prince et al., 2011a). The non-glyphosate herbicides applied on cotton in 2011, included ALS inhibitors (trifloxysulfuron, pyrithiobac), longchain fatty acid inhibitors (acetochlor, metolachlor), microtubule inhibitors (pendimethalin, trifluralin), PSII inhibitors (prometryn, fluometuron, diuron), PPO inhibitors (flumioxazin, fomesafen), synthetic auxins (2,4-D, dicamba), glufosinate, MSMA and paraquat (Monsanto, 2012b).

Table A-1. Herbicide Applications Registered for Use in Cotton in 2011[1]

Herbicide	Herbicide Family	Mode-of-Action (MOA)	Cotton Acres Treated (%)	Cotton Acres Treated per MOA (%)	Quantity Applied (1000 lb a.i.[2])	Total Quantity Applied/MOA (1000 lb a.i.[2])
Glyphosate	Glycine	EPSPS inhibitor	73	73	20,015	20,015
Pendimethalin	Dinitroanaline	Microtubule inhibitor	16	40	1,964	5,043
Trifluralin	Dinitroanaline		24		3,079	
Diuron	Urea	PSII inhibitor	15	34	1,727	3,737
Prometyrn	Triazine		10		1,102	
Fluometuron	Urea		8		870	
Linuron	Urea		<1		38	
Acifluorfen	Diphenylether	PPO inhibitor	<1	38	1	856
Carfentrazone	Triazolinone		<1		<1	
Flumiclorac	N-phenylphthalimide		<1		<1	
Flumioxazin	N-phenylphthalimide		19		192	
Fomesafen	Diphenylether		17		626	
Oxyfluorfen	Diphenylether		1		36	
Pyraflufen	Phenylpyrazole		<1		<1	
2,4-D	Phenoxy	Synthetic Auxin	17	27	1,659	2,023
Dicamba	Benzoic acid		10		364	
Pyrithiobac	Benzoate	ALS inhibitor	14	21	113	120

Table A-1. (continued). Herbicide Applications Registered for Use in Cotton in 2011[1]

Herbicide	Herbicide Family	Mode-of-Action (MOA)	Cotton Acres Treated (%)	Cotton Acres Treated per MOA (%)	Quantity Applied (1000 lb a.i. [2])	Total Quantity Applied/MOA (1000 lb a.i.[2])
Thifensulfuron	Sulfonylurea		<1		<1	
Thibenuron	Sulfonylurea		<1		<1	
Trifloxysulfuron	Sulfonylurea		6		6	
Acetochlor	Chloroacetamide	Long-chain fatty acid inhibitor	8	25	1,502	4,587
Metolachlor	Chloroacetamide		17		3,085	
Norflurazon	Pyridazinone	Inhibition of carotenoid	<1	<1	2	2
Paraquat	Bipyridylium	Photosystem-I-electron	10	10	735	735
Glufosinate-ammonium	Phosphinic acid	Glutamine synthesis	10	10	800	800
MSMA	Organoarsenical	Cell membrane disruption	6	6	1,066	1,066
Clethodim	Cyclohexanedione	ACCase inhibitor	<1	<1	3	3
Fluazifop	Aryloxphenoxy propionate		<1		<1	
Diflufenzopyr	Semicarbazone	Auxin transport	<1	<1	3	3
Clomazone	Isoxazolidinone	Diterpene synthesis	<1	<1	<1	<1
Total				99.4		38,992

[1] Updated version of Table VIII-9 of petition 12-185-01p_a1 (Monsanto, 2012a) with 2011 data (Monsanto, 2012b).
[2]lb a.i.= pounds active ingredient.

Source: Table A-33 (Monsanto, 2013a).

Dicamba is currently labeled for use in cotton although its use is limited to preplant applications due to cotton's susceptibility to dicamba. Consequently, the average application rate preplant in cotton is 0.26 pounds of dicamba per acre with one application per season. Dicamba preplant use in cotton has been on the rise in recent years, increasing from 140,000 acres in 2004, to 590,000 acres in 2008, and 1.4 million acres, or 9.6 percent of U.S. cotton acres, in 2011 (Monsanto, 2012b). This is primarily because it is a leading recommended herbicide for control of GR marestail and Palmer amaranth in the Southeast and Midsouth region (AgWatch, 2011; McClelland et al., 2006; University of Georgia, 2012)

The ten most widely used alternative herbicides in cotton in 2010 are listed in Table A-2 (ER Table B-18 (Monsanto, 2013a)) and compared to 2007 use.

Table A-2. Ten Most Widely Used Alternative Herbicides in U.S. Cotton Production

Herbicide	2007 Applications (million lb)[1]	2010 Applications (million lb)[1]
Trifluralin	2.8	3.1
Diuron	1.3	1.3
Pendimethalin	1.3	1.2
S-metolachlor	0.6	1.1
Prometryn	0.6	0.4
2,4-D, dimethylamine salt	0.3	0.4
Fluometuron	0.3	0.4
MSMA	0.4	0.3
Fomesafen	0.05	0.2
2,4-D, ethylhexyl ester	0.1	0.1

1 (USDA-NASS, 2014d)
Source: Table B-18 (Monsanto, 2013a).

Soil residual herbicides play an important role in cotton weed management by providing control of a number of weeds species that continuously germinate in cotton prior to canopy closure (Wilcut et al., 2003). Soil residual herbicides, such as pendimethalin, trifluralin, diuron, fluometuron, acetochlor, and metolachlor, are applied to more than 40% of the current cotton acres (Monsanto, 2012c). In addition, many of the soil residual herbicides are limited by application restrictions, plant-back restrictions, the need for adequate soil moisture for activation, and the need to apply prior to planting or with hooded sprayers in-crop to minimize crop injury. Approximately 20% of growers applied a fall residual herbicide to control weeds prior to planting the following spring, and 60% (continuous cotton system) to 75% (GR cotton/GR soybean rotation) applied a mixture of glyphosate and a synthetic auxin herbicide (2,4-D or dicamba) as a spring burndown application (Prince et al., 2011a). Post emergent residual herbicides, such as metolachlor and acetochlor, were applied on over 25% of cotton acres in 2010 (Monsanto, 2012c).

In glyphosate-resistant GE cotton, a total of 38 different non-glyphosate herbicides had been used in the PRE timing while 40 non-glyphosate herbicides had been used at the POST timing (Table A-3) (ER Table A-34 (Monsanto, 2013a)).

Table A-3. Non-Glyphosate Herbicides Used in Cotton from 2002-2011.

Preplant/preemergence Active Ingredients	Postemergence Active Ingredients
2,4-D	2,4-D
4-(2,4-dichlorophenoxy)butyric acid (2,4-DB)	Acetochlor
Alachlor	Acifluorfen
Bromoxynil	Alachlor
Carfentrazone-Ethyl	Bromoxynil
Clethodim	Carfentrazone-Ethyl
Clomazone	Clethodim
Cyanazine	Cyanazine
Dicamba	Dicamba
Diflufenzopyr	Dimethipin
Diuron	Diuron
Fluazifop	DSMA
Flumiclorac	Fenoxaprop
Flumioxazin	Fluazifop
Fluometuron	Flumiclorac
Fomesafen	Flumioxazin
Glufosinate	Fluometuron
Lactofen	Fomesafen
Linuron	Glufosinate
Metolachlor	Hexazinone
Metolachlor-S	Lactofen
MSMA	Linuron
Norflurazon	Metolachlor
Oxyfluorfen	Metolachlor-S
Paraquat	Metsulfuron
Pendimethalin	MSMA
Prometryn	Oxyfluorfen
Pyraflufen Ethyl	Paraquat
Pyrithiobac-Sodium	Pelargonic Acid
Quizalofop	Pendimethalin
Rimsulfuron	Prometryn
Saflufenacil	Pyraflufen Ethyl
Sethoxydim	Pyrithiobac-Sodium
Sulfosate	Quizalofop
Thifensulfuron	Rimsulfuron
Tribenuron Methyl	Sethoxydim
Trifloxysulfuron	Sulfosate
Trifluralin	Trifloxysulfuron
	Trifluralin
Total 38	**40**

Source: Table A-34, Monsanto ER (Monsanto, 2013a).

Further details on the use of non-glyphosate herbicides in cotton producing states can be found in Prince et al. (2011a; 2011b), where it is reported that approximately 50% of surveyed growers who did not have GR weeds on their farm used a non-glyphosate residual and/or postemergence herbicide in the 2009 growing season. For growers who have on-farm herbicide-resistant weed populations, the percentage of growers was higher, with 72% to 75% reporting the use of non-glyphosate herbicides. Older studies report that approximately 40 to 50% of the growers utilizing GT crops indicate that applying herbicides with different modes-of-action in sequence, rotating herbicides with different modes-of-action across the season, or tank mixing glyphosate with other herbicide modes-of-action are effective management practices to minimize the evolution and/or development of glyphosate resistance (Beckie, 2006; Beckie and Reboud, 2009; Diggle et al., 2003; Powles et al., 1996). The use of non-glyphosate herbicides in cotton production is expected to continue to increase as more growers adopt more diversified weed management strategies. Refer to Appendix A (see Monsanto ER (Monsanto, 2013a)) for details on alternative herbicides used in cotton production.

Appendix 2. Analysis of Trends of Non-Glyphosate Cotton Herbicide Use

The following information has been taken from the Monsanto document: (Monsanto, 2013a) Appendix A.

Herbicide Use with Glyphosate Resistant Cotton

This analysis utilizes unpublished grower survey data obtained from an independent, private market research company that provides farm-survey information on agricultural herbicide usage in the United States. This information reflects the most current data available on U.S. herbicide usage, and presents data on GT cotton from 2002 through 2011 to represent herbicide use after widespread adoption of GT cotton and after GR weeds had begun impacting weed control decisions in cotton cultivation. The majority of data are presented in terms of total acres treated (TAT), which is the number of acres treated with an herbicide. The use of TAT provides a way to look at herbicide use that is independent of the various use rates of herbicides. If an herbicide is used more than once on an acre, the TAT will reflect this multiple use, and consequently the TAT may exceed the number of crop acres planted. This method provides a more complete view of herbicide use.

This analysis organizes data in two broad usage sets (Table A-34): preplant/pre-emergence to the crop (PRE) and post-emergence in-crop use (POST). The PRE set are herbicides applied prior to planting the crop through planting of the crop, but before crop emergence regardless of their mode- of-activity. The POST set are herbicides applied after crop emergence regardless of their mode-of- activity. In GR cotton, a total of 38 different non-glyphosate herbicides had been used in the PRE timing while 40 non-glyphosate herbicides had been used at the POST timing (Table A-34). The total PRE and POST herbicides used in GR cotton acres from 2002-2011 are presented in Table A-4 and Table A-5 below, respectively.

Certain assumptions were made in order to define the level of herbicide use (non-glyphosate and glyphosate) in glyphosate-resistant cotton at a future time when there is peak use of dicamba in DGT [Monsanto's dicamba- and glufosinate-resistant] cotton. One of the assumptions is that total planted cotton acres will be less than the 2011 planted acres (i.e., a reduction in planted acres from approximately 14.5 million to approximately 10.5 million). Monsanto estimates an average planted acreage of 10.5 million acres per year for this analysis. Similarly, USDA (2013) predicts a decrease in cotton acreage, with projections for planted cotton acreage of 9.3 to 11.3 million acres for 2013 to 2022, with an average of 10.7 million acres per year. The predicted reduction is based on expected long-term economic conditions relative to the utilization and pricing of cotton. While acreage estimates were used to calculate the predicted herbicide use in glyphosate-resistant cotton, the comparisons between predicted herbicide use in the presence or absence of DGT cotton are similar regardless of acreage trends because the same predicted acres estimate is used for both analyses.

Table A-4. Total Treated Cotton Acres for PRE Herbicide Applications[1]

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Projected (2012-2020)
TAT non-glyphosate herbicides	7,608,153	6,973,079	8,022,758	8,278,629	10,422,198	8,619,214	7,645,112	8,720,633	13,079,934	18,532,420	15,752,557
% increase 2002-2009 and 2007-2011								15%		113%	
TAT for glyphosate only	4,794,054	4,481,055	6,085,131	6,605,653	8,160,846	5,959,715	5,020,737	4,362,308	6,133,464	6,653,710	4,790,671
Total TAT (non-glyphosate + glyphosate herbicides)	12,402,207	11,454,134	14,107,889	14,884,282	18,583,044	14,578,929	12,665,849	13,082,941	19,213,398	25,186,130	20,543,228
GR cotton planted acres[2]	10,169,767	9,694,232	10,754,975	11,282,527	11,880,216	9,058,136	7,838,072	7,732,469	9,511,862	13,016,858	
Total Planted Cotton Acres	14,380,987	13,626,965	13,869,061	14,024,973	15,113,121	10,731,987	9,308,988	9,042,201	10,801,010	14,533,017	10,500,000

[1] Unpublished grower survey data (Monsanto, 2012).

[2] Estimated.

Table A- 5. Total Treated Cotton Acres for POST Herbicide Applications[1]

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Projected (2012-
Total TAT non-glyphosate herbicides	4,666,015	4,119,878	4,864,283	4,625,240	5,513,925	2,941,420	3,303,968	3,734,015	6,341,041	11,018,661	9,365,862
% increase 2002-2007 and 2007-2011								-20%		220%	
TAT for glyphosate only	15,663,805	14,563,604	17,877,154	19,609,494	16,647,267	13,536,614	11,128,357	12,128,747	16,761,716	15,615,631	11,243,254
Total TAT (non-glyphosate + glyphosate herbicides)	20,329,820	18,683,482	22,741,437	24,234,734	22,161,192	16,478,034	14,432,325	15,862,762	23,102,757	26,634,292	20,609,116
GT Cotton planted acres[2]	10,169,767	9,694,232	10,754,975	11,282,527	11,880,216	9,058,136	7,838,072	7,732,469	9,511,862	13,016,858	
Total Planted Cotton acres	14,380,987	13,626,965	13,869,061	14,024,973	15,113,121	10,731,987	9,308,988	9,042,201	10,801,010	14,533,017	10,500,000

[1] Unpublished grower survey data (Monsanto, 2012).
[2] Estimated.

Analysis of PRE Cotton Herbicide Use From 2002-2011

The use of non-glyphosate herbicides included in the PRE set is influenced by use of conservation tillage (*i.e.*, reliance on herbicides to control emerged weeds prior to crop planting) and use of residual herbicides applied preplant and/or preemergent to crop emergence. The use of non- glyphosate PRE herbicides in glyphosate-resistant cotton was relatively flat from 2002 through 2009 with only a 15% increase in TAT between 2002 and 2009 (Figure A-1 and Table A-5). In 2009, glyphosate-resistant cotton was grown on 7.7 million acres. In the PRE segment, the primary non- glyphosate herbicides used were those providing postemergence control of broadleaf weeds (*e.g.*, 2,4-D, paraquat), preplant (*e.g.*, trifluralin, fomesafen, flumioxazin) or preemergence (*e.g.*, pendimethalin) control. From 2009 to 2011 there was a 113% increase in the use of non-glyphosate herbicides in the glyphosate-resistant cotton PRE segment. In 2011, glyphosate-resistant cotton was grown on approximately 13 million acres, a 68% increase from 2009. This data suggests that the growth in non-glyphosate herbicide use was not driven just by an increase in the total planted acres of glyphosate-resistant cotton. This increase in use of non-glyphosate herbicides in the 2009-2011 time period is consistent with the increased emphasis by public and private sectors promoting more diversified weed management and also the increase in emergence of glyphosate-resistant weeds during the same time period. Regarding future use of non-glyphosate herbicides, this analysis projects that non-glyphosate herbicide use will decrease 15% (a decrease from 18.5 million TAT to approximately 15.8 million), primarily due to an overall decrease in planted acres, even though use of non-glyphosate herbicides will increase, particularly in the western cotton markets, regardless of the commercialization of DGT cotton. Of the planted glyphosate-resistant cotton acres in 2011, approximately 65% received a non-glyphosate PRE herbicide application (Table A-6). The number of glyphosate applications per planted acre of glyphosate-resistant cotton in the PRE segment has remained flat from 2002 through 2011. This figure is not expected to change in the foreseeable future regardless of the commercialization of DGT cotton (Table A-6). However, as indicated above, the total use of glyphosate per year is expected to decrease due to a projected decrease in cotton acres.

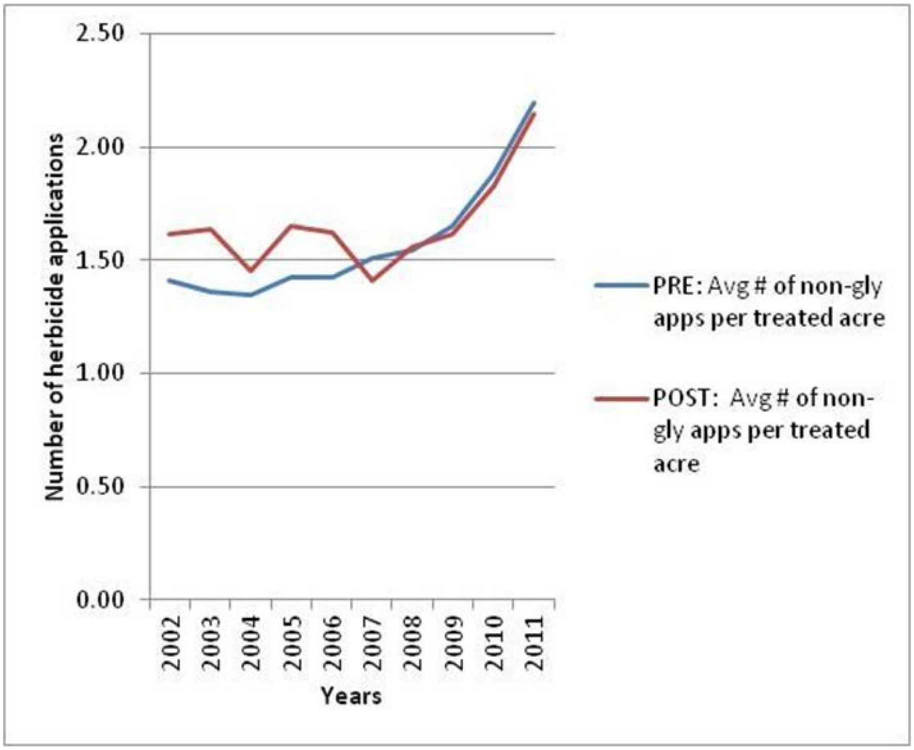


Figure A-1. Average Number of Preplant/Preemergence and Postemergence Non-Glyphosate Herbicide Applications in Cotton, 2002-2011,

Table A-6. Total Treated Cotton Acres for PRE Herbicide Applications[1]

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Projected (2012-2020)
TAT non-glyphosate herbicides	7,608,153	6,973,079	8,022,758	8,278,629	10,422,198	8,619,214	7,645,112	8,720,633	13,079,934	18,532,420	15,752,557
% increase 2002-2009 and 2007-2011								15%		113%	
TAT for glyphosate only	4,794,054	4,481,055	6,085,131	6,605,653	8,160,846	5,959,715	5,020,737	4,362,308	6,133,464	6,653,710	4,790,671
Total TAT (non-glyphosate + glyphosate herbicides)	12,402,207	11,454,13	14,107,88	14,884,282	18,583,044	14,578,929	12,665,849	13,082,941	19,213,398	25,186,130	20,543,228
GR cotton planted acres[2]	10,169,767	9,694,232	10,754,97	11,282,527	11,880,216	9,058,136	7,838,072	7,732,469	9,511,862	13,016,858	
Total Planted Cotton acres	14,380,987	13,626,96	13,869,06	14,024,973	15,113,121	10,731,987	9,308,988	9,042,201	10,801,010	14,533,017	10,500,000

Table A-7. Cotton Base Acres and Average Number of PRE and POST Herbicide Applications in Cotton from 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Preplant/Preemergence Segment										
Base Acres non-gly	5,393,689	5,114,256	5,964,796	5,796,824	7,301,901	5,700,249	4,950,783	5,278,197	6,927,575	8,445,599
% of GR planted acres	53%	53%	55%	51%	61%	63%	63%	68%	73%	65%
Avg # of non-gly apps per treated acre	1.41	1.36	1.35	1.43	1.43	1.51	1.54	1.65	1.89	2.19
Base Acres gly	4,206,852	3,944,302	5,015,080	5,139,869	6,244,992	4,840,283	4,113,912	3,737,966	5,022,647	5,632,286
% of GR planted acres	41%	41%	47%	46%	53%	53%	52%	48%	53%	43%
Avg # of gly apps per treated acre	1.14	1.14	1.21	1.29	1.31	1.23	1.22	1.17	1.22	1.18
Postemergence Segment										
Base Acres non-gly	2,893,224	2,511,625	3,347,572	2,799,905	3,390,985	2,088,573	2,122,123	2,311,575	3,462,215	5,128,952
% of GRplanted acres	28%	26%	31%	25%	29%	23%	27%	30%	36%	39%
Avg # of non-gly apps per treated acre	1.61	1.64	1.45	1.65	1.63	1.41	1.56	1.62	1.83	2.15
Base Acres gly	9,648,772	9,172,346	10,429,110	10,838,740	10,620,351	8,743,094	7,348,278	7,269,956	9,282,857	9,428,994
% of GR planted acres[2]	95%	95%	97%	96%	89%	97%	94%	94%	98%	72%
Avg # of gly apps per treated acre	1.62	1.59	1.71	1.81	1.57	1.55	1.51	1.67	1.81	1.66
GT cotton planted acres[2]	10,169,767	9,694,232	10,754,975	11,282,527	11,880,216	9,058,136	7,838,072	7,732,469	9,511,862	13,016,858
Total cotton planted acres	14,380,987	13,626,965	13,869,061	14,024,973	15,113,121	10,731,987	9,308,988	9,042,201	10,801,010	14,533,017

Analysis of POST Cotton Herbicide Use From 2002-2011

The use of herbicides from 2002 to 2011 was primarily influenced by the need to control weeds after they emerged in the crop or to extend the preemergence residual control of weeds longer into the growing season. As in the case of non-glyphosate PRE herbicides, the use of non-glyphosate POST herbicides applied in glyphosate-resistant cotton was flat to slightly reduced use from 2002 to 2009 (Figure A-1 and Table A-7). However, from 2009 to 2011 there was a 220% increase in TAT for the use of non-glyphosate POST herbicides in glyphosate-resistant cotton. In 2009, glyphosate- resistant cotton was grown on approximately 7.7 million acres, while in 2011 there were approximately 13 million planted acres, a 68% increase. As in the case for the PRE herbicides, these data indicate that the increase in non-glyphosate herbicide use was not solely related to an increase in planted glyphosate-resistant cotton acres. The increased use of non-glyphosate POST herbicides after 2009 is evidence of increased adoption of diversified weed management practices by farmers. These outcomes are consistent with farmer adoption of recommendations from the public and private sectors on how best to proactively and reactively manage weed resistance. Regarding future use of non-glyphosate herbicides in the POST segment, there will be an expected net 15% decrease, primarily due to a decrease in the planted acres of cotton, even though there will be increased use in certain market segments. In 2011, approximately 39% of glyphosate-resistant cotton acres received a non-glyphosate POST herbicide application (Table A-7). The number of glyphosate applications per planted acre of glyphosate-resistant cotton in the POST segment has remained flat from 2002 through 2011. This figure is not expected to change in the foreseeable future regardless of the commercialization of DGT cotton (Table A-7). However, as indicated above, total use of glyphosate per year is expected to decrease.

Table A-8. Total Treated Cotton Acres for POST Herbicide Applications[1]

	2002	2003	2004	2005	2006	2007	2008	2009
Total TAT non-glyphosate herbicides	4,666,015	4,119,878	4,864,283	4,625,240	5,513,925	2,941,420	3,303,968	3,734,015
% increase 2002-2007 and 2007-2011								-20%
TAT for glyphosate only	15,663,805	14,563,604	17,877,154	19,609,494	16,647,267	13,536,614	11,128,357	12,128,747
Total TAT (non-glyphosate + glyphosate herbicides)	20,329,820	18,683,482	22,741,437	24,234,734	22,161,192	16,478,034	14,432,325	15,862,762
GR Cotton planted acres[2]	10,169,767	9,694,232	10,754,975	11,282,527	11,880,216	9,058,136	7,838,072	7,732,469
Total Planted Cotton acres	14,380,987	13,626,965	13,869,061	14,024,973	15,113,121	10,731,987	9,308,988	9,042,201

1 Unpublished grower survey data (Monsanto, 2012).

2 Estimated.

Appendix 3. Dow's Estimate of Future Enlist Duo Use and Planting of DAS-81910-7 Cotton[15]

2

[15] Received by APHIS from Dow AgroSciences: DAS. (2014). "Estimate of Possible Herbicide Increase upon Introduction of DAS-8191Ø-7 Cotton ".

Estimate of Possible Herbicide Increase upon Introduction of DAS-8191Ø-7 Cotton

Introduction of New Technology

Dow's premix of 2,4-D choline + glyphosate (Enlist Duo) is currently under regulatory review at the Environmental Protection Agency (EPA) for use on DAS-40278-9 corn and DAS-68416-6 soybean [and has been subsequently approved]. Dow filed a label amendment and tolerance petition in July 2014 to extend the use of Enlist Duo to Enlist Cotton.

Enlist Duo features proprietary Colex-D™ Technology. Prominent attributes of this technology are a greatly reduced volatility and drift profile, very low odor, and improved handling characteristics (MRID 48862902 and 48844001). Enlist Duo is formulated as an approximate 1:1 ratio of 2,4-D choline:glyphosate.

The new use directions to be considered by EPA for Enlist Duo will allow a preemergent (burn down) application of up to 0.5-1 lb acid equivalents/acre (ae/ac) of 2,4-D (and glyphosate) and up to two applications (0.5-1 lb 2,4-D ae/ac each, and glyphosate) post-emergent through the bloom stage (ending at mid-bloom) (Figure A-2). Total seasonal use is limited to a total of 3 lbs 2,4-D ae/ac/season. DAS-81910-7 cotton will also tolerate applications of the herbicide glufosinate which is typical of existing, commercially-available glufosinate-resistant cotton.

Current 2,4-D Use Pre-plant in Cotton

While there is currently no EPA-approved use of 2,4-D on conventional cotton, the 2,4-D label permits use for pre-plant weed control (burn down), in accordance with label instructions. For example, Dow's DMA 4 Master Label provides specific use directions for control of broad leaf weeds in fallow land, at rates of 1-2 pints/acre for annual broadleaf weeds, or 0.5-1.0 lb acid equivalent/acre. The label states that planting of all non-labeled crops must not occur until 30 days after application.

Current cotton acreage is estimated by USDA at approximately 10.2 million acres (USDA-NASS 2013). 2,4-D for burn down is currently used on approximately 11.6% of cotton acres (Table A-8). When 2,4-D is utilized in a burn down or pre-plant treatment, it is generally combined in a tank mix with glyphosate or other non-selective herbicide and, when tank-mixed, 2,4-D is generally recommended at the lower end of the rate range of about 0.5 lbs ae/ac (Ohio State University Extension Weed Control Guide, 2014). 2,4-D is currently labeled for a single pre-plant application at 0.35 to 1 lbs ae/ac.

From 2008-2012, use of 2,4-D for pre-plant burn down has grown in total acres and in percentage of acres treated. This is likely due to an increase in glyphosate-resistant and hard-to-control weeds.

Table A-9. 2,4-D Pre-Plant Use in Cotton.

Year	Total Acres	Acres Treated with 2,4-D	Treated Acres % of Total Acres	Total Pounds 2,4-D	Pounds 2,4-D /Acre	Total Applications/ Acre
2010	10,700,000	1,373,815	12.4	858,153	0.62	1.03
2011	14,428,000	2,432,079	16.7	1,624,332	0.67	1.01
2012	12,076,000	2,266,383	16.9	1,579,914	0.70	1.11
2013	10,206,000	1,590,419	14.6	1,084,037	0.68	1.07

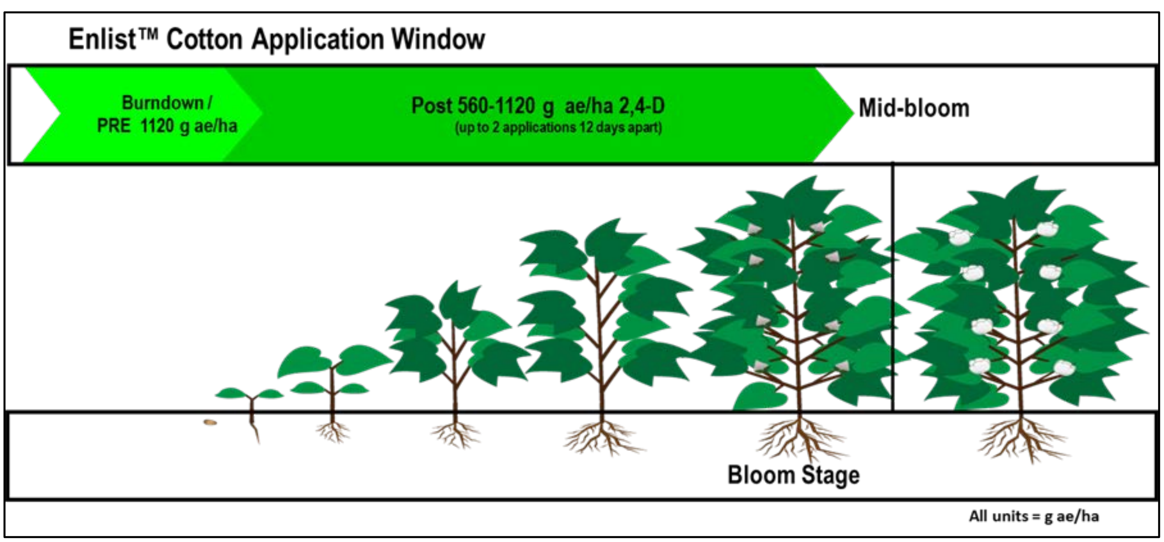
Estimated Application Rates of 2,4-D Choline on DAS-81910-7 Cotton

If Enlist Duo herbicide were approved for use on DAS-81910-7 cotton, the resulting use pattern of 2,4-D choline on DAS-81910-7 cotton could be:

- A single ~1.0 lb 2,4-D ae/ac pre-emergent application;
- Up to two post-emergent applications each up to 1.0 lb 2,4-D ae/ac.

Thus, under this scenario, use of Enlist Duo herbicide on DAS-81910-7 cotton would be authorized for a total possible seasonal use of up to 3 lbs ae/ac of 2,4-D choline (Figure A-2). Utilizing data demonstrating the current and broad use of glyphosate on cotton and field trial data on weed control with various herbicide application rates, DAS has estimated that farmers who grow DAS-81910-7 cotton will use an average of 0.875 lbs 2,4-D ae/ac/application with an average of 1.54 applications per season, including burn down and post emergent applications. The application rate (0.875 lbs 2,4-D ae/ac) is the midpoint between the medium and high rates allowed on the currently proposed Enlist Duo label and is consistent with the glyphosate rate needed for weed control. As Enlist Duo contains about a 1:1 ratio of 2,4-D and glyphosate, nearly identical rates of glyphosate will be applied.

Figure A-2. 2,4-D Use Pattern in Enlist Herbicide Resistant Cotton.

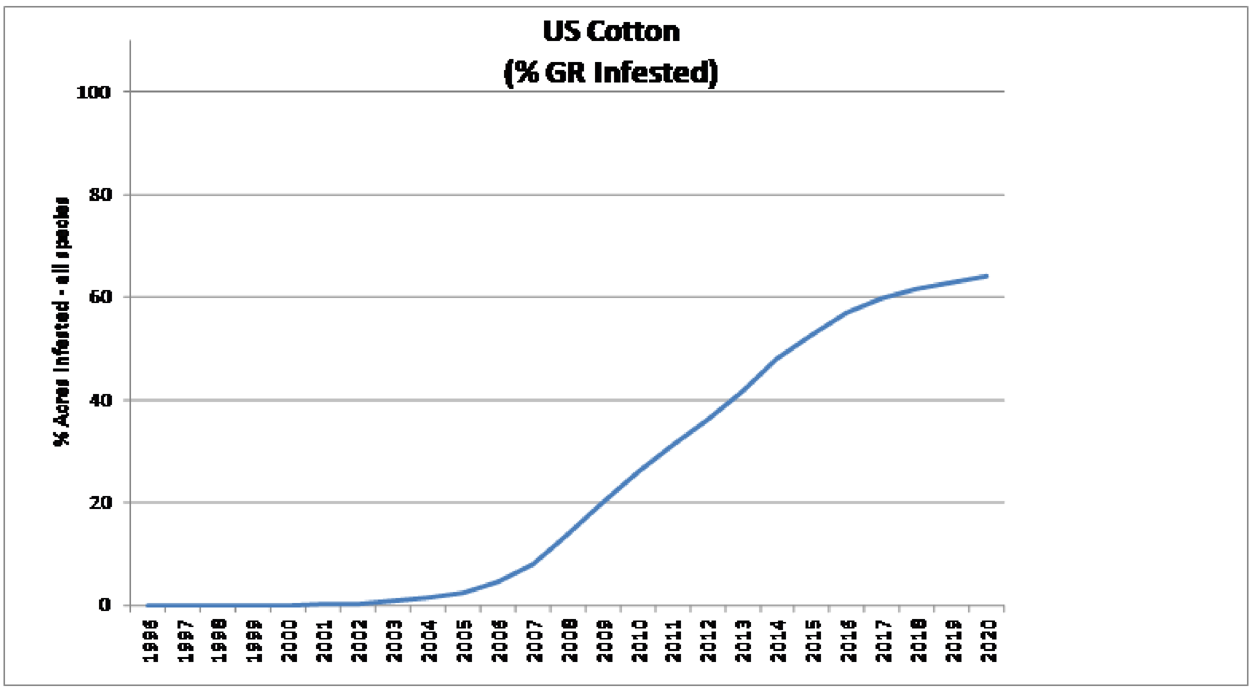


2,4-D Choline Salt Estimated Use on DAS-81910-7 Cotton

Estimating total acres of DAS-81910-7 cotton planted and accompanying use of Enlist Duo has inherent accuracy limitations; thus it is not possible to make predictions with certainty. Nevertheless, Dow has derived three scenarios to estimate the potential use of 2,4-D on DAS-81910-7 cotton after deregulation and commercialization:

2,4-D: ***Scenario One.*** The first scenario assumes that growers will only apply Enlist Duo to DAS-81910-7 cotton where growers are facing or actively trying to prevent the establishment of glyphosate-resistant weeds. Additionally this also assumes that all farmers with cotton acres that have glyphosate-resistant weeds will plant DAS-81910-7 cotton and will use Enlist Duo herbicide (a very aggressive assumption due to other weed control options available). Using third party market data, Dow has estimated that 25 percent of U.S. cotton acreage had glyphosate-resistant weeds in 2010, and that the percentage could grow to 52% of cotton acreage by 2015 and to 62 percent by 2020 (Figure A-3).

Figure A-3. Projected Cotton Acres Infested with Glyphosate-Resistant Weeds.



Assuming that minimal additional acreage would be treated to prevent establishment of glyphosate-resistant weeds, and using the assumptions set forth above regarding total cotton acres, application rates and applications per season, the following formula was used to calculate total lbs of 2,4-D ae that might be used on DAS-81910-7 cotton:

> 10.2 M acres x 62% resistant weed acres (in 2020) x .875 lbs 2,4-D ae/ac/application x 1.54 applications/year = 8.5 M lbs 2,4-D ae per year. This is an increase of about 7.4 M lbs per year, approximately a 7.9-fold increase in 2,4-D use in 2020 compared to the current yearly use of 2,4-D pre-plant in cotton.

2,4-D: ***Scenario Two.*** The second scenario assumes, for purposes of this discussion, that all acres of DAS-81910-7 cotton would receive applications of Enlist Duo, regardless of weed control need, and thus relies on estimates of what the projected market share of DAS-81910-7 cotton will be:

Of the current 10.2 M acres of U.S. cotton, Dow has approximately a 20 percent market share. At this time, Dow is not planning to breed DAS-81910-7 cotton into all of its cotton varieties. Thus, it is expected that DAS-81910-7 cotton would occupy less than Dow's current 20% of the market. For purposes of this estimate, 20% will be used as a minimum potential DAS-81910-7 cotton acreage. Through natural growth and potential future license agreements, Dow estimates that up to 45% of the cotton germplasm could carry the Enlist trait.

Due to the technical aspects of cotton seed breeding, rapid improvement of germplasm and stacking with other traits, this level of adoption of DAS-81910-7 cotton is estimated to take 5-10 years to reach maturity, which is consistent with other current herbicide resistant traits. Application rates of 2,4-D are as described above: an average of 0.875 lbs ae/ac/application with 1.54 applications per year.

Utilizing the data and assumptions stated in this scenario, the estimated range of acreage and 2,4-D volume can be estimated as follows:

> 10.2 M acres x 45% market share x 0.875 lbs 2,4-D ae/ac/application x 1.54 estimated applications per year = 6.2 M lbs 2,4-D ae per year. This is an increase of about 5.1 M lbs, approximately a 5.7 fold increase in 2,4-D compared to current yearly 2,4-D use pre-plant in cotton.

2,4-D: ***Scenario Three*****:** The third scenario assumes that all current glyphosate-resistant cotton acres would be planted to hybrids that also contain the DAS-81910-7 cotton trait. This is a high estimation of adoption rate, taking at least 5-10 years to achieve, but provides an upper confidence level on 2,4-D volume. While DAS-81910-7 cotton will be stacked with a glyphosate-resistant trait, it is impractical to assume that all glyphosate-resistant traits will be stacked with DAS-81910-7 cotton due to competing offerings by other seed companies and the likelihood of other herbicide-tolerant cotton options. Due to one developing technology that will be a direct competitor to Enlist, at least 32% of the market will not contain the DAS-81910-7 cotton trait. Therefore, 3.3 M acres can be subtracted from the 10.2 M acre total cotton acreage, leaving 6.9 M acres of the 10.2 M total cotton acres planted to a variety containing the DAS-81910-7 cotton trait under this scenario. Using the same application information and other assumptions identified in the previous two scenarios, 2,4-D volume can be estimated as follows:

> 6.9 M glyphosate-resistant acres x 0.875 lbs 2,4-D ae/ac/application x 1.54 estimated applications per year = 9.3 M lbs 2,4-D per year. This is an increase of about 8.2 lbs, approximately a 8.6 fold increase in 2,4-D use on cotton compared to the current yearly use of 2,4-D pre-plant in cotton.

Conclusion

Dow has provided these estimates as examples of possible increased use of 2,4-D associated with commercialization of DAS-81910-7 cotton (Enlist cotton) and subsequent EPA registration of Dow' Enlist Duo for use on DAS-81910-7 cotton. These calculations are good-faith estimates based on best available data and projections (current cotton acreage, market share, and weed resistance trends), and thus are not guarantees.

Appendix 4. Common Weeds in Cotton

Common Weeds in Cotton and Soybean

Weed species emerge in a particular order throughout the year with each species having one or more periods of high emergence. The initial emergence date can vary from year to year, but the order stays relatively constant. Weed emergence timing can dictate which weeds will be the most problematic in a specific crop production or be more easily controlled by a weed management practice (Buhler *et al.*, 2008). Table A-9 shows the problem weeds in cotton and soybean.

Table A-10. Summary of Problem Weeds Affecting Cotton and Soybean.

Broadleaf Weeds			Grass Weeds		
Cotton + Soybean	**Cotton**	**Soybean**	**Cotton + Soybean**	**Cotton**	**Soybean**
Browntop millet	Bindweed	Wild buckwheat	Barnyard grass	Bermuda grass	Fall Panicum
Cutleaf primrose	Black nightshade	Burcucumber	Crabgrass	Crowfoot grass	Quackgrass
Florida beggerweed	Common cocklebur	Canada thistle	Cupgrass	Large crabgrass	
Florida pusley	Common lambsquarter	Chickweed	Johnsongrass		
Foxtail	Common purslane	Cockeburr	Goose grass		
Ground Cherry	Common ragweed	Copperleaf hophorn	Broadleaf signal grass		
Hemp sesbania	Devil's claw	Dandelion			
Henbit	Hairy Nightshade	Honeyvine milkweed			
Horseweed	Junglerice	Eastern black nightshade			
Jimson weed	Palmer amaranth	Hairy nightshade			
Kochia	Red Sprangletop	Wild oats			
Lambsquarter	Russian thistle	Common pokeweed			
Morning Glory	Shepardspurse	Wild proso millet			
Mustard	Smellmelon	Common ragweed			
Nutsedge	Sprangletop	Giant ragweed			
Palmer pigweed	Spurred anoda	Field sandbur			
Prickly sida	Texas blueweed	Shattercane			
Pigweed	Volunteer peanut	Venice mallow			
Sicklepod	Volunteer corn	Volunteer cereal			
Smart weed	Field bindweed	Waterhemp			
Spurge	Horse purslane	Tropic croton			
Sunflower	Woolyleaf bursage				

Broadleaf Weeds			Grass Weeds		
Cotton + Soybean	**Cotton**	**Soybean**	**Cotton + Soybean**	**Cotton**	**Soybean**
Texas millet	Silverleaf nightshade				
Velvet leaf					
Volunteer Corn					

Source: (Monsanto, 2013a).
Notes:
Green: Weeds managed in both corn and soybean
Yellow: Weeds primarily managed in corn
Blue: Weeds primarily managed in soybean

Additional lists by state of the most common and troublesome weeds are compiled for an eight-state region for cotton (Southern Weed Science Society, 2013). Palmer amaranth is noted by seven states as the most troublesome weed of cotton, with morning glory weed as a next most troublesome in many states.

Key Herbicide Resistant Weeds of Cotton.

Problem weeds in cotton often are those with herbicide resistance. Table A-10 showing which weeds have resistance to two or more herbicides was compiled in 2006 (Burgos 2006).

Table A-11. Common Herbicide-Resistant Weeds Found in Cotton.

Weed Species	ACCase[1] Resistant	ALS Resistant	Dinitro Aniline Resistant	Glyphosate Resistant
Palmer amaranth	No	Yes	Yes	Yes
Common cocklebur	No	Yes	No	No
Common ragweed	No	Yes	No	Yes
Horseweed	No	Yes	No	Yes
Goosegrass	Yes[2]	No	Yes	Yes[2]
Johnsongrass	Yes	No	No	Yes[2]
Ryegrasses	Yes	Yes	No	Yes
Common waterhemp[3]	No	Yes	No	Yes
Giant ragweed[4]	N/A	Yes	N/A	Yes

From Burgos et al. (2006)

1. Resistance to the indicated Mode of Action. See Table 1.
2. Resistant biotypes of these weeds not found in the U.S.
3. From Baumann (2003).
4. Barnett and Steckel (2013).

References

Barnett, Kelly A. and Steckel, Lawrence E. (2013). Giant Ragweed (Ambrosia trifida) Competition in Cotton. Weed Science 61(4):543-548.

Baumann, 2003. Common waterhemp - not your average careless weed. Texas Cooperative Extension, http://cotton.tamu.edu/Weeds/Common%20Waterhemp.pdf

Buhler, DD; Hartzler, RG; Forcella, F; and Gunsolus, JL (2008) "Relative emergence sequence for weeds of corn and soybeans." http://www.extension.iastate.edu/Publications/SA11.pdf.

Burgos, N.R., Culpepper, A.S., Dotray, P.A., Kendig, J.A., Wilcut, J.W., Nichols, R.L. (2006) Managing herbicide resistance in cotton cropping systems. Bulletin. Cotton Inc. http://www.cotton.org/tech/pest/upload/07CIweedresistbulletin.pdf

Monsanto (2013) "Petitioner's Environmental Report for Dicamba-Tolerant Soybean MON 87708 and Dicamba and Glufosinate Tolerant Cotton MON 88701."

Nilda Burgos, Stanley Culpepper, Peter Dotray, J. Andrew Kendig, John Wilcut, Robert Nichols, (2006) Managing Herbicide Resistance in Cotton Cropping Systems, http://cotton.tamu.edu/Weeds/ManagingHerbicideResistance.pdf

Southern Weed Science Society (2013) Proceedings, Southern Weed Science Society, Volume 66:275-287 http://www.swss.ws/wp-content/uploads/2013/09/Southern-Weed-Survey-2013-Tables-BL-Crops.pdf