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MEMORANDUM

SUBJECT: Sulfonylurea Herbicides: Usage, Response to Comments, Herbicide Resistance Management Measures and Grower Impacts from Potential Risk Mitigation Measures

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SULFONYLUREA HERBICIDES: USAGE, RESPONSE TO COMMENTS, HERBICIDE RESISTANCE MANAGEMENT MEASURES, AND GROWER IMPACTS FROM POTENTIAL RISK MITIGATION MEASURES

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SUMMARY

Twenty-two of the sulfonylurea herbicides are currently undergoing registration review in the Office of Pesticide Programs (OPP) and are being evaluated as a group. No human health risks of concern have been identified. Ecological risks of concern have been identified only for terrestrial plants and both vascular and non-vascular aquatic plants. To mitigate these risks OPP is considering measures to address spray drift.

The sulfonylurea herbicides are currently used on millions of acres in the U.S. This document describes the use and usage of each of these chemicals and evaluates the impacts of potential risk mitigation measures being considered (*e.g.,* spray drift requirements, in-field buffers, and vegetative buffer strips). It also summarizes comments on benefits and usage placed into the individual dockets, and describes measures that could be taken to slow the development and spread of sulfonylurea resistant weeds.

Several of the spray drift management requirements (such as spray release height and wind speed restrictions) are not likely to produce grower impacts as these measures are current practice for applicators. However, requiring droplet sizes greater than medium spray droplets to be used during application will reduce the efficacy of some of these herbicides. The magnitude of the impacts from this requirement will vary based on active ingredient, application method, target species, use site, and current droplet size used. For some use sites, where very or extremely coarse spray droplets are currently being used with some of the sulfonylurea herbicides (e.g., metsulfuron-methyl in forestry), the impact is expected to be negligible. For crops with target weeds that necessitate fine or medium spray droplet size for effective weed control by certain sulfonylurea herbicides, the impacts will be much greater. Grower response to reduced sulfonylurea performance could include increasing the application rate for a given sulfonylurea (if allowed by the label), increasing the number of applications, increasing the application rates of tank mix partners, making additional herbicide applications with other herbicides, or changing to a different herbicide(s). This change in droplet size may also require the purchase of additional equipment such as nozzle bodies, tips, new pumps, larger spray tanks, or nurse tanks if higher gallons per acre of carrier are used. Further, some sulfonylurea products are co-formulated or tank mixed with other herbicides that require small droplet size to be efficacious. These products would not be usable if application with extremely coarse droplet size is required.

As an option to mitigate off-site movement, BEAD also evaluated in-field buffers, located on one side of the field next to the downwind edge of the field adjacent to sensitive habitats. Even small one-sided in-field buffers will potentially result in significant impacts for many crops. The distribution of agricultural field sizes are strongly skewed toward small field sizes (i.e. a large proportion of fields are small). Buffers may impact a relatively small number of acres, but will affect the majority of fields in a given crop. For fields at the 10th percentile or smaller (based on acreage), the lowest impact for a 50 foot buffer could be $32 lost per acre for wheat while the greatest impact could be $2,650 per acre for apples.

Not only would implementing in-field buffers be costly because of reduced crop production, but growers would need to manage the space taken out of production to reduce the encroachment of undesirable plant species - and habitat for pathogens and deleterious insects - into their agricultural fields. Based on work in California and Maryland it is estimated that it costs between $160 to $750 dollars per acre to establish a vegetative buffer strip depending on the amount of soil preparation required and type of crop to be planted. Yearly maintenance costs are estimated to be $40 to $240 per acre (for mowing or weed control applications).

The likelihood of the development of herbicide resistance increases with the reduction in the effective dosage of the herbicide that reaches its target site in the plant. Repeated applications of sub-lethal concentrations of herbicides, due to extremely coarse droplets, tends to remove the sensitive individuals in the population and leave the resistant individuals. Therefore, in the next generation the seed left in and on the soil have a higher percentage of resistant individuals. Sulfonylurea herbicides are of high concern for the development of herbicide resistance. Measures to help slow the development of herbicide resistance, and to manage it when identified, are described in the section on proposed herbicide resistance management measures.

I. BACKGROUND

FIFRA Section 3(g) mandates that EPA periodically review the registrations of all pesticides to ensure that they do not pose unreasonable adverse effects to human health and the environment. This periodic review is necessary in light of scientific advancements, changes in policy, and changes in use patterns that may alter the conditions underpinning previous registration decisions. In determining whether effects are unreasonable, FIFRA requires that the Agency consider the risks and benefits of any use of the pesticide.

Sulfonylurea herbicides inhibit acetolactate synthase (ALS), also called acetohydroxy acid synthase (AHAS), a key enzyme in the biosynthesis of the branched-chain amino acids isoleucine, leucine, and valine (LaRossa and Schloss 1984). Plant death in the weeds being targeted results from events occurring in response to ALS inhibition and low branched-chain amino acid production.

General agricultural usage data for 22 sulfonylurea herbicides is summarized in Table 1. Usage by crop for each chemical is presented in Section VIII. Many of the sulfonylurea herbicides are used in non-agricultural settings and these are listed in Table 2 along with the estimated pounds of active ingredient applied in these settings.

Table 1. Five Year Average Annual Application Rate, Acres Treated and Pounds Applied for 22 Sulfonylurea Herbicides Used in Agricultural Settings, 2009-2013.[1]

Active Ingredient*	Average Application Rate (pounds of active ingredient applied per acre)	Average Annual Total Acres Treated	Average Annual Pounds of Active Ingredient Applied
Thifensulfuron-methyl	0.009	14,190,600	128,900
Chlorimuron-ethyl	0.017	11,626,700	196,700
Metsulfuron-methyl	0.004	10,908,600	48,600
Tribenuron-methyl	0.006	9,488,700	54,900
Rimsulfuron	0.018	5,597,700	101,800
Chlorsulfuron	0.011	4,566,600	52,200
Triasulfuron	0.016	1,772,400	28,500
Nicosulfuron	0.020	1,577,800	32,000
Halosulfuron-methyl	0.028	1,256,800	35,800
Mesosulfuron-methyl	0.007	865,300	6,200
Prosulfuron	0.015	714,000	10,900
Trifloxysulfuron-sodium	0.008	619,600	5,200
Sulfosulfuron	0.027	473,700	12,600
Iodosulfuron-methyl-sodium	0.002	353,800	600
Bensulfuron-methyl	0.031	228,600	7,100
Primisulfuron-methyl	0.022	228,300	5,100
Triflusulfuron-methyl	0.010	100,600	1,000
Foramsulfuron **	0.029	86,600	2,500
Orthosulfamuron	0.061	44,200	2,700
Imazosulfuron***	0.169	28,000	4,700
Flazasulfuron****	0.045	500	25

Source: Market Research Data, 2009-2013.

* Sulfometuron-methyl usage information is limited to industrial vegetation (i.e., non-agricultural use sites), Table 2.

** Foramsulfuron was cancelled on all agricultural (corn) sites in 2015. Numbers presented represent corn usage before the cancellation.

*** Imazosulfuron was registered in late 2010.

****Flazasulfuron usage only appears in one year (2013). Total area treated in 2014 was about 22,000 acres.

[1] Usage data based on Market Research data (user surveys), 2009-2014. Average Application Rate is the application rate calculated by dividing the total pounds applied by the Total Area Treated of the chemical. Average Annual Total Acres Treated and Average Annual Pounds of Active Ingredient Applied is calculated by the sum of acre or pounds and dividing by the number of years. All numbers for Acres Treated and Pounds Applied are rounded to the nearest hundred when possible. Sulfometuron-methyl is limited to industrial vegetation and not included in Table 1.

Table 2. Sulfonylurea Herbicide Usage Reported for Non-Agricultural Sites 2011.

Active ingredient	Landscape, Nursery, and Turf (Pounds active ingredient)	Forestry, Pasture, Rights-of-Way, and utilities (Pounds active ingredient)
Chlorsulfuron	Usage not reported	35,700
Halosulfuron-methyl	1,000	Usage not reported
Foramsulfuron	1,200	Usage not reported
Metsulfuron-methyl	16,000	116,500
Sulfosulfuron	1,400	31,000
Sulfometuron methyl	300	114,800
Trifloxysulfuron-sodium	1,400	Usage not reported

Source: Kline, 2012a and b. These are the most recent data available. Information on the number of acres treated was not provided in this report. Note that other SUs are registered for these sites, but no usage were reported for flazasulfuron, imazosulfuron, and iodosulfuron-methyl.

II. ORGANIZATION OF THE DOCUMENT

This document first provides a general overview of the sulfonylurea herbicides, followed by a summary of the identified risks of concern and potential risk mitigation measures. Next, the potential impact of these potential measures are estimated. Herbicide resistance management measures are then described. This is followed by a section providing a response to general comments received during the comment period for the sulfonylurea preliminary risk assessments and finally, each sulfonylurea herbicide is discussed. This discussion includes a response to the active ingredient specific comments received.

III. OVERVIEW OF THE SULFONYLUREA HERBICIDES

The sulfonylurea herbicides (SUs) are a class of herbicides that were first introduced in 1982 to control nuisance broadleaf, grass, and sedge weeds. Although the SU herbicides have the same mechanism of action, minor changes in the sulfonylurea molecule allow for very different crop and weed specificity. For this reason, sulfonylureas may be used in almost every cropping or weed control situation. It is important to note, however, that generally the SUs are not interchangeable and cannot be easily compared to each other because of differences in the crop selectivity, weeds controlled, efficacy, and use patterns. This class has a wide-range of use patterns and applications methods, and a given individual SU herbicide can be taken up by the roots, foliage, or both roots and foliage of the target weeds.

Sulfonylurea herbicides are used as preplant, soil-incorporated, pre-emergence, and/or post-emergence applications to the crop to control target weeds. Sulfonylurea herbicides are acetolatate synthase (ALS) inhibitors and the Weed Science Society of America (WSSA) classifies their mechanism of action as Group 2 (WSSA, 2016). While sulfonylurea application rates are generally low compared to other herbicides (0.001 to 0.375 lb a.i./acre), the application rates vary widely among specific chemicals and among uses for the same chemical. The sulfonylurea herbicides have soil half-lives that range from several days to many months (US EPA, 2015), and they are degraded by soil microbes and chemical hydrolysis (Sarmah and Sabadie, 2002).

AGRICULTURAL USE

Sulfonylurea herbicides are used on a wide variety of agricultural sites such as rice, soybean, corn, grapes, orchards, pastures/rangeland, wheat, vegetables, fallow, pastures/rangeland, and many specialty crops.

NON-AGRICULTURAL USE

Chlorsulfuron, flazasulfuron, foramsulfuron, halosulfuron-methyl, imazosulfuron, iodosulfuron, metsulfuron, sulfosulfuron, trifloxysulfuron-sodium, and sulfometuron-methyl have non-agricultural uses that include turf management, rights-of-way (ROW) management, invasive species control, rangeland, and forestry. The sulfonylureas effectively control a wide range of weeds in these use-patterns. BEAD has included 2011 usage data on these non-agricultural use sites.

IV. RISKS OF CONCERN FOR THE SULFONYLUREA HERBICIDE

There are no identified risks of concern to human health from exposures (food, drinking water, residential, or worker exposures) to the sulfonylurea herbicides (US EPA, 2015b – 2015v). The screening-level ecological risk assessment (US EPA, 2015) did not identify any direct risks of concern to terrestrial or aquatic animals. However, these analyses showed that sulfonylurea herbicides posed risk to terrestrial plants, and most sulfonylurea herbicides have the potential to impact sensitive species hundreds of feet from the edge of treated fields. Furthermore, 15 SUs exceeded the level of concern (LOC) for vascular aquatic plants, and 3 SUs exceeded the LOC for non-vascular aquatic plants.

Off-site movement from both spray drift and runoff have the potential to negatively impact terrestrial plants. Effect distances from drift ranged from a few feet from the edge of the field to over 1,000 feet. The Agency analyzed the effect of droplet size on the risk to adjacent fields from spray drift using AgDRIFT™. Results suggest that increasing droplet sizes to coarse, very coarse, and extremely coarse can reduce the number of LOC exceedances for the sulfonylurea herbicides at various distances from the edge of the field, for both ground and aerial applications. The risk quotients (RQs) for drift were calculated using TerrPlant™ and range from 0.44 to 1203. Risks of concern were identified for 21 of the sulfonylurea herbicides.

In addition to risks from spray drift, risks to adjacent fields from a combination of runoff and spray drift were also incorporated into EPA's analysis of the SUs. For risks to terrestrial plants from runoff in dry areas, the RQs range from <0.1 (the lower bound of the model) for triflusulfuron-methyl to 727 for chlorimuron-ethyl as estimated using TerrPlant. For risks to terrestrial plants from runoff in semi-aquatic areas, the RQs range from 0.14 for triflusulfuron-methyl to 4000 for chlorimuron-ethyl.

It is important to characterize the risks identified in the screening-level ecological assessment. The application rate is one of the most significant inputs when modeling estimated environmental concentrations (EECs). To model the ECCs in the screening-level ecological risk assessment, a single application rate for a single use site was selected to represent all application rates used on all registered use sites for a given sulfonylurea herbicide. As is shown in Table 3, this selected application rate can differ substantially from the maximum label rate, the highest reported application rate, and the average application rate for the selected crop. Larger differences can be observed when comparing the rates between the selected use site and other registered sites for that herbicide. In some cases, applications rates for one sulfonylurea chemical on differing use sites can vary by more than an order of magnitude. In other cases, modeled rates and observed rates in the main agricultural use of the chemical align closely.

For example, metsulfuron was modeled at a rate of 0.15 pounds of active ingredient per acre (lb. a.i./A); the average reported rate in the highest total area treated and highest percent crop treated (PCT) crop where usage was reported (winter wheat) is 0.003 lb. a.i./A. Therefore, the typical application rates in a wheat production setting are approximately 50 times lower than what was modeled, suggesting the modeled estimated environmental concentration is highly conservative for this particular use as compared to that resulting from what is being used in the field. Similarly, the highest reported rates in the main uses were substantially less than modeled rates for 9 other herbicides (chlorimuron, chlorsulfuron, halosulfuron-methyl, imazosulfuron, iodosulfuron, nicosulfuron, rimsulfuron, tribenuron-methyl, and trifloxysulfuron-sodium) (Table 3). Highest reported rates from these herbicides ranged from 22-68% of the modeled rate. It is important to note, moreover, that these are highest reported rates and not necessarily indicative of the typical rates used on that crop.

Highest reported rates for the main agricultural uses of each chemical were close (+/- 20%) to model rates for 11 of the SUs: bensulfuron, flazasulfuron, foramsulfuron, mesosulfuron, orthosulfamuron, primisulfuron, prosulfuron, sulfosulfuron, thifensulfuron, triasulfuron, and triflusulfuron-methyl (Table 3). Market research data on sulfometuron-methyl were not available.

Table 3. Sulfonylurea use sites and application rates used in EPA's preliminary risk assessment (PRA), reported rates in the available usage data, and maximum label rates for highest total area treated crop.

Chemical	Model Use Sites and Application Rate Compared to Label and Actual Maximum Application Rate		Application Rates for Crop with Largest Total Area Treated (TAT) or High Percent Crop Treated (PCT) Crops for Each SU			
	Model Use Site and Model Application Rate°	**Maximum Observed Application Rate Applied**	**Crop with Largest Total Area Treated for Chemical×**	**Average Application Rate**	**Highest Reported Application Rate+**	**Maximum Label Rate**
BENSULFURON	rice - 0.063	*	Rice	0.031	0.063+	0.063
CHLORIMURON	soybean - 0.080	*	Soybean	0.017	0.054	0.080
CHLORSULFURON	rangeland/fallow - 0.062	0.047	Wheat, winter	0.012	0.023	0.023
FLAZASULFURON	grapes - 0.045	*	Grapes, wine	0.045	0.045	0.045
FORAMSULFURON	corn - 0.038	*	Corn	0.029	0.033	0.038
HALOSULFURON-METHYL	corn - 0.094	0.063	Rice Cucumbers (PCT) Pumpkins (PCT)	0.029 0.027 0.033	0.061 0.047 0.047	0.063 0.047 0.047
IMAZOSULFURON	melons, vegetables, rice - 0.30	*	Rice	0.169	0.19	0.25
IODOSULFURON	wheat - 0.0089	ND	Corn	0.002	0.002	0.002
MESOSULFURON	wheat - 0.013	0.013	Wheat, winter	0.010	0.013	0.013
METSULFURON	uncultivated areas/forestry - 0.15	ND	Wheat, winter	0.0030	0.0038+	0.0038
NICOSULFURON	corn- 0.066	*	Corn	0.020	0.034	0.066
ORTHOSULFAMURON	rice - 0.066	*	Rice	0.061	0.066	0.066
PRIMISULFURON	corn - 0.036	*	Corn	0.022	0.030	0.036
PROSULFURON	corn - 0.036	0.036	Sorghum	0.018	0.036	0.036
RIMSULFURON	Most uses - 0.063	0.063	Corn Potatoes (PCT) Tomatoes (PCT)	0.014 0.019 0.032	0.031 0.023 0.063	0.063 0.023 0.063
SULFOMETURON-METHYL	fallow, uncultivated - 0.380, 0.0281	ND	Non-agricultural	ND	ND	0.380

Chemical	Model Use Sites and Application Rate Compared to Label and Actual Maximum Application Rate		Application Rates for Crop with Largest Total Area Treated (TAT) or High Percent Crop Treated (PCT) Crops for Each SU			
	Model Use Site and Model Application Rate°	Maximum Observed Application Rate Applied	Crop with Largest Total Area Treated for Chemical×	Average Application Rate	Highest Reported Application Rate+	Maximum Label Rate
SULFOSULFURON	pastures - 0.094	0.094	Wheat, winter	0.026	0.032+	0.032
THIFENSULFURON	Most uses - 0.028	*	Wheat, winter	0.011	0.028+	0.028
TRIASULFURON	Pastures/Rangeland - 0.028	0.023	Wheat, Winter	0.016	0.026	0.026
TRIBENURON METHYL	field corn, blueberries - 0.031	0.011	Wheat, winter	0.006	0.016	0.016
TRIFLOXYSULFURON-SODIUM	sugarcane - 0.028	0.019	Cotton	0.007	0.012	0.012
TRIFLUSULFURON	sugarbeets - 0.031	0.031	Sugarbeets	0.010	0.031	0.031

*Modeled crop rate is the same as highest acreage rate.
× Halosulfuron-methyl and Rimsulfuron rows contain rate information from the crops with the largest total area treated and high percent crop treated crops. High percent crop treated crop indicated by (PCT).
°Rates and crops from Table 4.1 of the ecological risk assessment
+In some cases the maximum reported application rate value for a particular crop was greater than the current label rate. Generally this is based only on one reported value over the 5-yr interval and is considered to be a database artifact.
Source: Information on rates used are from Market Research Data (2015). ND means no data.

V. IMPACTS FROM POTENTIAL MITIGATION MEASURES

- The Agency is considering the following measures to mitigate potential risks associated with spray drift:
- For aerial applications: boom to wing length ratios, swath displacement, nozzle orientation, maximum release height of 10 feet, extremely coarse droplet size, wind speed maxima, and temperature inversion prohibitions
- For ground applications: maximum release height of 24 inches, extremely coarse droplet size, wind speed maxima, and temperature inversion prohibitions.
- The following section evaluates the grower-level impact that could result from the implementation of these measures.

IMPACTS FROM POTENTIAL SPRAY DRIFT RELATED REQUIREMENTS

Many of the potential spray drift-related requirements described in the Proposed Interim Decision (PID) for the sulfonylurea herbicides are currently standard practices used by applicators. For aerial applications these potential requirements are the boom to wing length ratios, swath displacement, application release height, and nozzle orientation. Wind speed maxima and temperature inversion prohibitions are currently on most labels for both ground and aerial applications.

However, limiting the ground application release height to a maximum of 24 inches may necessitate changes to existing spray equipment configuration in some situations. Release height, nozzle type and distance between nozzles on the boom all affect the spray coverage and these parameters may have to be adjusted to achieve the desired coverage.

BEAD does not anticipate that the requirements listed above will have substantial impacts on users. However, the potential requirements for applicators to use an "Extremely Coarse" spray droplet size (as defined by American Society of Agricultural and Biological Engineers (ASABE) S572.1) will have impacts on growers.

The ASABE uses the volume median diameter (VMD) droplet size to classify (and color code) spray nozzles. The VMD is an incomplete measure of droplet size because it does not reflect the distribution of droplets produced (or relative span). Spray nozzle manufactures provide information about the droplet size category produced at a range of pressures for a given nozzle. The ASABE standard applies to all pesticides applied using a ground-boom sprayer.

Table 4 compares the spray droplet size categories as classified by ASABE (2009). Note that when the volume is held constant, the number of droplets changes exponentially (based on the formula to calculate the volume of a sphere = $4/3 \pi r^3$). Requiring an extremely coarse droplet size will reduce the number of droplets by more than an order of magnitude. This increases the probability that the droplet will miss the target weed. Doubling droplet size from 150 to 300 microns increases its weight and volume by 8 times (Wilson, not dated). Further, Wolf (2000) showed that large droplets can rebound off the leaf, while smaller droplets were retained.

Table 4. Comparison of the number of droplets by size categories. Total volume is held constant (ASABE, 2009; Hipkins and Grisso, 2014).

Droplet Size	Nozzle Color	VMD Range	Relative Number of Droplets*
Fine	Orange	145-225	24-41
Medium	Yellow	226-325	8-11
Coarse	Blue	326-400	4
Very Coarse	Green	401-500	2
Extremely Coarse	White	501-650	1

*Relative number of droplets calculated assuming a constant volume based on nominal VMD (μm). Volume of a sphere = $4/3 \pi r^3$. VMD is the volume median diameter.

Herbicidal weed control is comprised of a complicated sequence of processes. These include droplet formation at the nozzle, distance travelled to the plant surface, droplet impact angle, retention on the leaf surface, deposition of the active ingredient, uptake of the active ingredient in to the plant tissue, transport within the plant tissue, and the resulting biological response. These processes are further affected by environmental conditions (e.g., temperature, humidity). Changes to the droplet size will cascade through the sequence of processes described above.

The mixture of compounds in the finished spray will also affect these processes. For example, each sulfonylurea product is formulated with a number of inert ingredients and can be co-formulated with other herbicides. Sulfonylurea herbicides are frequently tank mixed with other products. The use of crop oil concentrate or nonionic surfactants are recommended (unless incompatible with other tank partners) when using sulfonylurea herbicides. Additionally, there are over 750 adjuvant products for herbicides (Young, 2016), and some combination of these are almost always added to the spray tank. In addition to other herbicides or adjuvants, many formulations typically contain surfactants, solvents, emulsifiers, defoamers, stabilizer, anti-microbials, anti-freeze, pigments, buffers, and etc. (Gouge, 2010).

Knoche (1994) conducted an analysis of the published literature on the effects of droplet size and carrier volume on the efficacy (i.e. the herbicides impacts on plant weight, height, or visual evaluation) of foliage-applied herbicides. This review paper is based on over 170 published papers and examined performance related to droplet size and volume class, herbicide characteristics (i.e., systemic or foliar), and characteristics of the target weeds (i.e., monocotyledon vs dicotyledon; wettability of the leaf and stem surfaces, and leaf orientation). This study included herbicides from multiple mechanism of action groups and the results are representative of all herbicides applied to foliage.

The spray droplet size ranged from 43 μm to 1240 μm across all of the studies. The studies evaluated by Knoche (1994) showed decreased herbicide efficacy in 71% of the experiments as droplet size increased, 22% had no change, and 7% had increased efficacy. When examining carrier volume, he found that carrier volume effects were less consistent and suggested an optimum relationship. At high carrier volumes (> 43 gallons/acre), herbicide performance increased as the carrier volume decreased. However, at low carrier volumes (< 11 gallons/acre) herbicide performance decreased as the carrier volumes decreased, suggesting that there is an optimal range of droplet sizes for herbicide performance. Generally, this study concluded that improved performance as droplet size decreased was probably related to the following:

- Improved canopy penetration;
- An optimum relation of droplet size with impaction efficacy;
- Decreased deposition variability and decreased probability of a "complete miss;"
- Improved droplet retention on difficult-to-wet surfaces;
- Improved efficiency of the biological response for herbicides with limited mobility within in the leaf tissue.

More recent studies demonstrate that the magnitude of efficacy changes can be influenced by the herbicide and plant combination examined (Creech et al., 2016; Meyer et. al., 2015, Wolf et. al., 2000), as well as for plant growth stage (two- to four-leaf stage are easier to control than five- to eight-leaf stage) (Chachalis et al., 2001). These studies generally concluded that the most efficacious droplet sizes for herbicides were of fine to medium diameter. For control of tree species (white birch, alder, quaking aspen) larger droplet size can reduce efficacy by up to 29% (Prasad and Cadogan, 1992). The magnitude of these reductions in efficacy can be up to 50 percent as droplet size increases from medium to very coarse (Wolf and Caldwell, 2006).

Grower response to reduced sulfonylurea performance could include increasing application rate for a given herbicide (if allowed by the label), increasing the number of applications, increasing the application rates of tank mix partners, making an additional herbicide application with a different herbicide, or changing to a different herbicide(s). Pre-emergent / soil directed applications should be less affected than post-emergent foliar applications because these sites do not appear to be as sensitive to droplet size and spray coverage.

In some situations larger droplet sizes can lead to an increase in the number of gallons of finished spray being applied per acre. This would result in an increase in the number of times a tank is refilled and would reduce the efficiency of the sprayer (e.g., number of acres treated per hour) and may require the purchase of additional equipment, such as a nurse tank or sprayers with larger tanks.

As discussed above, changes in spray droplet size can negatively impact herbicide efficacy. The likelihood of the development of herbicide resistance increases with the reduction in the effective dosage of the herbicide that reaches its target site in the plant. Similar to a reduction in effective rates, increasing droplet size can reduce efficacy and increase the likelihood of survival of herbicide resistance biotypes. Thus, lower efficacy can increase the likelihood of selecting minor herbicide resistance traits leading to herbicide resistance evolution.

Requiring any droplet size larger than the optimal size (which is usually fine to medium) will affect the efficacy of that application. For some SU products, and for some tank mixes containing SUs, requiring an extremely coarse spray droplet size for the SUs and the resulting decrease in efficacy will be equivalent to removing the affected products from the marketplace. For example, Authority XL (279-3413) and Authority MAXX (279-9560) are products containing chlorimuron-ethyl and sulfentrazone, and are used on about 4 million acres annually (MRD, 2010-2014). Good coverage of the target weed surface is required for sulfentrazone to be effective (Sulfentrazone: Interim Review Decision, EPA-HQ-OPP-2009-0624), which cannot be achieved using extremely coarse droplet sizes. The requirement to apply these products using an extremely coarse spray droplet would render one of the two active ingredients ineffective and would negate the benefits of a co-formulated product.

As a group, the 22 SUs are applied to 50 to 60 million acres annually. Over 85 percent of these applications are made using co-formulated products or with tank mixes of multiple active ingredients (MRD, 2010-2014). EPA use requirements for co-formulated or mixed products are always based on the most restrictive requirement for any of the components. Many of the several hundred tank mix partners require a specific range of droplet sizes to be effective and the extremely coarse spray droplet size requirement would prevent some products from being used as a tank mix partner for the SUs. Growers would likely respond by changing their established tank mixes (either by replacing the SUs with a different herbicides, or by changing the tank mix partners).

Providing users with more than one way to reduce off site movement should lead to fewer impacts. The following are options to reduce off-site movement other than requiring extremely coarse droplet size:

- Use coarsest spray droplets size that preserves the efficacy of the product;
- Aerial applications should be made with ½ swath offset near the sensitive site;
- Use shielded ground boom sprayers at downwind field edge near the sensitive site;
- Use an off-field vegetative buffer to reduce runoff near the sensitive site.
- Use an off-field vegetative buffer (such as a tree or shrub buffer) that is taller than the target plants or the spray unit used for herbicide application to reduce drift[2]

POTENTIAL IMPACTS OF REQUIRING IN-FIELD BUFFERS

Initially the Agency considered in-field buffers as a potential mitigation. In this section, BEAD broadly considered the impacts, in terms of field area lost, to growers of imposing no-spray in-field buffer zones to ground- and aerially-applied pesticides to agricultural crops. Spray drift buffers may be considered as mitigation measures for risks to non-target plants resulting from drift from aerial and ground applications. BEAD is not able to assess the impacts of buffers applied to non-agricultural sites because of limited pesticide usage information. Moreover, buffers are not practicable in rights-of-way management and other settings that are by nature narrow and linear.

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[2] Buffers can help protect sensitive non-target areas from spray drift (Bentrup, 2008). Key design considerations:

- Use vegetation with fine or needle-like leaves;
- Use vegetation tolerant to the chemical being applied;
- Provide a permeable barrier to allow air passage;
- Buffer should be at least two times taller than the crop;
- Install the buffer in a location where drift from prevailing winds will be intercepted.

The impacts of 25, 50, and 100 foot in-field buffers were calculated for eight example crops with large sulfonylurea usage: almond, apple, pistachio, cucumber, corn, cotton, soybean, and wheat (spring and winter) (Appendix IV). These crops were selected because they represent a variety of crop types (i.e., orchard, vegetable, and agronomic), field sizes, and gross revenue per acre.

Field Size Data

Field size information was obtained from the Farm Service Agency (FSA) for five years (USDA FSA, 2010-2014). The FSA defines a field as an area within a farm that is separated by permanent boundaries such as fences, permanent waterways, woodlands, and roads. The field size data consist of national and state field sizes by crop that are reported by growers/producers to the FSA. EPA obtained these data and, upon initial review, has found the data to provide a reasonable estimate of average field size by crop at the national level but the reliability of field size data at the state level vary by crop. The reliability of the data was verified by comparing the sum of total acres by crop from the FSA data to the sum of total acres in the USDA Census of Agriculture.

Gross Revenue Data

USDA's Economic Research Service (ERS) collects data on agricultural production and prices. Data on yield (units) per acre and price received per unit were extracted from USDA NASS Quick Stats (2010-2014, 2011-2015) for the past 5 years, the values averaged to produce an average annual for these parameters and the average gross revenue per acre calculated (gross revenue per acre = yield (unit) per acre * price per unit) for each crop.

Buffers as a Proportion of Field Sizes

The analysis considers the impacts of a buffer on one side of a field where the buffer would necessitate a no-spray zone within the field that runs along the downwind edge of a field. The land area within the buffer zone can be determined by multiplying the width of the buffer with the estimated length of the field. For simplicity, we consider a rectangular field with length twice the width. The no-spray buffer zone is along the longer side (Figure 1). The area would be smaller if the buffer were along the shorter side but could be greater for fields of other shapes, such as narrow fields that run along roadways or waterways. The area of a rectangular field where the long side, y, is twice the length of the short side, x, is $x \cdot y = x \cdot 2x = 2x^2$. The area inside the buffer zone of width b is 2xb. The impact of the buffer, as a percent of field area, is $2xb/2x^2 = b/x$.

BEAD assumes that the area within the buffer, measured as a percent of the field area, is removed from production to estimate the impact of the buffer on a grower. It is important to note, however, that buffers may not necessarily result in the entire buffer area being removed from production. Growers may be able to use another product or application method in the buffer, although this may not always be feasible. The range of grower options when faced with a spray drift buffer for a pesticide are not evaluated by BEAD in this assessment.

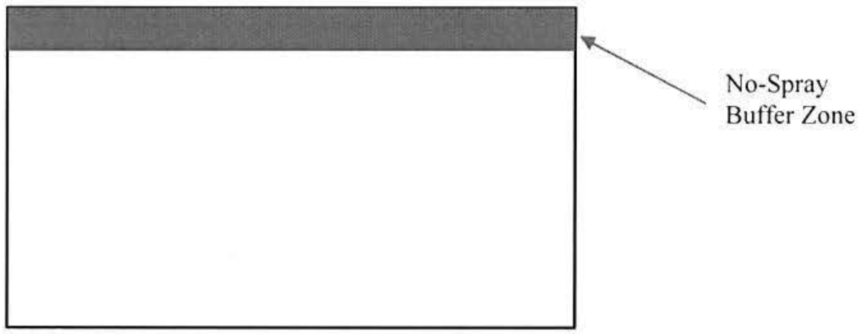

Figure 1. Illustration showing a rectangular field (2:1 length/width ratio) with a buffer (blue area).

The calculations to estimate the impacts of establishing buffers are described below.

For each crop:

- Combined all FSA datasets (2010 to 2014)
- Calculate the total annual average acres of this crop and the total annual average number of fields.
- Rank order the fields from the smallest to the largest acreage
- For each field determine the total area of the field and the area affected by a buffer of a given size (25, 50, and 100 feet). The upper limit of the calculated buffer is bounded by the field size.
- Beginning with the smallest field calculate the cumulative acreage, the cumulative area affected by each of the three buffers, and the cumulative number of fields
- At the 10^{th} percentile and the 50^{th} percentile (based on acreage), report the following:
  - Size of field at that percentile
  - Cumulative number of fields
  - Cumulative number of acres
  - Cumulative number of acres affected by the three buffers
  - Calculate the percentile of fields (cumulative number of fields ÷ total number of fields)
  - Calculate the average percentage of area affected by the three buffers (cumulative number of acres affected by the buffer ÷ total number of acres)
  - Calculate gross revenue lost per acre for each of the three buffers (average gross revenue per acre * average percentage of area affected)

Results

The impact, in terms of lost production, from a 25 foot, 50 foot and 100 foot spray drift buffer on almonds, apples, pistachios, and corn is shown in Tables 5 and 6. See Appendix IV for the impacts of an in-field spray drift buffer on additional crops. For each of the selected crops, Table 5 shows the 10th and 50th percentile field size, the number of fields and proportion of total fields at those field sizes or below, and the proportion of the total area of those fields in the buffer assuming a 25 foot, 50 foot and 100 foot spray drift buffer. For example, for almonds, the 10th percentile field size is 26.1 acres; there are 2,279 fields at or below this field size which is 34% of all almond fields; and 4.35% of the total area of the 2,279 almond fields at a field size 26.1 acres or below will be in the buffer with a 25 foot spray drift buffer.

In Table 5, the percentage of fields at or below the lowest decile (column five) was calculated by summing the number of fields at or below the field size at that decile and dividing by the total number of fields. The same method was employed for all fields at or below the 50th percentile field size. This statistic shows that for each crop there is a relatively large number of small fields on which the crop is grown. Columns six, seven and eight of Table 5, as described above, show the proportion of total acres of all of the fields at the decile field size or below that would be in the spray drift buffer with a 25 foot, 50 foot and 100 foot spray drift buffer.

Table 6 is a summary of the production value lost for the field sizes and spray drift buffer distances listed in Table 5. The value lost per acre is a based on the percentage of area grown in the spray drift buffer listed in Table 5 for the crop and percentile field size. That is, using the same almond example as above, on average, 4.35% of per acre gross revenues (or $252) will be lost for almond growers with field sizes of 26.1 acres or below from a 25 foot spray drift buffer. Because this is an average across all of the acres at or below that field size, some almond growers will face smaller per acre losses and others, with smaller fields, could face as much as a complete crop loss with a spray drift buffer.

Table 5. Field size, number and percentage of fields, and percentage of field area grown in spray drift buffer at 10th and 50th percentile field sizes with 25, 50, and 100 foot in-field spray drift buffers for almonds, apples, pistachios, and corn.

Crop	Percentile (based on total crop acres)	Field Size (in acres at this percentile)	Number of Fields (at or below this percentile)	Percentage of fields at percentile or below this percentile	Percentage of area grown (at or below this percentile) in spray drift buffer*		
					25-Foot Buffer	50-Foot Buffer	100-Foot Buffer
Almonds	10th	26.10	2,279	34	4.35	8.69	17.38
	50th	72.60	5,261	78	2.93	5.86	11.72
Apples	10th	2.50	8,710	47	14.87	29.68	58.02
	50th	10.4	16,275	87	8.77	17.52	34.77
Pistachios	10th	32.8	602	36	4.03	8.06	16.12
	50th	78.1	1,316	79	2.63	5.26	10.52
Corn	10th	13.00	1,642,983	50	6.80	13.60	27.18
	50th	61.20	2,872,925	87	3.79	7.59	15.18

Source: USDA FSA, 2010-2014.

*Assumes a rectangular field shape (2:1 length to width). The in-field buffer is assumed to be along the length of the field. Assumes that the entire area within the spray drift buffer being removed from production.

Table 6. Acres grown, gross revenue and gross revenue lost per acre of spray drift buffer for 10th percentile 50th percentile field size with 25, 50, and 100 foot buffers for almonds, apples, pistachios, and corn.*

Crop	National Acres Grown	Average Gross Revenue Per Acre	Acreage Percentile	Gross Revenue Lost Per Acre (25-foot buffer)[1]	Gross Revenue Lost Per Acre (50-foot buffer)[1]	Gross Revenue Lost Per Acre (100-foot buffer)[1]
Almonds	822,000	$5,787.68	10th	$251.56	$503.11	$1,006.11
			50th	$169.65	$339.30	$678.58
Apples	327,470	$8,942.52	10th	$1,329.91	$2,654.35	$5,188.08
			50th	$783.99	$1,566.88	$3,109.63
Pistachios	179,200	$7,481.02	10th	$301.45	$602.90	$1,205.62
			50th	$196.82	$393.64	$787.24
Corn	84,516,000	$800.94	10th	$54.45	$108.93	$217.66
			50th	$30.39	$60.79	$121.54

Sources: USDA NASS Quick Stat, 2010 – 2014, 2011 – 2015.

* Ratio of field length to field width.

[1] Equal to average gross revenue per acre times the percentage of area grown (at or below this percentile) in spray drift buffer from Table 5. For example, for almond at 10th percentile field size for a 25 foot spray drift buffer, the loss per acre is equal to the average gross revenue ($5,787.68) times the percentage of acre grown in spray drift buffer (4.35%).

Based on the information in Table 5, the lowest combined percentage of fields impacted at the 50th percentile size and smaller occurred for a 25 foot spray drift buffer in pistachios (2.63%). This percentage translates into a potential loss of $197 per acre for 79% of pistachio fields (Table 6).

The greatest combined percentage of fields impacted at the 10th percentile size and smaller occurred for a 100 foot spray drift buffer in apples (58.02%) (Table 5). This percentage of fields impacted translates into a possible loss of $5,188 per acre for 47% of apple producing fields (Table 6).

High value crops with smaller field sizes will be highly impacted by buffers as small as 25 feet. For example, ten percent of the apple acres are comprised of 8,710 fields that are 2.5 acres or less. Almost fifteen percent of the total area of these fields would be affected by a 25-foot infield single-sided buffer, assuming a 2:1 rectangular field shape. The average gross revenue of an acre of apples is $8,942. The potential loss in revenues for 34 percent of all almond fields has potential to be $1,330 per acre ($8,942*0.1487).

Buffers would also impact gross revenue in large field crops such as corn. For example, ten percent of corn acres are comprised of 1,642,983 fields that are 13 acres or less. BEAD estimates that 13.6 percent of the total area of these fields would be affected by a 50 foot infield single-sided buffer along the long edge, assuming a 2:1 rectangular field shape. The average gross revenue of an acre of corn is $800. The potential loss in revenues for 50 percent of all corn fields with a 50 foot buffer will be approximately $109 per acre ($800*0.136).

Characterization

BEAD characterizes the estimated per-acre impacts from buffers to be a reasonable high-end value. Each component of this calculation can be characterized as follows:

- Complete loss of production from buffer. This loss value is close to the worst case, however there would be additional costs that are not accounted for. Growers would still need to manage the vegetation in a buffer. The costs of vegetation management in the buffers are not included in this analysis and therefore the complete loss of production value may be an underestimate in some cases.

- Gross Revenue per acre. These are annual averages based on five years of data from USDA surveys. BEAD considered these data to be of the highest quality.

- Field shape and percent of area affected. The assumption of a 2:1 length to width rectangular field shape is considered by BEAD to represent a "central tendency" shape of all agricultural fields. Agricultural fields are created based on local topology (e.g., slope, waterways) and legal boundaries (i.e., political divisions, property ownership, and historical boundaries). While much of the United States relies on the US Public Land Survey System (USGS, 2016) to establish a grid of east-west and north-south boundaries, many boundaries were established using historical survey systems (25 states created from British, French, and Spanish colonies). While there are many circular fields (because of center-pivot irrigation systems) or square fields, there are also many fields that are irregular in shape, or are rectangular in shape in a much greater than a 2:1 ration because of conservation practices (e.g., contour strip farming, terracing, field shelterbelts). Further, the use of a one-sided buffer does not account for shifting winds or cross-winds.

POTENTIAL IMPACTS OF VEGETATIVE BUFFER STRIPS

Vegetative buffers and filter strips are areas of vegetation located within and between agricultural fields and the water bodies to which these fields drain. These buffers are intended to intercept and slow runoff in order to provide water quality benefits, and may be considered as mitigation measures for risks to non-target organisms resulting from runoff from aerial and ground applications. Vegetative buffer strips have been incorporated into many farming operations to reduce nutrient, sediment, and pesticide loading to receiving water bodies. The costs associated with vegetative buffer strips include the cost of taking agricultural land out of production (see "Potential Impacts of Requiring In-Field Buffer Strips" above) and the cost of planting and maintaining a vegetative buffer in the space that is taken out of production.

As described above, the cost of taking agricultural land out of production can be very high depending on the crop and the size of the buffer (as much as $5,200 per acre based on the examples presented in Table 5). Not only would implementing in-field buffers be costly because of reduced crop production, but growers would need to manage the space taken out of production to reduce the encroachment of undesirable plant species - and habitat for pathogens and deleterious insects - into their agricultural fields. Based on work in California and Maryland it is estimated that it costs between $160 to $750 dollars per acre to establish a vegetative buffer strip depending on the amount of soil preparation required and type of crop to be planted. Yearly maintenance costs are estimated to be $40 to $240 per acre (for four mowing or weed control applications). Maintenance costs could be higher if additional operations are required such as additional mowing or weed control expenses, reseeding of disturbed areas, or regrading of the filter strip with reseeding if sediment deposition were to jeopardize its function. (Lynch and Tjaden, 2003 and Solano and Yolo Co. Resource Conservation. Dist., 2006) While vegetative buffers may have the added benefit of reducing off-site movement and runoff, growers may find that vegetative buffers are not economically feasible because of the costs associated with managing these buffers.

VI. PROPOSED HERBICIDE RESISTANCE MANAGEMENT MEASURES

The development and spread of herbicide resistant weeds in agriculture is a widespread problem that has the potential to fundamentally change production practices in U.S. agriculture. While herbicide resistant weeds have been known since the 1950s, the number of species and their geographical extent, has been increasing rapidly. Currently there are 249 weed species worldwide with confirmed herbicide resistance. In the United States there are 155 weed species with confirmed resistance to one or more herbicides.

Management of herbicide resistant weeds, both in mitigating established herbicide resistant weeds, and in slowing or preventing the development of new herbicide resistant weeds is a complex problem without a simple solution. Coordinated efforts of growers, agricultural extension, academic researcher, scientific societies, pesticide registrants, and state and federal agencies are required to address this problem.

In September 2014, the Weed Science Society of America sponsored an international meeting, the Herbicide Resistance Summit II, hosted by the National Research Council (WSSAb, 2014). This meeting was organized to facilitate a more unified understanding of the herbicide resistance issues across the country, understanding of differences of viewpoints, and approaches to solutions. The meeting was attended in person or via webinar by participants from approximately 100 locations across the United States, Australia, Canada and Germany, underscoring the significance and widespread nature of this problem and its impact on agricultural productivity.

The Agency announced at this meeting that it would take a more proactive role in developing regulatory approaches for managing resistant weeds (Housenger, 2014). Shortly after this meeting, the Secretary of Agriculture announced USDA's herbicide resistance actions that were developed in collaboration with the Agency (USDA, 2014).

The EPA, Office of Pesticide Programs (OPP), approach is intended to provide growers and other users with detailed information and recommendations that can be used to slow the development and spread of herbicide resistant weeds. This is part of a more holistic, proactive approach recommended by crop consultants, commodity organizations, professional/scientific societies, researchers, and the registrants themselves. OPP's approach is measured, based on the inherent risk of weed resistance developing for a given herbicide, considering the target weeds and the agronomic practices of the registered crops. Situations with the least concern for the development of herbicide resistant weeds will have the fewest resistance management elements and the situations with the highest concern will have additional resistance management elements. Table 6 lists the herbicide resistance categories of concern, the criteria for each category, and herbicide resistance management elements for each category.

Table 7. Herbicide Resistance Categories of Concern* and Elements for Each Category.

Low Concern	Moderate Concern	High Concern
MOA's with no resistance weed species in the U.S.	MOA's with up to six resistant weed species in the U.S.	• Any new herbicide with a new or novel MOA, or • Herbicides for which resistant crop(s) have been developed (conventionally bred or GM), or • MOAs with the most resistant weeds in U.S. (1 to 49 species)
1. MOA on label 2. List seasonal and annual maximum number of applications and pounds (ai / acre) 3. Resistance management language from PRN 2001-5 or BMPs 4. Scout before and after application	Elements 1 through 4 plus 5. Definition of likely and confirmed resistance 6. Farmer should report lack of performance to registrant or its agent 7. List confirmed resistant species in separate table and list effective or recommended rates for these weeds with the table 8. Registrant report new cases of likely and confirmed resistance to EPA & users yearly	Elements 1 through 8 plus 9. Provide growers with: Resistance Management Plan, Remedial Action Plan, Educational materials on resistance management 10. For combination products with multiple MOAs, list which herbicide is controlling which weed and minimum recommended rate 11. Any additional specific requirements (e.g., mandatory crop rotation, unique agronomic aspects, time limited registration, etc.).

* If new resistant weed species are found a MOA may move to higher level category of concern.

Additional details are provided in the attached appendices, as follows:

Appendix I – Guidance for Pesticide Registrants on Pesticide Resistance Management Labeling (US EPA, 2001). Proposed update at https://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2016-0242
Appendix II – Definition of Resistance and Likely Resistance
Appendix III – Best Management Practices for Herbicide Resistant Weeds (from the Herbicide Resistance Action Committee and the Weed Science Society of America

HERBICIDE RESISTANCE CONCERNS WITH THE SULFONYLUREA HERBICIDES

Sulfonylurea herbicides are acetolactate synthase (ALS) inhibitors and the Weed Science Society of America classifies their mechanism of action as Group 2 (WSSA, 2016). This MOA is of high concern for the development of weed resistance development as demonstrated by the 49 cases of confirmed herbicide resistant weeds in the U.S. (Heap, 2016). Currently there is one sulfonylurea resistant crop, sorghum, which was conventionally bred for resistant to nicosulfuron and rimsulfuron.

Registrants should address elements one through 11 in Table 7. Table 8 describes these elements in greater detail and include instructions for the user, label language, and instructions to the registrant.

Table 8. Elements of Resistance Management or Stewardship Plan

Description
Element 1. List Mechanism of Action (MOA) Group Number. • This information is critical to allow the user to rotate between effective MOA's to reduce the buildup of resistant pests. ➢ Registrant is responsible for placement on label.
Element 2. List seasonal and annual maximum number of applications and amounts. • This information is critical to allow the user to know how many applications and amounts can be applied in order to develop an effective IPM plan for the season and the entire year. ➢ Registrant is responsible for placement on label.
Element 3 Resistance Management language from PR Notice 2001-5, and/or Best Management Practices (appropriate to crop) from Weed Science Society of America (WSSA) & Herbicide Resistance Action Committee (HRAC, 2015), and/or HRAC proposed guidelines for herbicide labels. • This is an educational opportunity to remind users to look for and follow a resistance management plan. ➢ Registrant is responsible for placement on label.
Element 4. User should scout before and after application. • Reminding the user to scout can help insure that the proper pesticide is applied based on the weed species and growth stage and determine if the pesticide applied provided effective control. ➢ Registrant is responsible for placement on label. ➢ User is responsible for following the recommendations.
Element 5. Definition of Likely Resistance. • It can take up to five years to confirm herbicide resistance. By describing likely resistance users could proactively identify and attempt to control weeds in the early stages before they become widespread in their fields. ➢ Registrant is responsible for placement on label.
Element 6. User should report lack of performance to registrant or their representative. • Reporting lack of performance can help provide the user with additional resources for the identification and control of problem weeds. In some cases lack of performance could be an early indication of likely resistance and contacting the registrant can help insure the weed is controlled before resistance becomes widespread in their fields. ➢ Registrant is responsible for placement on label. ➢ User is responsible for following the recommendations.

Description
Element 7. List confirmed resistant weeds in a separate table and list effective or recommended rates for these weeds with the table. • This is an educational opportunity to clearly indicate which weeds are prone to resistance and remind the users to select the correct rates for their crop and site. ➢ Registrant is responsible for placement on label.
Element 8. Registrant report new cases of likely and confirmed resistance to EPA and users yearly. This will be in addition to any adverse effects reporting. • This will allow the information regarding likely and confirmed resistance to be available in a timely manner to users, consultants, extension, etc. so that they are aware of and can proactively address the problem. • Provide weed species, crop or site, state, and herbicide used. ➢ Registrant is responsible for reporting.
Element 9. For sites of high concern provide growers with: □ Resistance Management Plan □ Remedial Action Plan (to control resistant weeds this season or next season) □ Educational materials on resistance management. • Plans should be locally developed and easily modified. EPA recommends that registrants work with extension, consultants, crop groups, HRAC, & USDA. • This is an educational opportunity to remind users of the importance of resistance management. ➢ Registrant is responsible for creating or providing educational materials.
Element 10. For combination products with multiple MOA, list which herbicide is controlling which weed (a 3 way mixture may only have 1 effective MOA for some problem weeds). List minimum recommended rate if resistance is suspected. • Using combination products with only one effective MOA can select for herbicide resistant weeds. • This will allow users to select herbicide combinations with multiple effective MOAs for the problem weeds on their fields. • Registrant is responsible for placing the list on the label or otherwise providing the information.
Element 11. Any additional specific requirements (e.g., mandatory crop rotation, unique agronomic aspects, additional training, time limited registration, etc.). • During discussions with the Agency, other elements may be deemed appropriate to help reduces the spread of resistance. • The elements may be on the label, the technical use agreement for the seed trait, or as a reporting requirement. ➢ Registrant is responsible.

Footnote: Mechanism of Action Group number comes from the WSSA; definition of resistance and likely resistance, PR Notice 2001-5 and BMP language are in Appendix 1-3.

IMPLEMENTATION TIMELINE AND OPPORTUNITIES FOR PUBLIC COMMENT

OPP is proposing to implement herbicide resistance measures for existing chemicals during registration review, and to implement herbicide resistance measures for new chemicals and uses at the time of registration. On June 3, 2016 two Pesticide Registration Notices on resistance management were opened for a 60 day comment which closes on August 2, 2016. The first notice is Draft guidance for pesticide registrants on herbicide resistance management labeling, education, training, and stewardship (FRL #: 9946-53 and OCSPP Docket #: OPP-2016-0226) available online at https://www.regulations.gov/docket?D=EPA-HQ-OPP-2016-0226 . The second notice is Guidance for pesticide registrants on pesticide resistance management labeling (FRL #: 9946-52 and OCSPP Docket #: OPP-2016-0242) available online at https://www.regulations.gov/docket?D=EPA-HQ-OPP-2016-0242 .

VII. RESPONSE TO COMMENTS RECEIVED ON DRAFT RISK ASSESSMENTS

EPA received public comments on the registration review preliminary risk assessment (PRA) for 22 sulfonylurea (SU) herbicides. Some of the comments received address the use and benefits of the sulfonylurea herbicides. BEAD appreciates the comments, has considered all of them, and addressed them as appropriate below. A number of comments provided very useful information related to non-agricultural sites. Several types of comments were received, including:

- Comments on the general utility of the sulfonylurea herbicides in agricultural crops, turf management, forest management, and rights-of-way (ROW) management
- Comments on the impacts of buffers to use sites
- A comment citing a survey of application rates and methods in forest management
- Comment on the importance of herbicides to managing resistant weeds

Most comments were posted on multiple dockets. Only one comment number per comment is cited in this document.

USE IN FOREST MANAGEMENT

Commenters: Dr. Andrew Ezell, Professor and Department Head, Mississippi State University, Department of Forestry (EPA-HQ-OPP-2012-0387-0033); Todd Hagenbuch, Vegetation Management Specialist, Arborchem Products (EPA-HQ-OPP-2012-0433-0037); Dave Jackson, Forester (EPA-HQ-OPP-2012-0387-0025); Aaron Hobbs, President, Responsible Industry for Sound Environment (EPA-HQ-OPP-2012-0387-0047)

Summary of Comments: Comments regarding forest management focused on best management practices that reduce off-site movement. Several commenters mentioned that Forestry Best Management Practices normally include buffers from standing water and other sensitive areas. Furthermore, several commenters mentioned that excessive in-field buffers would have a significant impact on forest management. Commenters also maintain that SUs are economical, provide a high degree of applicator safety, and are critical to controlling unwanted vegetation in forest management operations.

BEAD Response: BEAD appreciates this information. BEAD finds that these comments contain useful information on best management practices.

Commenter: Vickie Tatum, Ph.D., Program Manager, National Council for Air and Stream Improvement (EPA-OPP-2015-0433-0030)

Summary of Comment: In many forestry applications, vegetated buffers exist to intercept spray drift. Spray buffers surrounding commercial forests are typically forested, with varying heights of vegetation in the understory, and are under the management of forestland specialists. These spray buffers prevent sediment, nutrients, herbicides and other substances from moving off-site. In forestry settings, vegetated buffers not only serve to reduce runoff, but also to reduce non-target impacts from spray drift. The commenter also provided information from a recent survey conducted by NCASI. Most respondents who identified using aerial applications reported using extremely coarse, very coarse, or coarse droplets.

BEAD Response: BEAD appreciates this information. BEAD finds that this document contains useful information on application rates, methods, and best management practices. BEAD concurs that spray drift in forest settings can be different than spray drift in agricultural settings.

USE IN TURF MANAGEMENT

Commenters: L.B. McCarty, Ph.D., Professor of Turfgrass Science, Clemson University (EPA-HQ-OPP-2011-0994-0029); Jim Brosnan, Ph.D., Associate Professor, University of Tennessee (EPA-HQ-OPP-2012-0387-0027); Travis Gannon, Ph.D. and Matthew Jeffries, North Carolina State University (EPA-OPP_HQ-2012-0387-0044); Ramon Leon, Ph.D., Weed Scientist, University of Florida (EPA-HQ-OPP-2012-0387-0049); Thomas Delaney, Director, Government Affairs, National Association of Landscape Professionals (NALP) (EPA-HQ-OPP-2012-0387-0028)

Comment Summary:

Herbicide Resistance Management: Several commenters mentioned that sulfonylurea herbicides are integral to managing the evolution of resistance in weed populations.

Application Methods: Several commenters mentioned that most turf applicators use large droplet sizes and high volume application methods, and that aerial applications are not common practice in turf management. Users address drift management through spot treatments and drift reduction technology.

Spray buffers in turfgrass: Several commenters mentioned that large buffers would eliminate the use of sulfonylurea herbicides in turfgrass systems. Another comment stated that if large buffers are implemented, users are likely to apply other products.

Alternatives to other herbicides: Multiple commenters state that sulfonylureas (trifloxysulfuron-sodium, flazasulfuron, metsulfuron-methyl, and iodosulfuron) are diverse and effective alternatives to MSMA and atrazine.

BEAD Response: BEAD appreciates this information. BEAD has limited information on the usage of sulfonylureas in turf management and the benefits of the sulfonylurea herbicides in this use pattern are difficult to quantify. BEAD acknowledges that large buffers would severely hamper the use of sulfonylurea herbicides in turfgrass systems. Several herbicides are commonly used on this site: halosulfuron-methyl, foramsulfuron, metsulfuron, sulfosulfuron, and trifloxysulfuron-sodium.

Commenter: Jay McCurdy, Ph.D., Assistant Professor, Mississippi State University (EPA-HQ-2012-0387-0031)

Comment Summary: SUs are critical for weed management on turfgrass and other non-crop sites including invasive species management. SUs are a critical active ingredients to prevent resistance and there are no alternatives for some weeds. Approximately 2 million acres of turf grass are managed in the State of Mississippi. SU herbicides are critical to maintaining these areas for the safety of drivers, benefit of commerce, and wildlife habitat.

This comment also describes specific SU herbicides in turf:

- Metsulfuron-methyl is by some estimates the most often used SU herbicide for broadleaf weed control in southern markets.
- Foramsulfuron is one of only three viable postemergence herbicides for goosegrass control within maintained lawns. The other two are sulfentrazone and diclofop.
- Halosulfuron-methyl is one of the leading homeowner products for sedge control. It is safe across all warm- and cool-season turfgrass species. The only commercial alternative is Imazaquin.

BEAD Response: BEAD appreciates this information.

Commenter: Xi Xiong, Ph. D., Associate Professor of Turfgrass Management, University of Missouri-Columbia (EPA-HQ-OPP-2012-0387-0045)

Comment summary: The commenter mentions that unlike row crops where cultural practices such as tillage can be implemented for weed control, turfgrass as a perennial crop relies heavily on the use of herbicides. The commenter also mentions that sulfonylurea herbicides are an essential tool in an integrated weed control program due to their selectivity against some difficult-to-control grass weeds. The commenter then provides several examples of weed species and sulfonylurea herbicides that control these species:

> "For example, control of goosegrass *(Eleusine indica* (L) Gaertn.) on bermudagrass *(Cynodon* spp.) turf is best provided by foramsulfuron, as a replacement tor MSMA. Tropical signalgrass *(Urochloa subquadripara* (Trin.) R.D. Wester), another tough perennial weed in warm-season turf: has been

controlled by hand-pulling or non-selective herbicides for years due to the lack of selective postemergence herbicides. This situation was only changed recently (2012) when a 3-way herbicide combination was introduced to the turf market that contains two sulfonylurea compounds: foramsulfuron and halosulfuron. Other difficult-to-control weeds, such as perennial sedges *(Cyperus* spp.), are also best controlled by herbicides containing halosulfuron."

BEAD Response: BEAD appreciates this information.

Additionally, a document entitled "Use and Benefits of Foramsulfuron (Revolver® Herbicide, Tribute® Total Herbicide) and Iodosulfuron (Celsius® WG Herbicide)" (McCarty et al., 2016) was submitted to the Agency. BEAD finds this document to provide very useful information about the use of these two chemicals on turf.

RANGELAND AND PASTURE

Commenter: Robert K. Lyons, Ph. D., Professor and Extension Range Specialist, Texas A&M Agrilife Extension Service

Comment Summary: SU herbicides are important for Texas pastures/rangelands and manage over 30 different weed species. SUs are the only option for some brush species. Buffer limitations would severely reduce the effectiveness of SUs as untreated areas serve as a seed source for re-infestation of pastures.

BEAD Response: BEAD appreciates this information.

USE IN INDUSTRIAL, TRANSPORTATION, AND RIGHTS-OF-WAY VEGETATION MANAGEMENT

Commenters: Alabama Department of Transportation (EPA-HQ-OPP-2012-0387-0048); Jon Johnson, Research Associate, Pennsylvania State University (EPA-HQ-OPP-2012-0387-0024; Derek Smith, Vegetative Management Asset Engineer, North Carolina Department of Transportation (EPA-HQ-OPP-2012-0387-0034); Rand Swanigan, Senior Roadside Management Specialist, Missouri Department of Transportation (MoDOT) (EPA-HQ-OPP-2012-0387-0036); Jay McCurdy, Ph.D., Assistant Professor, Mississippi State University (EPA-HQ-2012-0387-0031)

Comment Summary: Multiple commenters identified sulfonylurea herbicides as integral to controlling invasive species on roadsides and SUs specifically target noxious and invasive species such as Johnsongrass. Furthermore, stakeholders indicate that applicators use large droplet size and use a wide range of equipment such as backpack sprayers, ground booms, or hydraulic sprayers with fixed heads to make applications to target pests. Commenters maintain that SU herbicides assist in increasing safety on roadways by reducing mowing and increasing visibility. Restricting the use of SU herbicides poses potential negative impacts for highway right-of-way management, including bank stability associated with frequent mowing near traffic and decreased weed control options for vigorously growing johnsongrass, vasseygrass, foxtails, and increased movement of invasive species. Also, commenters mentions that SUs control weeds in perennial native grasslands, including the federal Conservation Reserve Program.

BEAD Response: BEAD appreciates this information.

Additionally, a document entitled "The Use and Benefits of Sulfonylurea Herbicides" (Holt, 2016) was submitted to the Agency. Although the benefits in this use pattern are difficult to quantify, BEAD concludes that the utility of sulfonylurea herbicides to rights-of-way (ROW) management is likely very high.

Some of the benefits of sulfonylurea herbicides according to Holt (2016):

Roadside benefits:

- Keep shoulder clear, increase sight distance, and increase sign visibility
- Increases drainage from roadside
- Decrease maintenance of guard rails and medians
- Reduces fire hazard

Electric Utility Benefits:

- Clearance for conductors
- Emergency line service access and clearance

Railroad:

- Keeps yards free of weeds
- Vegetation management on tracks, bridges, and crossings to maintain sight distance and increase visibility

VALUE OF SULFONYLUREA HERBICIDES

Commenter: Sheryl Kunickis, Director, Office of Pest Management Policy, Agricultural Research Service, United States Department of Agriculture (USDA) (EPA_HQ_2012-0387-002)

Comment Summary: The SUs are important tools for weed management in all areas of production agriculture, forestry, and rangeland weed management. Three critical areas of importance include weeds management in minor crops, invasive weed management, and herbicide resistance management. Select SU herbicides are among the few herbicide options available for minor, high cash value crops (e.g., halosulfuron-methyl and imazosulfuron on vegetable crops). Halosulfuron-methyl is used as an alternative to methyl bromide in select crops. Other SU herbicides such as chlorsulfuron, metsulfuron, rimsulfuron, sulfometuron-methyl and sulfosulfuron are used alone or in mixtures for managing invasive annual and perennial grass and broadleaf species, both annual and perennial species in pasture, range, Conservation Reserve Program land, forest, native grass establishment, and restoration. Key invasive species controlled by select SU herbicides includes cheat grass, yellow star thistle, Canada thistle, and others. The forest service uses SUs to control noxious weeds and for conifer release and preparation. The herbicides are applied using backpacks or boom sprayers.

BEAD Response: BEAD appreciates this information and its characterization of use sites.

VIII. OVERVIEW OF INDIVIDUAL SULFONYLUREA HERBICIDES

This section summarizes characteristics of each individual sulfonylurea herbicide. This includes registered crops, the types of weeds targeted, application timing, and the route of absorption into the weed. Information about the active ingredient properties (uptake by roots and/or foliage), role in pest management, and target pests was obtained from the Herbicide Handbook (WSSA, 2014) and the Crop Data Management Systems (CDMS) Label Database. Two usage tables are presented for nearly every chemical discussed. The tables rely on different years of data (2009-2013 versus 2010-2014) so the estimates of acres treated may be different between the two tables. The first table provides agricultural usage information including screening-level estimates of the amount used and the percent of the crop that is treated. Further, information about the average and "high-end" (90^{th} to 100^{th} percentile) reported application rates used for each chemical, the number of applications made, and the amount of the chemical that is applied by aerial equipment is provided. The second table provides an estimate of the amount of the herbicide applied by air for each crop.

Usage data is based on Market Research Data (user surveys), 2009-2014. The average rate is the reported application rate calculated by dividing the total pounds applied by the total area treated of the chemical. "High-end" application rate and percentile is a reported rate near the 90^{th} percentile (based on acreage treated) and the percentile associated with that rate. The rate is presented in terms of acres treated. For example, in Table 9, 92% of acres treated received applications at a rate of 0.047 lb. ai/acre or less. Number of applications and percentile is also presented in terms of acres. For example, in Table 9, 90% of acres treated received 1 application and 10% of acres treated received 2 applications. For a given crop, the percent crop treated is usually presented at the national level. It is defined as base acres treated (BAT) divided by the crop area grown (CAG), which is the number of acres planted of a given crop. The BAT for a particular crop is the number of acres treated at least once with the active ingredient.

BENSULFURON-METHYL

Bensulfuron-methyl is used for control of terrestrial and aquatic broadleaf and rush weed species in rice. The average percent crop treated from 2009-2013 was 7.4% and it was used on an average on 228,600 acres from 2009-2013 (Table 9). Bensulfuron-methyl is systemic after absorption by roots and foliage and can control weeds as a soil (preemergence) or foliar (post-emergence) application (WSSA, 2014). Bensulfuron-methyl is only registered on rice where it is applied by aerial (59% of treated acres) and ground (41% of treated acres) equipment (Table 10).

Bensulfuron-methyl has over 30 weeds listed on the label and controls a wide range of unusual and difficult to control weeds such as blunt spikerush, California arrowhead, ducksalad, Eisen waterhyssop, roundleaf waterhyssop, purple ammania, redstem, ricefield bulrush, southern naiad, smallflower umbrellaplant, water plantain, and waterwort. Based on Market Research Data (2010-2014) other target weeds include sesbania, curly indigo, and ducksalad.

Table 9. Table of Bensulfuron-methyl Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Rice	228,600	7,100	7.4%	0.031	0.047 (92%)[3]	1 (90%) 2 (10%)

Source: Market Research Data, 2009-2013.

Table 10. Crops with aerial applications of Bensulfuron-methyl, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Rice	188,100	110,100	59%

Source: Market Research Data, 2010-2014.

CHLORIMURON-ETHYL

Chlorimuron-ethyl is a broad spectrum herbicide for control of broadleaf and sedge weeds that was used on an average of over 11,000,000 acres of soybeans from 2009-2013 (Table 11). The average percent crop treated in soybeans from 2009-2013 is approximately 14%. It can control broadleaf, grass, and sedge weeds as a soil (preemergence) or foliar (post-emergence) application and is absorbed rapidly into leaves and is thoroughly systemic after absorption by the roots and foliage (WSSA, 2014). Chlorimuron is registered on 7 crops/sites and has over 70 weeds on its label. Chlorimuron-ethyl is used on six different crops (dry beans and peas are two separate crops whose usage data is merged) and the available usage data suggests that it is applied by air and ground equipment to three of those crops (Table 12). Chlorimuron-ethyl is widely used in soybeans because of the range of weeds that it can control (with over 70 weeds listed on the label) and good crop safety.

Table 11. Table of Chlorimuron-ethyl Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Dry Beans/Peas	1,600	20	0.3	0.013	0.013 (100%)	1 (100%)
Fallow	7,800	90	0.1	0.011	0.026 (93%)	1 (100%)
Peanuts	52,300	900	4.4	0.017	0.019 (98%)	1 (98%) 2 (2%)
Rice	10,500	140	2.0	0.013	0.013 (100%)	1 (100%)
Soybeans	11,554,300	195,600	14.1	0.017	0.027 (90%)	1 (96%) 2 (4%) 3 (<1%)

[3] Column 6 consists of the reported rate at and associated percentile with that rate. When available, the 90th percentile rate was chosen. Otherwise, a reported rate near to the 90th percentile was chosen. In many cases the maximum reported rate (100th percentile) is shown.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Squash	100	0	1.0	0.004	0.04 (100%)	Not reported

Source: Market Research Data. 2009-2013.

Table 12. Crops with Aerial applications of Chlorimuron-ethyl, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Dry Beans/Peas	1,600	800	50%
Rice	10,900	10,500	97%
Soybeans	13,747,800	176,200	1%

Source: Market Research Data. 2010-2014.

CHLORSULFURON

Chlorsulfuron is a broad spectrum herbicide for control of over 90 broadleaf and grass weed species. It does not provide effective control of sedge species. It can control weeds as a soil (preemergence) or foliar (post-emergence) application and is rapidly absorbed by foliage and roots and then readily translocated in the xylem but less so in the phloem (WSSA, 2014).

Chlorsulfuron is registered on thirteen different crops and use sites including grain crops, soybean, pasture and fallow land. The greatest use on crops is on winter wheat with an average of over 4 million acres treated (Table 13). Chlorsulfuron is used on approximately 300,000 acres of rangeland, pastures, electrical and pipeline rights-of-way and railroad rights-of-ways (Kline, 2012a). It can applied by aerial and ground equipment. The available usage data suggests that it is applied by air to three crops (Table 14).

Chlorsulfuron is used by the BLM on Rangeland, Oil and Mineral sites, Rights Of Way, and Recreational Resources (Bureau of Land Management, 2008). The typical use rate for the BLM is 0.07 lb. a.i./A between 2011 and 2013 when it was used on an average of 11,000 acres per year. (Bureau of Land Management, 2011).

Chlorsulfuron is also used by the U.S. Forest Service. In 2015, USFS Region 5 (California, Hawaii, and the Pacific Islands) used chlorsulfuron on approximately 55 acres for invasive plant treatment. Typical use rate for these applications was 0.0064 lb. a.i./A (U.S. Forest Service, 2015).

Table 13. Table of Chlorsulfuron Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Barley	28,400	290	0.9	0.010	0.014 (96%)	1 (100%)
Corn	1,300	20	< 0.1	0.012	0.012 (100%	1 (100%)

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Fallow	63,000	530	0.4	0.008	0.015 (96%)	1 (49%) 2 (51%)
Pastureland	126,200	1,000	0.1	0.008	0.016 (91%)	1 (92%) 2 (8%)
Sorghum (Milo)	3,400	40	0.1	0.011	0.012 (100%)	1 (100%)
Soybeans	9,000	100	< 0.1	0.012	0.013 (100%)	1 (100%)
Wheat, Spring	43,100	600	0.3	0.014	0.015 (96%)	1 (100%)
Wheat, Winter	4,288,300	49,500	10.8	0.012	0.016 (94%)	1 (97%) 2 (3%) 3 (<1%)

Source: Market Research Data. 2009-2013.

Table 14. Crops with Aerial applications of Chlorsulfuron, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Barley	26,200	19,000	73%
Pastureland	162,100	9,000	6%
Wheat, Winter	4,380,800	131,100	3%

Source: Market Research Data, 2010-2014

FLAZASULFURON

Flazasulfuron first received conditional registration in 2007 for use on non-residential turf and golf courses. In 2013 new uses were approved for citrus, confer trees, grapes, sugarcane, and tree nuts. Flazasulfuron is now registered on fifteen crops (grapes, citrus, conifer, and tree nuts) and in turf grass. It can control broadleaf, grass, and sedge weeds as a soil (pre-emergence) or foliar (post-emergence) application, is readily absorbed by roots and foliage, and translocated primarily by the phloem (WSSA, 2014).

Market research data from 2009-2013 only show usage on wine grapes (Table 15); however, more data were available from the California Department of Pesticide Regulation (CPDR) (Table 16). The percent crop treated for oranges in 2014 was 4% (Market Research Data, 2014). No applications by air were reported in the survey data for this chemical (Market Research Data, 2014). CPDR data shows two applications by air in 2013, but these applications do not appear to have been categorized correctly.

Table 15. Table of Flazasulfuron Use by Crop, Average for 2013-2014*.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Grapes, Raisin	1,200	50	< 1%	0.045	0.045 (100%)	Not reported
Grapes, Wine	7,000	300	< 1%	0.040	0.045(100%)	Not reported
Oranges	4,000	200	<1%	0.045	0.045(100%)	Not reported

Source: Market Research Data, 2009-2013. *Usage data is available for 2013 – 2014 only. Number of applications is not reported for all crops.

Table 16. Table of Flazasulfuron Use in California by Crop, Average for 2012-2014

Crop	Acres Treated	Pounds of Active Ingredient	Average Rate (lb. ai/acre)	Rate and Upper Percentile (lb. ai/acre)	Number of Applications and Total Percentile
Grapefruit	6	< 1	0.047	0.048(100%)	1 (100%)
Grapes	1,400	50	0.035	0.045(100%)	1 (100%)
Grapes, Wine	7,000	200	0.032	0.045(100%)	1 (100%)
Oranges	400	20	0.045	0.048(100%)	1 (100%)
Tangelo	70	3	0.047	0.052(100%)	1 (100%)

Source: California Department of Pesticide Regulation, 2012-2014.

FORAMSULFURON

Foramsulfuron is an herbicide for foliar (post-emergence) control of broadleaf and grass weeds in turfgrass but does not provide effective control of sedges (WSSA, 2014). Foramsulfuron is translocated in both the xylem and the phloem (WSSA, 2014). Corn uses were removed from the label in 2015. Before those uses were removed it was applied annually to approximately 86,000 acres of field and sweet corn from 2009-2013 (Market Research Data). For golf courses approximately 1,200 pounds of foramsulfuron were applied in 2011 (Kline, 2012b). BEAD does not have data to show that it is applied by air and aerial applications of an herbicide to turfgrass would be unusual.

HALOSULFURON-METHYL

Halosulfuron-methyl is a broad spectrum herbicide for control of broadleaf and sedge weeds as a soil (preemergence) or foliar (post-emergence) application (WSSA, 2014). It does not provide effective control of grass species. The label lists over 50 broadleaf and sedge weeds. It is labeled on 113 crops/sites and used on a wide range of field, fruit, orchard, turf, and vegetable crops. Market research data show use on wide variety of crops (Tables 17 and 18). It has little potential for carryover and allows a wide range of rotational crops.

There were approximately 1,000 pounds of halosulfuron-methyl applied by landscape operators in 2011 (Kline, 2012b). Corn, rice and sorghum are the only crops where BEAD has data on aerial applications. Approximately 57% of halosulfuron-methyl is applied aerially to rice (Table 18).

Table 17. Table of Halosulfuron-methyl Use by Crop, Average for 2009-2013

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Alfalfa	6,000	200	< 0.1	0.025	0.031 (100%)	1 (100%)
Almonds	100	4	< 0.1	0.047	0.047 (100%)	Not reported
Apples	200	20	< 0.1	0.077	0.094 (100%)	Not reported
Asparagus	2,000	90	6.8	0.043	0.047 (97%)	Not reported
Barley	300	10	< 0.1	0.023	0.023 (100%)	1 (100%)
Beans (Snap, Bush, Pole, String)	32,000	900	12.4	0.027	0.035 (87%)	Not reported
Caneberries	400	20	6.4	0.047	0.047 (100%)	Not reported
Cantaloupes	6,100	100	8.3	0.023	0.035 (93%)	Not reported
Celery	25	1	0.2	0.023	0.023 (100%)	Not reported
Corn	223,300	5,400	0.2	0.024	0.047 (97%)	1 (87%) 2 (13%)
Cucumbers	35,400	900	27.2	0.027	0.038 (95%)	Not reported
Dry Beans/Peas	90,300	2,500	3.3	0.028	0.031 (100%)	1 (100%)
Fallow	5,500	200	< 0.1	0.044	0.047 (100%)	1 (100%)
Lima Beans	1,100	30	3.0	0.027	0.047 (100%)	Not reported
Pastureland	2,400	80	< 0.1	0.035	0.035 (100%)	1 (100%)
Peppers	1,000	40	1.2	0.040	0.047 (100%)	Not reported
Pistachios	800	40	0.5	0.047	0.047 (100%)	Not reported
Pumpkins	20,300	700	23.8	0.033	0.047 (100%)	Not reported

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Rice	730,800	21,500	23.1	0.029	0.047 (99%)	1 (86%) 2 (13%) 3 (1%)
Sorghum (Milo)	22,000	600	0.3	0.028	0.039 (96%)	1 (100%)
Soybeans	500	20	< 0.1	0.031	0.031 (100%)	1 (100%)
Squash	6,500	200	12.8	0.033	0.047 (100%)	Not reported
Sugarcane	23,500	700	2.9	0.031	0.031 (99%)	1 (100%)
Sweet Corn	6,200	200	1.0	0.026	0.031 (98%)	Not reported
Tomatoes	16,700	500	3.2	0.031	0.047 (100%)	Not reported
Walnuts	700	30	0.2	0.044	0.047 (100%)	Not reported
Watermelons	22,800	700	15.6	0.029	0.035 (94%)	Not reported

Source: Market Research Data, 2009-2013. Number of applications is not reported for all crops.

Table 18. Crops with Aerial Applications of Halosulfuron-methyl, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Corn	245,600	1,600	1%
Rice	825,200	435,600	52%
Sorghum (Milo)	24,500	100	< 1%

Source: Market Research Data, 2010-2014

IMAZOSULFURON

Imazosulfuron is registered on approximately 20 crops including rice, fruits, and vegetables and has over a dozen broadleaf and sedge weeds on its label. Imazosulfuron is also registered for use on residential and commercial turfgrass and sod farms but the available usage data (Kline 2012b) did not indicate any usage on turf. Market research data show use on rice (Table 19). Imazosulfuron provides soil (preemergence) and foliar (post-emergence) control of annual broadleaf and sedge weed species; it does not provide effective control of grass species and has rapid foliar and root uptake (WSSA, 2014). In Arkansas it has been demonstrated to provide excellent control of hemp sesbania and yellow nutsedge (Still et. al., 2009). Approximately 37% of imazosulfuron is applied aerially to rice (Table 20).

Table 19. Imazosulfuron Use by Crop, Average for 2012-2014

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Rice	209,000	36,500	2.7	0.175	0.19 (100%)	1(100%)

Source: Market Research Data, 2012-2014.

Table 20. Crops with Aerial applications of Imazosulfuron Average for 2012-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Rice	41,800	15,200	36%

Source: Market Research Data, 2012-2014.

IODOSULFURON-METHYL-SODIUM

Iodosulfuron-methyl-sodium is registered for use on 15 crops and several additional sites including cereals, corn, cotton, sorghum, soybeans, ornamentals, turf, and roadside management. Iodosulfuron-methyl-sodium has over two dozen annual and perennial broadleaf weeds on its label. It provides foliar (postemergence) control of broadleaf weed species and is translocated in plants (WSSA, 2014). Market research data show use in corn and soybean (Tables 21). In corn and soybean, iodosulfuron-methyl-sodium is predominately used preplant or after harvest. This provides the user with a long window in which to make the application. BEAD does not have any data to indicate that iodosulfuron-methyl-sodium is applied aerially.

Table 21. Table of Iodosulfuron-methyl-sodium Use by Crop, Average for 2009-2013

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Corn	183,400	300	0.2	0.002	0.002(100%)	1(100%)
Soybeans	170,400	300	0.2	0.002	0.002(100%)	1(100%)

Source: Market Research Data, 2009-2013

MESOSULFURON-METHYL

Mesosulfuron-methyl is a foliar (postemergence) selective grass and broadleaf herbicide registered in barley, fallow, triticale, and wheat with over two dozen broadleaf and grass weeds on the label. Market research data show use on barley, fallow, and wheat (Tables 22). Mesosulfuron-methyl is applied by ground and aerial methods with approximately 3% of the spring wheat and 13% of the winter wheat acre treatments made by air (Table 23).

Table 22. Table of Mesosulfuron-methyl Use by Crop, Average for 2009-2013

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Barley	1,700	< 10	0.2	0.002	0.002(100%)	1(100%)
Fallow	3,900	10	0.1	0.003	0.003(100%)	1(100%)
Wheat, Spring	343,500	100	2.3	0.003	0.013(100%)	1(100%)
Wheat, Winter	516,200	5,200	1.3	0.010	0.013(100%)	1(98%) 2(1%) 3(1%)

Source: Market Research Data, 2009-2013

Table 23. Crops with Aerial applications of Mesosulfuron-methyl Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Wheat, Spring	280,500	7,700	3%
Wheat, Winter	596,200	80,000	13%

Source: Market Data Research, 2010-2014

METSULFURON-METHYL

Metsulfuron-methyl is used on several large acreage crops including: alfalfa, corn, cotton, pastures, fallow land, small grain (barley and wheat), and soybean crops (Table 24). Metsulfuron-methyl is also used for other non-crop sites such as turfgrass, by professional lawn care operators and turf farms, and for industrial vegetation management such as: forests, rangeland, and rights of way, for utilities, highways, and railroads. It is labeled on 11 crops and sites. Metsulfuron-methyl is labeled for control of over 60 broadleaf weed species. Metsulfuron-methyl can control weeds as a foliar (post-emergence) application where it is readily translocated but does not control grass or sedge weeds (WSSA, 2014). It has little potential for carryover and allows a wide range of rotational crops (WSSA, 2014). It is labeled for grasses grown under the Conservation Reserve Program and in several pasture grass species for broadleaf weed control. In pasture situations it can be used to reduce seedheads in grass species thus improving the forage quality by reducing nutrients being diverted to seedhead production by the grass plants (metsulfuron-methyl label).

Barley, fallow, pastureland, sorghum, and wheat (spring and winter) are crops where BEAD has data on aerial applications (Table 25). For industrial vegetation management (forests, rangeland, rights-of-way) over 3.2 million acres are treated with over 116,000 pounds (Kline, 2012a). In the turf market over 16,000 pounds of metsulfuron-methyl were applied in 2011 and no use was reported on golf courses (Kline, 2012b).

Metsulfuron-methyl is used by the BLM on rangeland, forestland, oil and mineral sites, rights of way, and recreational resources at a typical use rate of 0.12 lb. a.i./A between 2011 and 2013 where it was used on an average of 10,000 acres per year (BLM, 2008; BLM, not dated). Metsulfuron-methyl is recommended for release treatments in conifer and hardwood timber plantings (a release treatment removes plants that compete for nutrients, sunlight, and water) (Penn State University, 2016).

Relevant Information from Stakeholders

EPA received information from the National Council for Air and Stream Improvement in a comment on the "Preliminary Ecological Risk Assessment for Registration Review of 22 Sulfonylurea Herbicides." In 2012 NCASI conducted survey of 12 forest product companies about their use of herbicides in operational forestry and 26 responses were received covering the South, Pacific Northwest, and North (6.5 million hectares under management). This comment provides information from forestry operations that use sulfometuron methyl:

- Describes the use of spray buffers in forestry;
- Use patterns related to forestry rotations;
- Use of spray drift technologies (droplet size used, boom length, GPS technology, metrological information);
- Application rates in forestry.

> "In general, herbicide application rates used in operational forestry are lower than the maximum rates allowed by the label. For metsulfuron-methyl, area-weighted average application rates were 0.035 lbs. a.i./acre (South) and 0.045 lbs. a.i./acre (PNW), which were 23% and 61% of the maximum label rate for the applicable region. Respondents from the North did not report using metsulfuron-methyl in 2011. For sulfometuron methyl, area-weighted average application rates were 0.036 (North), 0.109 (South) and 0.113 (PNW) lbs. a.i./acre (10%, 29%, and 60% of the maximum label rate for the applicable region)."

Table 24. Table of Metsulfuron-methyl Use by Crop, Average for 2009-2013

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Alfalfa	1,200	11	< 0.1	0.009	0.015 (96%)	1 (100%)
Barley	122,700	412	4.0	0.003	0.004 (99%)	1 (100%)
Corn	1,300	3	< 0.1	0.002	0.002 (100%)	1 (100%)
Fallow	535,600	2,425	2.8	0.005	0.004 (91%)	1 (62%) 2 (38%) 3 (<1%)
Pastureland	1,477,600	20,717	1.5	0.014	0.019 (90%)	1 (95%) 2 (5%)

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
						3 (<1%)
Pecans	1,700	21	0.5	0.012	0.014 (100%)	Not reported
Sorghum (Milo)	133,500	473	1.9	0.004	0.008 (96%)	1 (87%) 2 (13%)
Soybeans	9,100	23	< 0.1	0.003	0.003 (98%)	1 (100%)
Wheat, Spring	369,600	1,184	2.5	0.003	0.004 (99%)	1 (98%) 2 (2%)
Wheat, Winter	8,256,100	23,330	20.1	0.003	0.004 (99%)	1 (92%) 2 (6%) 3 (2%)

Source: Market Research Data, 2009-2013. Number of applications is not reported for all crops.

Table 25. Crops with Aerial applications of Metsulfuron-methyl, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerial and Ground	Percent of Total Area Treated Aerially
Barley	115,300	5,500	5%
Fallow	542,200	11,200	2%
Pastureland	1,613,600	560,600	35%
Sorghum (Milo)	106,700	3,300	3%
Wheat, Spring	288,000	57,500	20%
Wheat, Winter	8,014,500	454,900	6%

Source: Market Research Data, 2010-2014

NICOSULFURON-METHYL

Nicosulfuron methyl is a foliar (postemergence) herbicide applied to control grass and broadleaf weeds with over three dozen weeds listed on the label. Nicosulfuron is rapidly absorbed by the foliage and translocated to the growing points of the plant (WSSA, 2014). It is predominately used in corn, but also used in sweet corn, soybeans, pastures, peas, sunflower, and recently registered on ALS resistant Inzen sorghum (Tables 26). Approximately 0.4% of the corn acres that are treated are applied by air (Table 27).

Table 26. Table of Nicosulfuron Use by Crop, Average for 2009-2013

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Corn	1,499,200	29,500	1.6	0.02	0.035(100%)	1 (96%) 2(4%)
Pastureland	43,100	1,700	< 0.1	0.039	0.053(100%)	1(94%) 2(6%)

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Soybeans	7,900	100	< 0.1	0.011	0.011(100%)	1(100%)
Sweet Corn	27,500	700	5.0	0.026	0.062 (100%)	Not reported

Source: Market Research Data, 2009-2013. Number of applications is not reported for all crops.

Table 27. Crops with Aerial applications of Nicosulfuron, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated Aerially	Percent of Total Area Treated Aerially
Corn	1,318,400	4,700	< 1%

Source: Market Research Data, 2010-2014

ORTHOSULFAMURON

Orthosulfamuron provides foliar (post-emergence) control of broadleaf, rush, and sedge weed species with two dozen broadleaf, sedge, and semi-aquatic weeds on the label. It is only registered on rice and can be applied in the early post-emergence to the middle or late post-emergence stage of growth. Market research data show use on rice (Table 28) with approximately 49% of the acres treated with orthosulfamuron are applied by air (Tables 29).

Table 28. Table of Orthosulfamuron Use by Crop, Average for 2009-2013

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Rice	44,200	2,700	1.5	0.061	0.066(100%)	1 (100%)

Source: Market Research Data, 2009-2013

Table 29. Crops with Aerial applications of Orthosulfamuron, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Rice	38,800	19,000	49%

Source: Market Research Data, 2010-2014

PRIMISULFURON

Primisulfuron methyl is a foliar (postemergence) herbicide used in corn to control annual and perennial grasses, sedges, and many annual broadleaf weeds with 60 weeds listed on the label. Primisulfuron is readily absorbed by both foliage, and is translocated primarily through the phloem to the shoot growing points (WSSA, 2014). Primisulfuron is registered for use on turf and corn (Table 30). BEAD does not have any data to indicate that primisulfuron is applied aerially.

Table 30. Table of Primisulfuron Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Corn	228,300	5,100	0.3	0.022	0.027 (99.9%)	1 (99%) 2 (1%)

Source: Market Research Data, 2009-2013

PROSULFURON-METHYL

Prosulfuron-methyl is a postemergence (foliar) herbicide used in corn and other cereal crops to control annual broadleaf weeds with 60 weeds listed on the label. Market research data show use on barley, corn, sorghum, and wheat (Table 31). Prosulfuron-methyl is readily absorbed by the foliage and roots, with extensive translocation in both the xylem and phloem (WSSA, 2014). Prosulfuron-methyl is registered on 12 crops/sites. Prosulfuron-methyl is applied by ground and aerial methods. The available usage data suggest that the chemical is applied by air to corn, sorghum, spring wheat and winter wheat (Table 32).

Table 31. Table of Prosulfuron-methyl Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Total Percentile
Barley	5,300	400	0.2	0.016	0.018 (100%)	1(100%)
Corn	174,300	9,000	0.2	0.010	0.036 (100%)	1 (99%) 2 (1%)
Fallow	9,400	800	0.2	0.018	0.018(100%)	1(100%
Sorghum	345,600	30,100	5.3	0.018	0.036(100%)	1(97%) 2(3%)
Wheat, Spring	56,200	3,700	0.4	0.013	0.018(100%)	1(100%)
Wheat, Winter	123,300	9,600	0.3	0.016	0.018(100%)	1 (100%)

Source: Market Research Data, 2009-2013

Table 32. Crops with Aerial applications of Prosulfuron-methyl, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Corn	170,300	1,300	1%
Sorghum	334,100	10,800	3%
Wheat, Spring	53,500	700	1%
Wheat, Winter	114,800	5,900	5%

Source: Market Research Data, 2010-2014

RIMSULFURON

Rimsulfuron is applied as a foliar (postemergence) herbicide for the control of broadleaf, sedge, and grass weeds with 70 weeds listed on the label. Rimsulfuron is absorbed rapidly in the foliage (post-emergence) and readily translocated in the xylem and phloem (WSSA, 2014). Label information indicates that rimsulfuron can be applied in the fall to control problematic winter weeds and allow the grower to plant rotational crops without phytotoxic effects the next year. Rimsulfuron has over 60 registered crops and sites and is predominately used in corn, potato, tomato, and many orchard and vine crops (Table 33). The crops with aerial usage in our survey data are corn, soybeans, potatoes, cotton, and rice (Table 34).

Table 33. Table of Rimsulfuron Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Almonds	164,000	8,600	15.7	0.053	0.063(100%)	Not reported
Apples	38,000	2,000	10.3	0.054	0.063(100%)	Not reported
Apricots	1,400	70	13.0	0.047	0.063(100%)	Not reported
Caneberries	500	20	4.2	0.031	0.047(100%)	Not reported
Cherries	16,400	900	10.9	0.053	0.063(100%)	Not reported
Corn	4,193,700	57,600	4.2	0.014	0.031(100%)	1 (96%) 2 (4%) 3 (<1%)
Cotton	43,600	700	0.6	0.016	0.016(100%)	1 (100%)
Fallow	5,600	80	0.2	0.014	0.014(100%)	1 (100%)
Grapes, Raisin	28,200	1,500	11.9	0.054	0.063(100%)	Not reported
Grapes, Table	27,600	1,700	29.6	0.062	0.063(100%)	Not reported
Grapes, Wine	114,700	6,000	19.4	0.053	0.063(100%)	Not reported
Hazelnuts	700	30	3.5	0.046	0.063(100%)	Not reported
Lemons	2,600	200	4.0	0.061	0.063(100%)	Not reported
Oranges	49,200	2,800	6.2	0.056	0.063(100%)	Not reported
Peaches	10,000	600	8.5	0.055	0.063(100%)	Not reported
Pears	3,400	200	5.7	0.052	0.063(100%)	Not reported
Pistachios	36,000	2,000	17.3	0.055	0.063(100%)	Not reported
Plums/Prunes	9,800	500	10.4	0.055	0.063(100%)	Not reported

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Potatoes	347,200	6,600	31.8	0.019	0.023(100%)	1 (90%) 2 (8%) 3 (2%)
Soybeans	343,000	4,400	0.8	0.013	0.016(100%)	1 (99%) 2 (<1%)
Sweet Corn	3,300	30	1.0	0.010	0.012(100%)	Not reported
Tomatoes	140,900	4,500	33.6	0.032	0.063(100%)	Not reported
Walnuts	17,800	900	5.9	0.048	0.063(100%)	Not reported

Source: Market Research Data, 2009-2013. Number of applications is not reported for all crops.

Table 34. Crops with Aerial applications of Rimsulfuron, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Corn	4,619,500	168,000	4%
Cotton	94,800	12,600	13%
Potatoes	346,200	19,500	6%
Rice	6,200	4,600	74%
Soybeans	672,400	86,000	13%

Source: Market Research Data, 2010-2014

SULFOMETURON-METHYL

Sulfometuron-methyl is a broad-spectrum herbicide that provides soil (preemergence) and foliar (post-emergence) control of annual, biennial, and perennial broadleaf, grass and sedge weeds. Sulfometuron-methyl has over 40 crops and sites and 90 weeds listed on the label. Sulfometuron-methyl is readily absorbed by foliage and roots and translocates in the both the xylem and phloem, but not extensively, and it accumulates in the meristematic tissue (WSSA, 2014). Sulfometuron-methyl is registered for weed control in turf management, invasive and noxious weed control in forest settings, forest site preparation (release treatments), rights-of-way vegetation management and other non-crop sites. For industrial vegetation management (forests, rangeland, and rights-of-way) almost 1 million acres are treated with over 115,000 pounds (Kline, 2012a). For nursery and greenhouse operations over 335,000 pounds of sulfometuron-methyl were applied in 2011 (Kline, 2012b).

Sulfometuron-methyl is used by the U.S. Forest Service (USFS), the Bureau of Land Management (BLM), and the National Park Service to control invasive species (Table 35). Furthermore, sulfometuron-methyl is recommended for release treatments in conifer and hardwood timber plantings (a release treatment removes plants that compete for nutrients, sunlight, and water) (Penn State University, 2016). The BLM uses sulfometuron-methyl for vegetation control in their Public-Domain Forest Land, Energy and Mineral Sites, Rights-of-Way, and Recreation programs. The BLM typically applies sulfometuron-methyl at 0.131 lbs. a.i/A on average between 2011 and 2013 where there were an average of 850 acres treated per year (BLM not dated). Application methods include on foot or horseback with backpack sprayers or from all-terrain vehicles or trucks equipped with spot or boom/broadcast sprayers. The BLM uses sulfonylurea herbicides (and other herbicides) "to improve ecosystem health by manipulating vegetation to enhance native plant communities, improve riparian and wetland areas and improve water quality" (BLM, 2015). Additionally, multiple products containing sulfometuron-methyl are prohibited from being applied aerially on BLM areas.

As of 2004, the only sulfometuron-methyl products used by USFS were Oust® and Oust XP®, neither of which were applied aerially (Klotzbach and Durkin, 2004); however, sulfometuron-methyl is registered for aerial applications. The most common methods of application on USFS land for Oust® and Oust XP® were backpack (selective foliar) and boom spray (broadcast foliar). Boom spray is primarily used in rights-of-way management (Klotzbach and Durkin, 2004).

Table 35. Sulfometuron Methyl Usage by Federal Agencies

Agency (Year)	Acreage	Pounds	Calculated lbs ai/acre
U.S. Forest Service (Cota, 2004)	915	87.5	0.0956
Bureau of Land Management (2011)	1,116	101.48	0.0909

SULFOSULFURON

Sulfosulfuron can be applied to the soil (pre-emergence) and foliage (post-emergence) as an herbicide for control of grasses, broadleaf weeds and sedges in wheat and non-crop areas. There are over two dozen different weeds listed on the label. Sulfosulfuron can be absorbed by foliage or roots (WSSA, 2014). Sulfosulfuron is registered in 5 crops, industrial vegetation management, and 16 turf/ornamental sites. Market research data show use on fallow areas, pastures, and wheat (Table 36). Based on the available data, sulfosulfuron is applied aerially to wheat (Table 37). For industrial vegetation management on roadways, 667,000 acres are treated with over 31,000 pounds of active ingredient (Kline, 2012a).

Table 36. Table of Sulfosulfuron Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Total Percentile
Pasture	9,300	2,700	< 0.1	0.008	0.094 (100%)	1 (83%) 2 (17%)
Wheat, Spring	19,200	3,000	0.1	0.004	0.031(100%)	1 (100%)
Wheat, Winter	445,300	57,000	1.1	0.016	0.033(100%)	1 (88%) 2 (12%)

Source: Market Research Data, 2009-2013

Table 37. Crops with Aerial applications of Sulfosulfuron, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Wheat, Winter	372,400	62,600	17%

Source: Market Research Data, 2010-2014

THIFENSULFURON

Thifensulfuron is labeled for use on 20 crops and sites including small grain (barley, flax, oats, safflower, triticale, and wheat) and soybean crops (Table 38) primarily for control of small seeded broadleaf weeds. There are over 60 weeds listed on the label. Thifensulfuron is applied as a foliar (post-emergence) application to weeds and is readily absorbed by foliage and roots and translocates extensively in the xylem and phloem and accumulates in the meristematic tissue (WSSA, 2014). It controls a wide range of weeds, has little potential for carryover, is available in a wide range of premixes, and allows a wide range of rotational crops (thifensulfuron label). Barley, corn, cotton, rice, soybeans, and wheat are the only crops where BEAD has data on aerial applications (Table 39).

Table 38. Table of Thifensulfuron Use by Crop, Average for 2009-2013

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Alfalfa	20	0	< 0.1	0.015	0.015 (100%)	1 (100%)
Barley	549,800	6,000	18.0	0.011	0.019 (95%)	1 (98%) 2 (2%)
Corn	1,939,700	12,700	2.0	0.007	0.016 (98%)	1 (98%) 2 (2%)
Cotton	150,300	1,600	1.3	0.011	0.016 (100%)	1 (94%) 2 (6%)
Fallow	132,500	900	0.6	0.007	0.013 (90%)	1 (46%) 2 (45%) 3 (9%)
Pastureland	3,900	30	< 0.1	0.008	0.015 (100%)	1 (100%)
Peas (Fresh/Green/ Sweet)	50	0	0.1	0.003	0.003 (100%)	Not reported
Rice	180,700	1,400	5.6	0.008	0.003 (99%)	1 (90%) 2 (9%) 3 (1%)
Sorghum (Milo)	3,300	40	0.1	0.012	0.019 (100%)	1 (100%)
Soybeans	3,707,800	24,800	4.6	0.007	0.015 (93%)	1 (97%) 2 (3%)

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Wheat, Spring	2,790,300	27,600	18.4	0.010	0.015 (94%)	1 (98%) 2 (2%)
Wheat, Winter	4,730,100	53,900	11.8	0.011	0.019 (90%)	1 (62%) 2 (36%) 3 (2%)

Source: Market Research Data, 2009-2013. Number of applications is not reported for all crops.
Footnote: Percentile for number of applications is based on area treated.

Table 39. Crops with Aerial applications of Thifensulfuron, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Barley	552,400	9,900	2%
Corn	2,277,700	115,200	5%
Cotton	225,600	22,000	10%
Pastureland	4,900	200	4%
Rice	305,600	175,500	57%
Soybeans	4,736,200	142,800	3%
Wheat, Spring	2,865,830	127,800	4%
Wheat, Winter	4,883,000	410,400	8%

Source: Market Research Data, 2010-2014

TRIASULFURON

Triasulfuron has activity as a soil (preemergence) and foliar (post-emergence) herbicide primarily used to control broadleaf weeds, is absorbed by both roots and foliage, and the chemical is readily translocated to the meristematic tissue (WSSA, 2014). Triasulfuron is registered for use on wheat, barley, pasture, rangeland, fallow cropland, and Conservation Reserve Program acres with over 75 weeds listed on the label. It is used primarily in wheat and barley (Table 40). Triasulfuron is applied aerially in pastureland and wheat (Table 41). .

Table 40. Table of Triasulfuron Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Barley	11,400	700	0.5	0.005	0.016 (100%)	1 (100%)
Fallow	95,300	7,500	0.6	0.009	0.026(100%)	1 (100%)
Pasture	41,600	3,900	< 0.1	0.008	0.023 (100%)	1 (90%) 2 (100%)

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Wheat, Spring	46,300	3,200	0.3	0.004	0.023(100%)	1 (100%)
Wheat, Winter	1,577,900	127,200	4.0	0.016	0.026(100%)	1 (99%) 2 (<1%) 3(<1%)

Source: Market Research Data, 2009-2013

Table 41. Crops with Aerial applications of Triasulfuron, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Pastureland	40,300	12,800	32%
Wheat, Spring	19,400	900	5%
Wheat, Winter	1,743,600	32,400	2%

Source: Market Research Data, 2010-2014

TRIBENURON-METHYL

Tribenuron-methyl is primarily used as a foliar (postemergence) broadleaf herbicide in cereal crops and is rapidly absorbed by the roots and foliage, and predominately translocated in the phloem (WSSA, 2014). Tribenuron-methyl is primarily used in cereal crops but is registered for use on 31 crops/sites (Table 42). Tribenuron-methyl lists over 60 broadleaf and grass weed species on the label. Tribenuron-methyl is commonly applied by air in many crops, especially rice, wheat, and corn (Table 43).

Table 42. Table of Tribenuron-methyl Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Barley	559,600	13,500	18.2	0.005	0.016 (100%)	1 (99%) 2 (1%)
Corn	132,300	6,000	0.1	0.009	0.011(100%)	1 (100%)
Cotton	106,700	4,200	0.9	0.008	0.013 (100%)	1 (92%) 2 (8%)
Fallow	135,300	2,800	0.65	0.004	0.012(100%)	1 (47%) 2 (45%) 3(8%)
Pastureland	3,900	80	< 0.1	0.004	0.008(100%)	1 (100%)
Rice	108,500	5,600	3.7	0.010	0.013(99.8%)	1 (100%)
Sorghum	3,000	70	0.1	0.005	0.005(100%)	1 (100%)

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Soybeans	966,200	39,800	1.3	0.008	0.015(100%)	1 (99%) 2 (<1%)
Sunflowers	204,800	17,300	11.3	0.017	0.023(100%)	1 (96%) 2 (4%)
Wheat, Spring	2,872,300	61,200	18.9	0.004	0.016(100%)	1 (98%) 2 (2%)
Wheat, Winter	4,396,000	124,100	10.9	0.006	0.016(100%)	1 (95%) 2 (4%) 3 (1%)

Source: Market Research Data, 2009-2013

Table 43. Crops with Aerial Applications of Tribenuron-methyl, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Barley	573,000	11,400	2%
Corn	201,700	25,000	12%
Cotton	129,700	9,400	7%
Pastureland	4,900	200	4%
Rice	150,000	79,900	53%
Soybeans	1,079,600	48,100	4%
Sunflowers	223,900	3,800	2%
Wheat, spring	3,022,700	122,500	4%
Wheat, winter	4,543,700	484,000	11%

Source: Market Research Data, 2010-2014

TRIFLOXYSULFURON-SODIUM

Trifloxysulfuron-sodium is a foliar (postemergence) herbicide used primarily in cotton to control broadleaf, grass and sedge weeds with over 65 weeds listed on the label. Both shoots and roots adsorb trifloxysulfuron-sodium and it is translocated to the meristematic tissue (WSSA, 2014). Market research data shows use on cotton and sugarcane (Table 44). For golf courses approximately 1,000 pounds of trifloxysulfuron-sodium were used in 2011 (Kline, 2012b). Aerial applications are not permitted according to the trifloxysulfuron-sodium label.

Table 44. Table of Trifloxysulfuron-sodium Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Cotton	504,200	16,600	4.4	0.007	0.012(100%)	1 (98%) 2 (2%)

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Sugarcane	114,700	9,500	12.7	0.017	0.019 (100%)	1(83%) 2(17%)

Source: Market Research Data, 2009-2013

TRIFLUSULFURON-METHYL

Triflusulfuron-methyl provides foliar (postemergence) control of broadleaf and grass weeds in sugarbeets. It has over two dozen weeds listed on the label. Very little triflusulfuron is moved out of the leaf when foliar applied and it has little or no soil activity (WSSA, 2014). Triflusulfuron-methyl is also registered on for weed control in chicory, endive, and garden beets. For table beets it is recommended for control of pigweed, kochia, sheperdspurse and velvetleaf (Peachey, 2016). Market research data only reports usage data on sugarbeets (Table 46). Approximately 8% of the triflusulfuron-methyl treated sugar beet acres are treated by air (Table 47).

Table 46. Table of Triflusulfuron-methyl Use by Crop, Average for 2009-2013.

Crop	Acres Treated	Pounds of Active Ingredient	Percent Crop Treated	Average Rate (lb. ai/acre)	High-End Rate and Associated Percentile (lb. ai/acre)	Number of Applications and Percentile
Sugar Beets	100,600	5,400	3.6	0.010	0.032 (100%)	1 (9%) 2 (33%) 3 (40%) 4 (17%) 5 (<1%)

Source: Market Research Data, 2009-2013

Table 47. Crops with Aerial applications of Triflusulfuron, Average for 2010-2014.

Crop	Total Acres Treated, Aerial and Ground	Total Acres Treated, Aerially	Percent of Total Area Treated Aerially
Sugar Beets	76,500	5,900	8%

Source: Market Research Data, 2010-2014

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X. APPENDICES

Appendix I. Guidance for Pesticide Registrants on Pesticide Resistance Management Labeling*

1. The following general resistance management labeling statements are recommended for herbicide products containing only a single active ingredient or only active ingredients from the same group:

a. "For resistance management, (name of product) is a Group (mode of action group number) herbicide. Any weed population may contain or develop plants naturally resistant to (name of product) and other Group (mode of action group number) herbicides. The resistant biotypes may dominate the weed population if these herbicides are used repeatedly in the same field. Other resistance mechanisms that are not linked to this mode of action but are specific for individual chemicals, such as enhanced metabolism, may also exist. Appropriate resistance-management strategies should be followed."

For products containing active ingredients from different groups, the statement should be modified to reflect the situation, for example:

b. "For resistance management, please note that (name of product) is both a Group (mode of action group number) and a Group (mode of action group number) herbicide. Any weed population may contain plants naturally resistant to Group (mode of action group number) and/or Group (mode of action group number) herbicides. The resistant individuals may dominate the weed population if these herbicides are used repeatedly in the same fields."

2. The following additional resistance management labeling statements are recommended for herbicides, although each bulleted statement may not be appropriate or pertinent for every product label:

"To delay herbicide resistance:

a. Rotate the use of (name of product) or other Group (mode of action group number) herbicides within a growing season sequence or among growing seasons with different herbicide groups that control the same weeds in a field.

b. Use tank mixtures with herbicides from a different group if such use is permitted; Use the less resistance-prone partner at a rate that will control the target weed(s) equally as well as the more resistance-prone partner.

c. Adopt an integrated weed management program for herbicide use that includes scouting and historical information related to herbicide use and crop rotation, and that considers tillage (or other mechanical control methods), cultural (e.g., higher crop seeding rates;

precision fertilizer application method and timing to favor the crop and not the weeds), biological (weed-competitive crops or varieties) and other management practices.

d. Scout after herbicide application to monitor weed populations for early signs of resistance development. Indicators of possible herbicide resistance include: (1) failure to control a weed species normally controlled by the herbicide at the dose applied, especially if control is achieved on adjacent weeds; (2) a spreading patch of non-controlled plants of a particular weed species; (3) surviving plants mixed with controlled individuals of the same species (Norsworthy, et al., 2012). If resistance is suspected, prevent weed seed production in the affected area by an alternative herbicide from a different group or by a mechanical method such as hoeing or tillage. Prevent movement of resistant weed seeds to other fields by cleaning harvesting and tillage equipment when moving between fields, and planting clean seed.

e. If a weed pest population continues to progress after treatment with this product, discontinue use of this product, and switch to another herbicide with a different target mode of action, if available.

f. Have suspected resistant weed seeds tested by a qualified laboratory to confirm resistance and identify alternative herbicide options.

g. Contact your local extension specialist or certified crop advisors for additional pesticide resistance-management and/or integrated weed-management recommendations for specific crops and weed biotypes.

h. For further information or to report suspected resistance, contact (company representatives) at (toll free number) or at (Internet site).

* On June 3, 2016 an updated Pesticide Registration Notices on resistance management was opened for a 60 day comment which closes on August 2, 2016. The notice is Guidance for pesticide registrants on pesticide resistance management labeling (FRL #: 9946-52 and OCSPP Docket #: OPP-2016-0242) available online at https://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2016-0242 .

Appendix II. Definition of Resistance and Likely Resistance

According to the Weed Science Society of America "Herbicide resistance is the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. In a plant, resistance may be naturally occurring or induced by such techniques as genetic engineering or selection of variants produced by tissue culture or mutagenesis." "Herbicide tolerance is the inherent ability of a species to survive and reproduce after herbicide treatment. This implies that there was no selection or genetic manipulation to make the plant tolerant; it is naturally tolerant." (http://weedscience.org/documents/resistancecriterion.pdf).

Indicators of likely herbicide resistance (called possible resistance in Norsworthy et al 2012, Page 39) include (1) failure to control a weed species normally controlled by the herbicide at the dose applied, especially if control is achieved on adjacent weeds; (2) a spreading patch of non-controlled plants of a particular weed species; and (3) surviving plants mixed with controlled individuals of the same species.

APPENDIX III. BEST MANAGEMENT PRACTICES FOR HERBICIDE RESISTANT WEEDS

Crop Selection and Cultural Practices:

1. Understand the biology of the weeds present.
2. Use a diversified approach toward weed management focused on preventing weed seed production and reducing the number of weed seeds in the soil seed-bank.
3. Emphasize cultural practices that suppress weeds by using crop competitiveness.
4. Plant into weed free fields, keep fields as weed free as possible, and note areas where weeds were a problem in prior seasons.
5. Incorporate additional weed control practices whenever possible, such as mechanical cultivation, biological management practices, crop rotation, and weed-free crop seeds, as part of an integrated weed control program.
6. Do not allow weed escapes to produce seeds, roots or tubers.
7. Manage weed seed at harvest and post-harvest to prevent a buildup of the weed seed-bank.
8. Prevent field-to-field and within-field movement of weed seed or vegetative propagules.
9. Thoroughly clean plant residues from equipment before leaving fields.
10. Prevent an influx of weeds into the field by managing field borders.
11. Fields should be scouted before application to ensure herbicides and application rates will be appropriate for the weed species and weed sizes present.
12. Fields should be scouted after application to confirm herbicide effectiveness and to detect weed escapes.
13. If resistance is suspected, treat weed escapes with an alternate mode of action or use non-chemical methods to remove escapes.
14. Avoid outcrossing to weedy relatives, in crops that outcross. Control weedy relatives in surrounding field margins. Research has demonstrated that the pollen can move _____ feet.

Herbicide Selection:

1. Use a broad spectrum soil applied herbicide with a mechanism of action that differs from this product as a foundation in a weed control program.
2. A broad spectrum weed control program should consider all of the weeds present in the field. Weeds should be identified through scouting and field history.
3. Difficult to control weeds may require sequential applications of herbicides with alternative mechanisms of action.
4. Fields with difficult to control weeds should be rotated to crops that allow the use of herbicides with alternative mechanisms of action.
5. Apply full rates of this herbicide for the most difficult to control weed in the field. Applications should be made when weeds are at the correct size to minimize weed escapes.
6. Do not use more than two applications of "this herbicide" or any herbicide with the same mechanism of action within a single growing season unless mixed with another mechanism of action herbicide with overlapping spectrum for the difficult to control weeds.
7. Report any incidence of non-performance of this product against a particular weed species to the _______________ representative (list contact information here).

Footnote: Most items are taken from the Herbicide Resistance Action Committee / Weed Science Society of America list of Best Management Practices.

Appendix IV. Potential Impacts of Buffers

Table A. Field size, number and percentage of fields, and percentage of field area grown in spray drift buffer at 10th and 50th percentile field sizes with 25, 50, and 100 foot in-field spray drift buffers for almonds, apples, pistachios, cucumber, corn, cotton, soybean and wheat.*

Crop	Percentile (based on total crop acres)	Field Size (in acres at this percentile)	Number of Fields (at or below this percentile)	Percentage of fields at or below this percentile	Percentage of area grown (at or below this percentile) in spray drift buffer *		
					25-Foot Buffer	50-Foot Buffer	100-Foot Buffer
Almonds	10th	26.10	2,279	34	4.35	8.69	17.38
	50th	72.60	5,261	78	2.93	5.86	11.72
Apples	10th	2.50	8,710	47	14.87	29.68	58.02
	50th	10.4	16,275	87	8.77	17.52	34.77
Pistachios	10th	32.8	602	36	4.03	8.06	16.12
	50th	78.1	1,316	79	2.63	5.26	10.52
Cucumber	10th	9.7	3,672	64	9.41	18.72	36.21
	50th	38.00	5,156	89	4.81	9.60	18.94
Corn	10th	13.00	1,642,983	50	6.80	13.60	27.18
	50th	61.20	2,872,925	87	3.79	7.59	15.18
Cotton	10th	16.60	162,005	49	5.93	11.87	23.73
	50th	77.60	288,365	87	3.35	6.70	13.39
Soybean	10th	12.50	1,422,742	48	6.85	13.69	27.37
	50th	54.10	2,558,876	86	3.91	7.81	15.63
Wheat	10th	19.40	660,406	49	5.53	11.06	22.12
	50th	82.89	1,169,335	86	3.12	6.25	12.49

Source: USDA FSA, 2010-2014.

*Impacts are estimated assuming a rectangular field shape (2:1 length to width). The in-field buffer is assumed to be along the length of the field. Assumes that the entire area within the spray drift buffer being removed from production.

Table B. Acres grown, gross revenue, and gross revenue lost per acre to spray drift buffer for 10th percentile and the 50th percentile field size with 25, 50, and 100 foot buffers for almonds, apples, pistachios, and corn.*

Crop	National Acreage	Average Gross Revenue Per Acre ($)	Acreage Percentile	Value Lost Per Acre (25-foot buffer)[1]	Value Lost Per Acre (50-foot buffer)[1]	Value Lost Per Acre (100-foot buffer)[1]
Almonds	822,000	$5,787.68	10th	$251.56	$503.11	$1,006.11
			50th	$169.65	$339.30	$678.58
Apples	327,470	$8,942.52	10th	$1,329.91	$2,654.35	$5,188.08
			50th	$783.99	$1,566.88	$3,109.63
Pistachios	179,200	$7,481.02	10th	$301.45	$602.90	$1,205.62
			50th	$196.82	$393.64	$787.24
Cucumber	122,008	$3,285.94	10th	$309.10	$615.24	$1,189.89
			50th	$157.95	$315.31	$622.50
Corn	84,516,000	$800.94	10th	$54.45	$108.93	$217.66
			50th	$30.39	$60.79	$121.54
Cotton	8,746,360	$799.78	10th	$47.46	$94.93	$189.79
			50th	$26.78	$53.59	$107.11
Soybean	78,115,600	$513.60	10th	$35.15	$70.29	$140.49
			50th	$20.06	$40.11	$80.20
Wheat	46,651,200	$295.42	10th	$16.34	$32.68	$65.34
			50th	$9.23	$18.45	$36.90

Sources: USDA NASS Quick Stat, 2010 – 2014, 2011 – 2015.

* Ratio of field length to field width.

[1] Equal to average gross revenue per acre times the percentage of area grown (at or below this percentile) in spray drift buffer from Table A. For example, for almond at 10th percentile field size for a 25 foot spray drift buffer, the loss per acre is equal to the average gross revenue ($5,787.68) times the percentage of acre grown in spray drift buffer (4.35%).