Mapping

Spatial Mapping of Potential Dicamba Use

Post-emergence dicamba could potentially be used anywhere soybeans or cotton are grown. To map this we used the Cropland Data Layers from the United States Department of Agriculture that spatially depict the areas where soybeans and cotton have been grown in each year from 2012 - 2016.[1] We combined maps from these five years for soybeans and cotton, which must be done to get an accurate footprint of commonly rotated crops.[2] So the data-layer footprint for soybeans and cotton encompasses anywhere that soybeans and cotton have been grown in the past five years. Not all of this acreage will be treated with dicamba — only about 50 percent to 60 percent from recent projections. However, it's impossible at this point to estimate which land parcels will be treated and which won't. So a caveat of this mapping is that it cannot identify which areas will be sprayed with dicamba, only which areas have the potential to be sprayed following EPA's recent approval for use on genetically engineered cotton and soybean.

Temporal Mapping of Potential Dicamba Use

To identify a temporal window in which dicamba would be sprayed on cotton and soybeans in each state, we used data from the USDA's National Agricultural Statistics Service on usual planting and harvesting dates for U.S. field crops.[3] Since dicamba has been approved for pre-plant use for some time, we wanted to get an idea of when and where dicamba would be sprayed post-emergence or "in-crop," which represents the new use that was approved on dicamba-tolerant crops. The USDA data identifies a range of dates that are "most active" for planting or harvesting in each state. This represents the temporal window in which 70 percent of the crop is planted or harvested in each state.

Soybeans

The start date for when spraying could occur post-emergence was identified by using the "most active" planting date range identified by USDA.[4] An additional seven days were added to the start date of that range to account for the time it takes for the planted crop to emerge from the ground.

The date when post-emergence spraying would cease was identified by adding 44 days to the end date of the "most active" planting date range identified by USDA. Post emergence spraying must cease once the plant reaches R1 stage or "first flower" as per the pesticide label.[5] How long it takes for a soybean to reach R1 stage is region and date dependent. For mapping, the number of days from planting to R1 stage was estimated by averaging studies done in three regions (avg. 44 days).

> Eastern region (PA): average taken from 5/11 and 6/11 planting dates for both varieties (40 days).[6]
>
> Midwest region (IN): average taken from 5/10, 5/30 and 6/6 planting dates (48 days).[7]
>
> Southern region (MS): average of 4 maturity groups planted on 5/15 (44 days).[8]

Soybean

State	Most Active-plant		MA-plant plus 7 days		MA-plant plus 44 days	
	begin	end	begin	end	begin	end
AL	25-May	25-Jun	1-Jun	2-Jul	8-Jul	8-Aug
AR	5-May	22-Jun	12-May	29-Jun	18-Jun	5-Aug
DE	30-May	28-Jun	6-Jun	5-Jul	13-Jul	11-Aug
GA	17-May	26-Jun	24-May	3-Jul	30-Jun	9-Aug
IL	8-May	12-Jun	15-May	19-Jun	21-Jun	26-Jul
IN	5-May	10-Jun	12-May	17-Jun	18-Jun	24-Jul
IA	8-May	2-Jun	15-May	9-Jun	21-Jun	16-Jul
KS	15-May	20-Jun	22-May	27-Jun	28-Jun	3-Aug
KY	16-May	27-Jun	23-May	4-Jul	29-Jun	10-Aug
LA	23-Apr	4-Jun	30-Apr	11-Jun	6-Jun	18-Jul
MD	28-May	26-Jun	4-Jun	3-Jul	11-Jul	9-Aug
MI	11-May	9-Jun	18-May	16-Jun	24-Jun	23-Jul
MN	8-May	2-Jun	15-May	9-Jun	21-Jun	16-Jul
MS	26-Apr	31-May	3-May	7-Jun	9-Jun	14-Jul
MO	13-May	24-Jun	20-May	1-Jul	26-Jun	7-Aug
NE	11-May	31-May	18-May	7-Jun	24-Jun	14-Jul
NJ	20-May	1-Jun	27-May	8-Jun	3-Jul	15-Jul
NY	19-May	22-Jun	26-May	29-Jun	2-Jul	5-Aug
NC	20-May	30-Jun	27-May	7-Jul	3-Jul	13-Aug
ND	14-May	3-Jun	21-May	10-Jun	27-Jun	17-Jul
OH	3-May	30-May	10-May	6-Jun	16-Jun	13-Jul
OK	27-Apr	27-Jun	4-May	4-Jul	10-Jun	10-Aug
PA	20-May	10-Jun	27-May	17-Jun	3-Jul	24-Jul
SC	27-May	27-Jun	3-Jun	4-Jul	10-Jul	10-Aug
SD	15-May	11-Jun	22-May	18-Jun	28-Jun	25-Jul
TN	15-May	25-Jun	22-May	2-Jul	28-Jun	8-Aug
TX	30-Mar	30-May	6-Apr	6-Jun	13-May	13-Jul
VA	15-May	3-Jun	22-May	10-Jun	28-Jun	17-Jul
WV	10-May	30-Jun	17-May	7-Jul	23-Jun	13-Aug
WI	12-May	5-Jun	19-May	12-Jun	25-Jun	19-Jul

date range when post-emergence spraying may occur

*Florida use omitted because Florida monarch population was not analyzed in this report.
Most active-plant: date range when 70 percent of the crop is planted in each state[4]
MA-plant plus 7 days: time it takes for planted crop to emerge from ground, when spraying can begin
MA-plant plus 44 days: time it takes planted crop to reach R1, when spraying must cease

Cotton

The start date for when spraying could occur post-emergence was identified by using the "most active" planting date range identified by USDA.[9] An additional seven days were added to the start date of that range to account for the time it takes for the planted crop to emerge from the ground.

The date when post-emergence spraying would cease was identified by subtracting seven days from the end date of the "most active" harvesting date range identified by USDA.[9] Post-emergence spraying must cease seven days prior to harvest as per the pesticide label.[5]

Cotton

State	Most Active-plant		MA-plant plus 7 days		Most Active-harvest		MA-harvest minus 7 days	
	begin	end	begin	end	begin	end	begin	end
AL	24-Apr	24-May	1-May	31-May	20-Sep	20-Oct	13-Sep	13-Oct
AR	30-Apr	23-May	7-May	30-May	29-Sep	6-Nov	22-Sep	30-Oct
GA	2-May	31-May	9-May	7-Jun	10-Oct	2-Dec	3-Oct	25-Nov
KS	20-May	15-Jun	27-May	22-Jun	25-Oct	15-Dec	18-Oct	8-Dec
LA	24-Apr	17-May	1-May	24-May	23-Sep	23-Oct	16-Sep	16-Oct
MS	27-Apr	19-May	4-May	26-May	27-Sep	29-Oct	20-Sep	22-Oct
MO	29-Apr	23-May	6-May	30-May	27-Sep	9-Nov	20-Sep	2-Nov
NC	1-May	20-May	8-May	27-May	10-Oct	15-Nov	3-Oct	8-Nov
OK	11-May	10-Jun	18-May	17-Jun	15-Oct	9-Dec	8-Oct	2-Dec
SC	1-May	20-May	8-May	27-May	15-Oct	13-Nov	8-Oct	6-Nov
TN	1-May	25-May	8-May	1-Jun	30-Sep	10-Nov	23-Sep	3-Nov
TX	8-Apr	7-Jun	15-Apr	14-Jun	13-Sep	21-Dec	6-Sep	14-Dec
VA	25-Apr	11-May	2-May	18-May	8-Oct	20-Nov	1-Oct	13-Nov

date range when post-emergence spraying may occur

*Florida use omitted because Florida monarch population was not analyzed in this report.
*Arizona and New Mexico use omitted because western monarch population was not analyzed in this report.
Most active-plant: date range when 70 percent of the crop is planted in each state[9]
MA-plant plus 7 days: time it takes for planted crop to emerge from ground, when spraying can begin
Most active-harvest: date range when 70 percent of the crop is harvested in each state[9]
MA-harvest minus 7 days: spraying must cease 7 days before harvest as per label

Combining States With Similar Spray Windows

In order to reduce the number of layers and improve the online map performance, we combined states with similar spray windows into a single layer. The final spray window dates used in our mapping are outlined below.

Soybean - Spray Windows for Mapping

State	group	start	end
TX	1	1-May	18-Jul
LA	1	1-May	18-Jul
MS	1	1-May	18-Jul
OK	1	1-May	18-Jul
OH	2	12-May	18-Jul
IN	2	12-May	18-Jul
IA	2	12-May	18-Jul
MN	2	12-May	18-Jul
IL	2	12-May	18-Jul
AR	3	12-May	5-Aug
NE	4	19-May	20-Jul
MI	4	19-May	20-Jul
WI	4	19-May	20-Jul
ND	4	19-May	20-Jul
VA	4	19-May	20-Jul
SD	4	19-May	20-Jul
WV	5	23-May	9-Aug
MO	5	23-May	9-Aug
KS	5	23-May	9-Aug
TN	5	23-May	9-Aug
KY	5	23-May	9-Aug
GA	5	23-May	9-Aug
NY	5	23-May	9-Aug
NC	5	23-May	9-Aug
NJ	6	27-May	20-Jul
PA	6	27-May	20-Jul
AL	7	3-Jun	9-Aug
SC	7	3-Jun	9-Aug
MD	7	3-Jun	9-Aug
DE	7	3-Jun	9-Aug

*Florida use omitted because its monarch population was not analyzed in this report.

Cotton - Spray Windows for Mapping

State	group	start	end
AL	8	1-May	30-Oct
AR	8	1-May	30-Oct
GA	8	1-May	30-Oct
KS	8	1-May	30-Oct
LA	8	1-May	30-Oct
MS	8	1-May	30-Oct
MO	8	1-May	30-Oct
NC	8	1-May	30-Oct
OK	8	1-May	30-Oct
SC	8	1-May	30-Oct
TN	8	1-May	30-Oct
VA	8	1-May	30-Oct
TX	9	15-Apr	14-Dec

*Florida use omitted because its monarch population was not analyzed in this report.
*Arizona and New Mexico use omitted because western monarch population was not analyzed in this report

Monarch Butterfly Data

We obtained data from a citizen database of monarch egg and larva observations[10] from Journey North, a nonprofit organization that collects and maintains databases of animal observations from citizen scientists in North America. Journey North began collecting data for all monarch egg and larva sightings in 2016.[11] So we had two years of data to utilize (2016 and 2017). Ultimately we decided only to use data from 2016. 2017 was an unusual year for the eastern monarch migration due to aberrant weather patterns, which resulted in one of the latest southern migrations since the early 1990s.[12] Our goal was to get a sense of how dicamba would affect the typical monarch migration; thus we used all monarch egg and larva sightings for 2016 only in our mapping. The database consisted of more than 4,500 records from 1/1/2016 to 12/31/2016 with an associated latitude and longitude of where the observation was recorded and a time stamp.

The Journey North database is an amazing resource; however, the data were not collected as part of a scientific study. It is simply a collection of observations. A visual overview of the data indicates that it overlaps well with past scientific assessments of natal origins of monarchs.[13] These data have the added benefit of containing a temporal stamp, which is absolutely necessary for this type of analysis. Therefore the data used here give a good general overview of monarch egg and larva instances.

Final Animated Map

We used these records to create an animated map that shows the locations and time when monarch eggs and larva were sighted continent-wide, along with the locations and timing of when cotton and soybean crops may be sprayed with dicamba. As the map progresses, as indicated in the time slider, white butterfly icons begin to appear in accordance with the monarch egg and larva observation time. The butterfly icons grow and remain visible for approximately two weeks, representing the time they are in the egg and larva metamorphosis phase.[14] The cotton and soy crops in each state grouping (nine groupings total) become visible during the temporal window when dicamba is anticipated to be used.

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[1] USDA, National Agricultural Statistics Service. CropScape and Cropland Data Layer. Available here: https://www.nass.usda.gov/Research_and_Science/Cropland/Release/index.php.

[2] EPA. Biological Evaluation Chapters for Chlorpyrifos ESA Assessment. Chapter 1, Attachment 1-3. Available here: https://www.epa.gov/endangered-species/biological-evaluation-chapters-chlorpyrifos-esa-assessment.

[3] USDA, National Agricultural Statistics Service. Field Crops Usual Planting and Harvesting Dates (October 2010). Available here: http://usda.mannlib.cornell.edu/usda/current/planting/planting-10-29-2010.pdf.

[4] USDA, National Agricultural Statistics Service. Field Crops Usual Planting and Harvesting Dates (October 2010). Pg 25. Available here: http://usda.mannlib.cornell.edu/usda/current/planting/planting-10-29-2010.pdf.

[5] See EPA approved master label for new dicamba products. Section 12. Available here: https://www3.epa.gov/pesticides/chem_search/ppls/000524-00617-20171012.pdf.

[6] Parker, A, Fry, K and Reese, K. DuPont Pioneer Agronomy Sciences. Planting Date Effect on Soybean Reproductive Duration. 2015. Available at: https://www.pioneer.com/home/site/us/pioneer_growingpoint_agronomy/2016/plant-date-soybean-r-stage-duration/#soybean-gdu-accumulation.

[7] Casteel, S. Soybean Physiology: How Well Do You Know Soybeans? Soybean Station, Purdue University. 2010-11. Pg 22. Available at: https://www.agry.purdue.edu/ext/soybean/Arrivals/10SoyDevt.pdf.

[8] Koger, T, Catchot, A, Allen, T, Zhang, L, Eubank, T, Blessitt, B, Smith, J, Owen, L. Guide to Soybean Growth Stages. Mississippi State University Extension Service. Available at: http://www.mssoy.org/uploads/2012/03/guidetosoybeangrowthstages.pdf.

[9] USDA, National Agricultural Statistics Service. Field Crops Usual Planting and Harvesting Dates (October 2010). Pg 11. Available here: http://usda.mannlib.cornell.edu/usda/current/planting/planting-10-29-2010.pdf.

[10] Journey North was contacted and provided us with the data requested, which was all monarch egg and larva sightings for the years of 2016 and 2017. Data and maps can be accessed here: http://www.learner.org/jnorth/maps/archives.html.

[11] "First sightings" have been collected for longer but we were interested in "all sightings" to get a sense of where monarch eggs and caterpillars were throughout the spring and fall migration.

[12] Ward, B. "What's behind monarchs' late 2017 migration?" Yale Climate Connections. Nov. 16, 2017. Accessed Dec. 13, 2017. Available here: https://www.yaleclimateconnections.org/2017/11/whats-behind-monarchs-late-2017-migration/; and Trezza, J. "Monarch butterfly migration was off this year and researchers are worried." Washington Post. Jan. 20, 2018. Accessed Jan. 22, 2018. Available here: https://www.washingtonpost.com/national/health-science/monarch-butterfly-migration-was-off-this-year-and-

researchers-are-worried/2018/01/19/177555f2-f65a-11e7-beb6-c8d48830c54d_story.html?utm_term=.8190aa502f4b

[13] Wassenaar, L.I., and Hobson, K.A. (1998). "Natal origins of migratory monarch butterflies at wintering colonies in Mexico: new isotopic evidence." Proceedings of the National Academy of Sciences, 95(26): 15436–15439; and Flockhart, D.T.T., Wassenaar, L.I., Martin, T.G., Hobson, K.A., Wunder, M.B., and Norris, D.R. (2013). "Tracking multi-generational colonization of the breeding grounds by monarch butterflies in eastern North America." Proceedings of the Royal Society B: Biological Sciences, 280(1768): 20131087–20131087.

[14] The monarch spends approximately 3-5 days as an egg and 9-14 days as a caterpillar. University of Minnesota Monarch Lab. Monarch Life Cycle – Egg and Larva. Accessed 12/13/2017. Available here: https://monarchlab.org/biology-and-research/biology-and-natural-history/breeding-life-cycle/life-cycle/.