Pesticide Program Dialogue Committee

Emerging Agricultural Technologies Working Group

2022 – 2023 Final Report

Contents

Executive Summary

This report is the second year of work emerging from a Pesticide Programs Dialogue Committee (PPDC) Emerging Technologies Working Group (ETWG); the ETWG began work in the Fall of 2020 and to reflect its first year of work provided a report and a presentation to the PPDC in the fall of 2021 (report and presentation). The recommendation to the PPCD from the ETWG to continue the working group into 2022 was accepted and approved; in the Spring of 2022 the PPDC also accepted and approved revised charge questions for the work of the ETWG (See *Figure 1*):

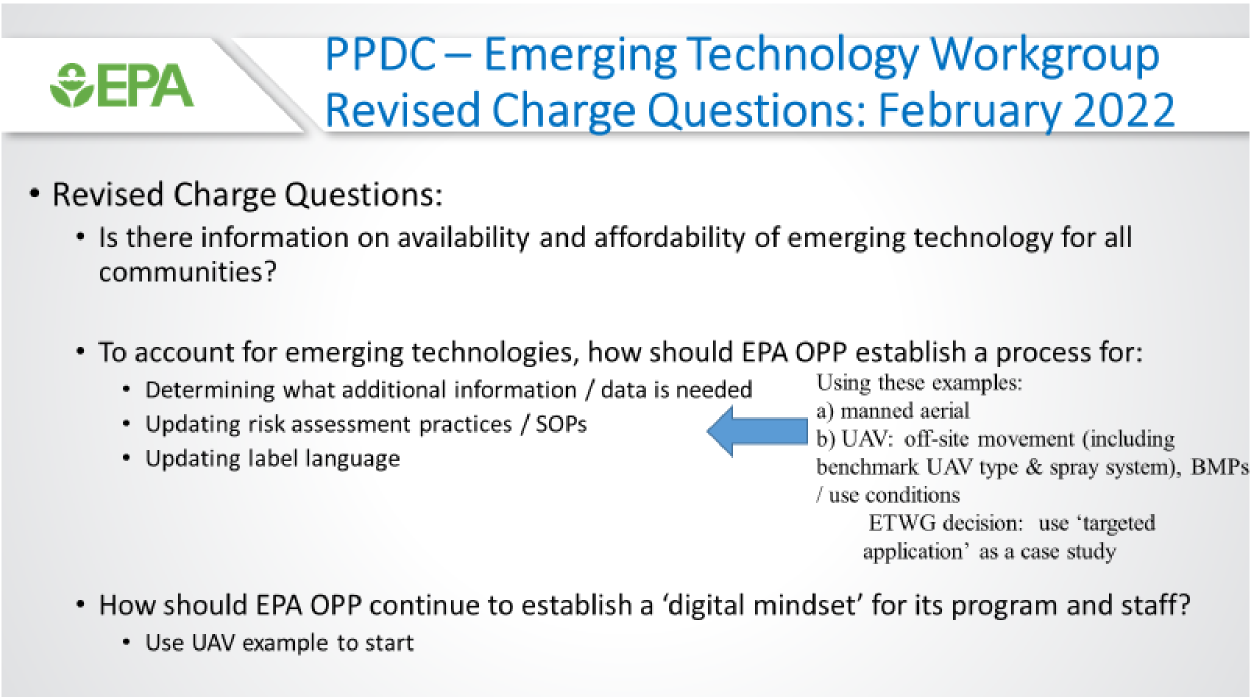


Figure 1. Revised Charge Questions Approved by the PPDC in February 2022

After the formal approval of the charge questions, the ETWG determined that a formation of a subteam to work on a 'targeted application case study' to inform the second charge question response was needed. The work of this subteam is reflected in a specific 'targeted application' section of this report.

As was the case with last year's ETWG report before going into more detail on the recommendations to the PPDC, we would again like to urge the Environmental Protection Agency (EPA) Office of Pesticide Programs (OPP) to consider the implementation of our recommendations as an opportunity to proactively prepare for a paradigm shift toward safer, more sustainable agriculture in the US and be an even more important stakeholder in shaping the future of US agriculture. The increased digital and other technological capacity that is driving 'the internet of things' has shown no signs of slowing the adoption of emerging technologies in US agriculture; in fact, there are indications that the pace of adoption of emerging technologies in agriculture has increased. As has been the case in the past with technologies, particularly those involving pest management product applications, the shape and speed of the adoption of technologies that will deliver on the promise of precision and digital agriculture will be influenced by the decisions that EPA OPP will make in considering the recommendations in this report. Therefore, we renew our call for EPA OPP to view the regulation of relevant emerging technologies as a potentially historic opportunity to improve US agriculture and invest in efforts to develop the digital infrastructure needed to address the emerging field of machine autonomous application (e.g., development of a digital / autonomous machine-readable pesticide labels).

EPA OPP should stay connected to multiple stakeholders engaged in the emerging technologies space to stay informed on how these technologies are being adopted and implemented. As stated in last year's report many stakeholders (nationally and internationally), from governmental, academic, Non-Governmental Organizations, and industry groups, are involved in these and other initiatives, and awareness of and collaboration with these stakeholders will increase coordination and efficient uptake of existing and new information.

Below are key recommendations reflected in this ETWG report:

1. **<u>Digital Infrastructure (particularly for machine actionable instructions)</u>: As with our last report the ETWG urges EPA OPP to work to build a digital mindset for its program by establishing projects and/or pilots that work toward building a digital infrastructure that would allow pest management application recommendations and implementable actions**. **The development and adoption of digital labels / use instructions / label and labeling requirements that can be read, directly delivered to digital devices (e.g., notebook or tablet computer, or a mobile phone) and/or delivered to and acted on by autonomous machines – including robots[1] - is not just a need for the future but is a current need. We suggest that the PPDC sunset the ETWG and urge EPA OPP to establish a PPDC working group that will support efforts to build the much-needed digital infrastructure**.
   Again, we recognize that OPP has taken small steps in label review to compare PDF files of labels and undertaken other similar digital initiatives; however, more sophisticated digital capabilities are needed as digitalization of agriculture needs to be enabled to fully implement the benefits of precision farming. The society that EPA serves has widely adapted smartphone technology, as current estimates show that over 85% of the US adult population has access to the pocket computer called a smartphone – a doubling in smartphone users over the last decade. Given this surge of use of digital devices in the US and the inevitable digitalization of agriculture, all avenues for forward progress must be explored including the establishment of programs and approaches within OPP that foster and implement a digital approach and mindset; a paper-based approach and process in current use by EPA OPP for communicating use instruction for pesticides is and will not be adequate for EPA OPP and its stakeholders. Further recent decisions made by EPA OPP – including those aimed at EPA OPP meeting its obligations under the Endangered Species Act (ESA) – make it clear that the need for the implementation of site-specific mitigations that are more localized and geographically precise is increasing. Site specific and field level use instructions and mitigations bring a level of complexity that will require the adoption and implementation of digital technology. Growers and pesticide users need simple and effective ways of understanding label and labeling requirements across the multiple pest management products they likely need in their operation; however, the complications facing a grower and pesticide users is increasing, not only by increasing pesticide product mitigation requirements currently being proposed by EPA OPP but also the desire to participate in emerging markets or additional conservation programs (e.g., carbon sequestration, sustainability certifications, putting land in USDA NRCS or other conservation programs, adding pollinator habitat) that are likely to require digital-based verification of pest

[1] Note that any reference to 'delivered to autonomous machines' in this report refers to software delivered actions or directions and does not refer to changes in the machine itself (e.g., no change in hardware inferred).

management decisions and actions.[2] The need to reduce this increasing complexity to manageable levels leads to the ETWG belief that the goal is to create a digital infrastructure that would allow pest management application recommendations and implementable actions – including pesticide directions for use, label and labeling requirements, and pesticide applications - to be delivered on a notebook or tablet computer, or a mobile phone and/or delivered directly to an autonomously acting machine or robot. In our current state where we use an 'app' for checking the up-to-date weather forecast, paying bills or other banking transactions, or to provide navigation while we are driving an automobile (e.g., that require real time linkages to data), the development of such a digital infrastructure would benefit multiple stakeholders. Again, the paper-based approach that served us well in the past is no longer adequate to address the demands and opportunities provided by the evolution of technology in agriculture. Therefore, once again the ETWG urges EPA OPP to work to build a digital mindset for its program by establishing projects and/or pilots that work toward building a digital infrastructure for use directions; as the ETWG has stated, the development and adoption of digital labels / use instructions that can be read and acted on by autonomous machines, including robots is not just a need for the future, but is a current need. In conclusion, we suggest that the PPDC sunset the ETWG and urge EPA OPP to establish a PPDC working group that will support efforts to build the much-needed digital infrastructure.

2) **<u>Adjust Exposure Estimates in Risk Assessments</u>: To identify and overcome the barriers to updating exposure and risk assessment assumptions and approaches, the ETWG recommends that EPA OPP conduct a LEAN analysis to work toward improved method for adapting to assure that representative use conditions and assumptions are included in all environmental and ecological assessments, especially those for manned aerial application and 'targeted applications' as defined in this report.**
The ETWG continues to urge EPA OPP to obtain a greater understanding of how the use of emerging agricultural technologies might potentially lead to exposures or risks that differ from those accounted for in currently employed methods (or Standard Operating Procedures) and policies used to derive exposure estimates and complete risk assessments. For example, if a determination is made that an emerging technology will decrease exposure, exposure estimates utilized by EPA OPP to make regulatory decisions should reflect this reduction, otherwise a powerful incentive for implementing the benefit of reduced exposure will be lost; this point is particularly relevant for the 'targeted application case study' that is presented in this report. As stated in last year's report, we recommend to the PPDC that EPA OPP's initial focus should be on establishing regulatory equivalency related to pesticide application, registration, exposure, spray drift, and residue for drone/UAV technology and use of existing exposure estimates to reflect currently employed manned aerial application technology; however, once evidence of a change in anticipated exposure or risk is confirmed or existing exposure models account, EPA OPP should move to reflect these changes in their exposure estimation models. The ETWG continues to commend EPA OPP on its engagement with other ongoing initiatives (like the OECD efforts in emerging technologies such as the Working Party on Pesticides RNAi Expert Group or the Drone / UASS Subgroup) to maximize effectiveness and efficiency in making these determinations related to emerging technologies. Finally, given the importance to make changes to EPA OPP exposure

---

[2] Kahiluoto, H., Smith, P., Moran, D. *et al.* Enabling food security by verifying agricultural carbon. *Nature Clim Change* **4**, 309–311 (2014). https://doi.org/10.1038/nclimate2209

and risk assessment practices and assumptions, the ETWG recommends that EPA OPP conduct a LEAN analysis to work toward improved method for adapting to assure that representative use conditions and assumptions are included in all environmental and ecological assessments, especially those for manned aerial application and 'targeted applications' as defined in this report.

3) **<u>Develop and Implement Site-Specific Exposure and Risk Assessment Methodology</u>: We recommend that EPA OPP initiate a case study that leverages existing tools to develop localized / site specific estimates using a population of established crop / farm sites / vector management use sites**.
The basis for working toward a site-specific approach for the exposure component of pest management risk assessment has been proposed (see Appendix 2, 3 and 4), as has using web-based tools that enable single field / site specific assessment, particularly for species in aquatic environments including listed endangered species. Instead of utilizing the current approach (e.g., using conservative exposure scenarios that are meant to be representative of regional or national use conditions), a digital mindset might lead EPA OPP to develop and use a tool to estimate exposures using a population of established crop / farm sites / vector management sites; this population of specific use sites would then allow regulatory decisions informed by a range of actual site-specific use sites (e.g. from the most vulnerable to the less vulnerable from an environmental / ecological perspective) depending on the properties of the active ingredient, the proposed use pattern, the characteristics of the specific use sites, and the nontarget species with protection goals in proximity to the use site. Such an approach could also incorporate the benefits of conservation measures or other changes in use conditions that could be employed to decrease off-site movement particularly in vulnerable use sites or in the protection of endangered species. Case study(ies) could be generated for a population of actual use sites using limited geographically (e.g., to an individual state), by cropping system (e.g., an orchard crop), or by a grouping of endangered species (e.g., as in the on-going EPA OPP endangered species pilots). The ETWG believes that coupling the site-specific approach with digital infrastructure that autonomously delivers use instructions to application equipment has the potential to provide a more precise and protective regulatory system.

Below are summaries of the answers to the PPDC charge questions that are provided in more detail in this ETWG report:

Charge Question 1: Is there information on availability and affordability of emerging technology for all communities? The ETWG believes that due to the potential for retrofitting existing equipment, financial grants and other publicly funded enabling programs (e.g., training for use of emerging technologies), and the emergence of contract service providers, many of the emerging technologies that are driving toward precision and digital agriculture have the potential to be accessed by prospective user communities in the United States.

Chapter 2 – Charge Question 2: To account for emerging technologies, how should the EPA establish a process for: Determining what additional data and/or information is needed, Updating risk assessment practices and/or SOPs, Updating Label Language? As reflected in our recommendations given the importance to make changes to EPA OPP exposure and risk assessment practices and assumptions to reflect current practices in agriculture and vector control as well as emerging technologies, the ETWG recommends that EPA OPP conduct a LEAN analysis to work toward improved methods for adapting to assure that representative use conditions and assumptions are included in all environmental and ecological assessments, especially those for manned aerial application and for targeted application as defined in this report.

EPA OPP has been closely following the developments associated with use of Unmanned Aerial Vehicles for pest management purposes, particularly through active engagement and support for OECD working groups; the ETWG continues to support EPA OPP in this effort and recommends that exposure and risk assessment approaches and label language that is appropriate and 'fit for purpose' for this application method continue to be developed and considered for implementation.

The ETWG believes that EPA OPP must account for targeted application (as defined in this report) in their exposure and risk assessment process to encourage adoption of this technology. Without a change in risk assessment approach from EPA OPP, environmental and ecological benefits of targeted application will be unaccounted for and/or the benefits and/or potential risks associated with these technologies will not be characterized. We also encourage the development of label language that appropriately describes targeted applications, communicates that exposure may be reduced proportionally with targeted application, and recognizes that target applications can help protect endangered species and mitigations like no-spray buffer zones may be decreased when targeted applications are deployed.

Chapter 3 – Charge Question 3: Establishing a Digital Mindset, Digital Tools Could Enable Local / Site-Specific Use Directions. The ETWG recommendations provide a good summary to our answers to this charge question, particularly in our recommendation of the development of digital infrastructure to enable direct communication and/or implementation of use instructions to digital devices such as mobile phones and autonomous application machines to enable pest management decisions and actions and case studies to develop and implement a site-specific approach for exposure / risk assessment.

Finally, we want to acknowledge the ETWG members and thank them for their contributions to this report (see *Table 1*), and to also express our appreciation for the EPA OPP staff that worked to support the ETWG during its two years of work.

Table 1: PPDC ETWG Roster (2021 and 2022)

Ed Messina and Amy Blankinship(Co-chairs 2022), **John Orlowski :** EPA OPP
Alberta "Carla" Theriault (through Feb 2023), **Michele Arling** (March 2023)**:** EPA Designated Federal Official
Greg Watson (co-chair 2022)**, Sarah Hovinga:** Bayer Crop Science
Ruben Arroyo: Riverside County Department of Agriculture and Measurement Standards
Manojit "Mano" Basu: Crop Life America (Co-chair 2021)
Scott Bretthauer, Damone Reabe, Andrew Moore: National Agricultural Aviation Association
Emily Bryson: California Dept. Pesticide Regulation
Dan Cederberg, Brian Satorius (previous), Bart Bolman and Kari Kavanagh (current): Teejet
Gilbert Del Rosario: Corteva Agriscience
Adam Finch: BASF
Rebecca "Becca" Haynie: Syngenta
Ramon Leon: North Carolina State University
Timothy Lane: Battelle
Lauren Lurkins: Illinois Farm Bureau
Bob Mann: National Association of Landscape Officials
Daniel Markowski: American Mosquito Control Association
Dan Martin, Brad Fritz: USDA ARS
Jacob Moore: ADAMA
Kimberly Nesci, Michele Ranville, Julie VanAlstine: USDA OPMP (2022)
Robby Personette: Wisconsin Dept. of Agriculture (2021)
Karen Reardon: Responsible Industry for a Sound Environment (RISE)
Margaret Reeves: Pesticide Action Network
Bryan Sanders: HSE-UAV (2021)
Dwight Seal: North Carolina Dept. of Agriculture (2022)
Scott Shearer: Ohio State University (2021)
Christina Stucker-Gassi: Northwest Center for Alternatives to Pesticides
Nick Tindall: Association of Equipment Manufacturers
Anne Turnbough: AMVAC Chemical

Chapter 1 – Charge Question 1: Is there information on availability and affordability of emerging technology for all communities? [3]

One of the key questions present for any technology regardless of the part of the economy that the technology is intended to be used is the ratio of potential benefits to the cost of adoption of the new or emerging technology. This is certainly the case in agriculture, as the user community for emerging technology in this sector must weigh the potential benefit of a new technology with the cost of adoption within the confines of the economic situation of each user. One of the ways that lower cost of entry for new technologies in the equipment sector for the application of pest control products is to retrofit existing application equipment with technological upgrades. In general, the lower cost of entry for retrofitting already purchased application equipment compared to a purchase of new application equipment should provide the potential for more users to take advantage of the benefits of emerging technologies. Another potential way all communities may have access to emerging technologies is by taking advantage of offering subscription-based or contracted services to operations that cannot afford to purchase the equipment outright; also, there are financial and training opportunities provided by state or federal agencies that can assist in access and affordability of emerging technologies or the training needed to adopt them.

Please note in this section that terms like 'field' are utilized, however, most of the content of this section is also relevant to non-agricultural uses. Please also note that there is additional information regarding this charge question in the Targeted Application section of this report (see Chapter 2).

Applicator Retrofitting Benefits

The ability to retrofit has created a unique opportunity for the grower community, as it provides them the opportunity to reap the rewards of the rapid pace at which technology has advanced throughout the years without having to go out and buy a completely new machine. Rather, it affords them the ability to purchase said technology and incorporate it into a machine that they already own.

While the benefits of retrofitting are recognized by growers, not everyone is retrofitting their machinery. According to the Association of Equipment Manufacturers, those typically who are retrofitting are the second owner of the agricultural machinery. By being able to retrofit these machines, the 'second owners' are then afforded the ability to see similar increased efficiencies and gains in environmental stewardship that the grower that purchases a newer sprayer foresees. Not only does retrofitting allow access to new application technologies, but it also leads to a cost savings to the grower that takes this approach as they now can keep an older piece of machinery relevant for a longer period improving their balance sheet compared to the purchase of a new machine.

For specific examples, below please find a description of several different technologies that can be retrofitted onto a sprayer, all of which come with their own set of benefits.

[3] A special thanks to the Association of Equipment Manufacturers for their contribution to this section of the report.

Data Management Technologies: Collection, management, and analysis of data has only increased in importance as technological advancements have continued to be present and adopted throughout society; the agricultural sector has also benefited from this trend. Growers have been tracking data for years (e.g., fields that produce greater yields, which crop, or crop variety is better suited to their farm), but it has historically been collected in different, and mostly inconsistent ways. Over the last decade we have seen an increase in the number of data management technologies available to farmers to help provide them with more consistent, reliable data enabling them to make better decisions. Technologies like yield monitors, weather stations (e.g., on application machinery), Global Positioning System (GPS) location, application rate controllers, & application controls / input have become available to actually collect relevant application data in a reliable and accurate manner.

Data management technologies give farmers a platform to manage and collect numerous types of data. For sprayers the two major types of data collected are machine and 'as applied' data (e.g., information on machine location, speed, etc. and information on how an application was executed). Having access to this data has provided growers with the ability to make both predetermined and subsequent real time decisions for the field the grower is working in while also ensuring that their machine is operating at an optimal performance level.

For example, data management technology is used in the following ways:

- Last pass covered sharing, multiple types of data that the grower is receiving from the machine
- Enables the ability to monitor product placement and application totals in real time (e.g., during an application)
- Data transfer off the machine to a laptop, notebook, or other computer to understand performance of machine and products applied. This can then be used to better understand field by field profitability.

By implementing these and similar technologies, a grower can make informed decisions based off the needs of an individual area of a field. Gone are the days where one set application rate or agronomic approach is used for an entire field, but by using available spray boom and other technologies now a grower can divide a field into more localized sections and make decisions based off the needs of that field section. The use of real time data such as the weather also allows the farmer to make real time adjustments that help to ensure more accurate placement of the application. Pairing this with machine data that helps a farmer monitor the status of his machine to avoid something such as a clogged nozzle, all make sure that they are putting the proper application in the right place at the right time at the proper rate.

Steering & Guidance Control: While data is a key enabler to most pest control application technologies, so is steering and guidance control. These controls utilize a GPS device to determine and map a piece of equipment's location within a field. By knowing the location of a machine, a grower is then able to:

- Utilize autosteer to maintain a consistent speed and location within the field
- Implement section control and variable rate application through controls within the boom and nozzles
- Establish field boundaries and buffer zones (e.g., internal & external field boundary mapping)
- Collect agronomic field data linked to a specific location within a field to make better decisions (e.g., on-machine sensors)

GPS-enabled technologies such as autosteer allow farmers to accurately be within centimeters of a precise location in a field; knowing the machine's exact location and the ability to utilize section control and variable rate application helps to not only reduce potential spray swath overlap but ensure that the inputs are being delivered at the correct rate. A more uniform application rate can also be delivered due to the machine running at more consistent speeds as it moves across the field. Vision guidance has only increased the accuracy of the machines location within the field and helps to prevent the machine from driving down rows as well (i.e., keep the machines tires between crop rows). All of this can help a grower realize productivity gains of at least 20% (Association of Equipment Manufacturers).

Section Control: A spray boom with section control is another tool to ensure the accurate application of a pest control product. If under manual control section control allows for the grower – but more often via autonomous machine control - to shut off portions of the boom to ensure that the intended area of the field is receiving the application. Depending on the system there is the ability to shut off complete sections of the boom or all the way down to individual nozzles. This technology works in conjunction with technologies such as guidance control and agronomic prescriptions (a 'prescription' in this context means pre-treatment scouting and detailed field data analysis that can be utilized to create a treatment map for each field area; see targeted application section of this document for more details) to adjust based off the needs of the different areas within a field. Section control also can work to ensure that proper no-spray buffer zones near areas like surface water, well, or sensitive areas with protection goals are being met.

This integration with other technologies also allows for:

- Turn compensation in areas like the headland rows (i.e., turning in a circle can lead to different application rates being applied in such areas)
- Reduced overapplication
- Reduced spray drift
- Is a key enabler to targeted spray technologies (see Targeted Application section of this document for more details)

As with other technologies that can be found on several modern sprayers, section control of a spray boom helps to ensure that a product is being placed within the field reliably and accurately.

Rate Control: There are also technologies that enable to control the rate at which a machine applies an application. Rate control provides an applicator with the ability to adjust the rate of application down to a nozzle-by-nozzle basis based off the needs/conditions of the field. This is done by the applicator entering a desired application volume into the spray system controller which then sets the spray pressure that gives the necessary flow for the application volume and sprayer travel speed being used. As a result, the machine can adjust based off speed and weather conditions to ensure that the correct desired rate is being maintained.

Rate control also enables to apply a variable rate to a field based off an application prescription (again, a prescription here means using pre-treatment scouting to deliver a detail GPS driven application map). Some of the technologies that enable rate control to happen as well as ensure a consistent rate include:

- Pulse Width Modulation- Ensures consistent droplet size across wide speed range
- On/off nozzles- Positive on and off shut off reducing application in unwanted areas and provides more consistent droplet size due to positive shut off versus pressure drop

- Stacked (tiered nozzles)- Combination of multiple nozzles to achieve flow while maintaining target droplet size
- Mounted weather stations that feed current conditions to the controller to allow for necessary adjustments to be made

By incorporating these technologies an applicator can maintain the proper application rate and droplet size throughout a field even with varying conditions. Maintaining the proper rate and droplet size helps to ensure maximum efficacy of the product being applied while also reducing spray drift.

Boom Height Control: Another technology that helps ensure the proper placement of an application is boom height control; in this case technology is utilized to control the height of the boom relative to the target spray range, canopy, and/or ground location. Boom height control is enabled by controlling the sprayer chassis with roll compensation through sensors that look ahead and determine the distance between the chassis and the targeted spray location.

Boom height control helps to:

- Reduce off target movement
- Ensure proper coverage of the crop being sprayed reducing the potential for over or under application
- Improve efficacy of products being applied as proper boom height is an important component of consistent coverage

Because the control sensors maintain a certain height, outside factors such as wind become less of a factor and as a result the potential for spray drift is reduced.

Targeted Application Technologies: Targeted application technologies are a combination of all the other technologies to implement action that helps achieve the goals of right place, right rate, right time. It is a utilization of imagery identification, such as cameras, and other sensors to identify weeds and target them specifically. This leads to an even more granular, localized placement of the application. There is a section of this document that is dedicated to targeted application technologies, but it is relevant to mention this topic in this section as well because components of these technologies can also be retrofitted onto existing machinery.

As noted in the use of the plural, targeted spray technologies are not just one singular technology; rather targeted application technologies are a combination of several technologies working in unison (e.g., to identify a weed and apply the application in the correct spot or to manage off-site movement to protected areas - see 'DriftRadar', Bayer receives Future Prize | LECTURA Press). These target application technologies include:

- Artificial Intelligence
- Lighting (i.e., on the application boom)
- Cameras or other forms of imager identification
- Section control units

At this point in time, these targeted application systems have been mostly aimed toward postemergence weed control. As a result of being able to more accurately identify and target weeds within a field with a targeted application system, growers are given the opportunity to potentially reduce inputs by up to 90% and place the application only where it is needed for weed control. However, as was noted above, a grower must have several enabling technologies that must work in unison to make this targeted application system work.

Retrofitting Costs and Challenges

While retrofitting affords growers significant benefits and makes technology more widely available, it does come with its own set of challenges. The technologies given as examples in the preceding section can sometimes be difficult to integrate into a current operation based off several factors such as:

- Current technologies already implemented in the operation, difficult to make changes
- Age and structural integrity of current application machinery
- Level of technological expertise of the grower / operator
- Every grower operation is different and has different needs

Along with the above, there is also a cost associated with the technologies:

Data Management: $90 - $400 per month	Rate Control: $8,000 - $12,000
Steering and Guidance Control: $7,000 - $15,000	Boom Height Control: $15,000 - $18,000
Section Control: $350 per foot on average	Targeted Spray Technology: Emerging Market

Estimates from Association of Equipment Manufacturers. Note that these estimates came from research focused on row crop application equipment; while typically smaller farms will either buy used, lease, or contract hire application services and larger farms will either buy new or lease, actual decisions by operators will be dependent on multiple factors including farm size, operator preference, row crop or vegetable crops in the operation, etc.).

Please note also that autosteer and autonomous control functions are not the same; the primary use of autosteer is to keep the machine straight while going down rows in a field, then allow for the operator take over steering at the headland rows which are not normally straight. Autonomous control retrofit solutions are meant to remove the manual operator from the machine completely and were not included in this cost estimate; autonomous control solutions for various categories are emerging into the market making cost estimates or rates of adoption difficult to access.

While there is a cost associated with these technologies, many of them are smaller in comparison with the purchase of a new sprayer. Another point to mention is that these technologies do not have to be retrofitted onto a self-propelled sprayer; often, they can also be fitted onto a pull behind sprayer that is just a typically a less costly option compared with a self-propelled unit.

It should be noted that these cost estimates are ranges and may vary based on a specific operation circumstance such as size of operation or cropping system. This brief article gives some insight to sprayer ownership in the United States: - Sprayer Equipment Ownership by State and Farm Size | FBN. Also alternatives to single ownership include joint ownership, co-op ownership, leasing, and contract hire (later covered in next section).

Contract Services

Another important factor that should be considered in this charge question is the evolution of contract service organizations that specialize in application services that employ many of the emerging technologies mentioned above. Growers and operators of agricultural operations may avoid the large cost of entry that comes with the purchase of new application equipment, or even the relatively smaller costs of retrofitting their existing equipment by using contract service providers. Using contract services also avoids the learning curve for users of new, emerging technologies as contract providers will more quickly gain experience and efficiencies in their use and implementation. There is also a cost consideration compared to new application or retrofitting existing equipment; for example, this survey collects costs of contracted services (per acre) for some emerging technologies such as GPS mapping ($2.70/acre) and GPS soil grid testing ($6.50/acre): 2022 Iowa Farm Custom Rate Survey (iastate.edu) . . As such, contract application service providers can be very valuable for growers and operators in the adoption of emerging technologies. Good examples of contract service providers and the importance of their services can be found in the Manned Aerial portion of this document.

Grant Opportunities

There are multiple sources of grants or other tools available to support access to emerging technologies; for example, the Center for Digital Agriculture at the University of Illinois has a number of programs that aid growers in accessing emerging technologies (https://digitalag.illinois.edu/funded-projects/). Other examples include the Farm Innovation Grants in Michigan (https://www.michigan.gov/mdard/business-development/grantfund/farm-innovation-grants), Beginning Farm or Farmworker program in California that specifically targets 'support for socially disadvantaged beginning farmers in the first ten years of business' (https://www.cdfa.ca.gov/bfftp/pdf/2022_RFA_BeginFarmFarmWorkerProgram.pdf), AgVentures program in North Carolina (https://agventures.ces.ncsu.edu/application-for-ag-ventures-grant/), and the USDA administered Beginning Farmer and Rancher Development Program (https://sustainableagriculture.net/publications/grassrootsguide/farming-opportunities/beginning-farmer-development-program/) are other grant programs that provide assistance to access innovation. Finally, of particular relevance to this charge question, USDA has developed an equity plan to assist Black, Hispanic, Native American, Asian American and other farmers of color which includes funding to provide support for underserved communities (e.g., From Learning to Leading: Cultivating the Next Generation of Diverse Food and Agriculture Professionals https://www.usda.gov/media/press-releases/2022/08/24/usda-announces-550-million-american-rescue-plan-funding-projects).

Conclusion

Overall, there are several economic and environmental benefits that can be attributed to the emerging application technologies listed above; all these technologies help growers adhere to the 4 R's (right place, right rate, right substance, right time). As noted in the introduction to this section, these technologies do not just apply to pest protection in agriculture but are also transferrable to non-agricultural uses and applications other than pest protection (e.g., nutrient application). The increased potential for accuracy and efficacy with these technologies also helps decrease the risk to the operator and occupational bystanders due to less exposure because of more accurate placement of the substance. The ability to retrofit these technologies makes these benefits more accessible to growers and pest management operators as these technologies become more scalable across operations of all sizes due to the lower price point associated with retrofit options. Access to emerging technologies can also be achieved by utilizing a contract application provider that employs these technologies.

As technologies continue to evolve at an ever more rapid pace it is very important that regulation enables the adoption of these technologies to allow growers can benefit from their use and better protect human health and the environment by reducing the exposure or risk to pesticide applications (please see the Target Application section in this report for additional details) and address many of the issues currently facing agriculture, such as labor shortages, rising chemical costs and climate change. It also becomes ever more important for those overseeing these regulations to continue to engage with industry and academia to stay up to date on the latest application technologies being introduced and implemented in the marketplace.

References

Below are a few studies that support the assertion made in the above section and go into much greater depth on the gains that these and other technologies can deliver:

Studies on Application Technologies:
Environmental Benefits of Precision Agriculture Study – AEM
Precision Ag Study unveiled by AEM, Ag organizations
Farm Data Usage In Commercial Agriculture – Purdue
Farm Data Usage in Commercial Agriculture - Center for Commercial Agriculture (purdue.edu)

Chapter 2 – Charge Question 2: To account for emerging technologies, how should the EPA establish a process for: Determining what additional data and/or information is needed, Updating risk assessment practices and/or SOPs, Updating Label Language

To begin to address this charge question the ETWG wants to acknowledge and commend the efforts that EPA OPP have and continue to make to stay engaged with groups like the OECD Working Party on Pesticides Drone / UASS Subgroup, attend and contribute to stakeholder meetings like the Remotely Piloted Aerial Application Systems (RPAAS) Workshop, and provide input to groups working in the emerging technology space like the National Agricultural Aviation Association (NAAA), the Unmanned Aerial Pesticide Application System Task Force (UAPASTF) and the Crop Life America Drones Working Group (CLA DWG). The ETWG also wants to acknowledge the work of the State Lead Agencies that partner with EPA OPP in the regulation of pest management products as many of these agencies have been active in work involving emerging technologies. All these activities and engagements allow EPA OPP to fulfill one of the ETWG responses to this charge question: EPA OPP should stay connected to multiple stakeholders engaged in the emerging technologies space to stay informed on how these technologies are being adopted and implemented. As stated in last year's report many stakeholders (nationally and internationally), from governmental, academic, Non-Governmental Organizations, and industry groups, are involved in these and other initiatives, and awareness of and collaboration with these stakeholders will increase coordination and efficient uptake of existing and new information.

Given that there were specific examples meant to help inform the response to this charge question, the report will now turn attention to those noted specific examples: manned aerial application, UAV application, and targeted application:

Manned Aerial Application

Manned aerial application of pest management products provides an important contract service for agriculture and pest management operators in the US; manned aerial applications can be made when fields are too wet for ground equipment, or when predictions or measurements of pest populations dictate a rapid treatment to prevent significant losses in yield & quality or to mitigate a public health concern. Most manned aerial applications for pest control made in the US are implemented by small businesses (e.g., average of 6 employees or less, with 2 aircraft); these firms treat nearly 127 million acres of U.S. agricultural land each season (~ 28% of all land used for crop production in the U.S). In addition to the agricultural acres, aerial applicators annually apply to 5.1 million acres of forest land, 7.9 million acres of pasture and rangeland, and 4.8 million acres for mosquito control and other public health directed treatments. To provide insight into the economic value of manned aerial application of pest management products, a recent presentation has estimated the value of the aerial application industry to farmers, input suppliers, processors, and agricultural transportation and storage industries for corn, wheat, cotton, soybean, and rice production in the U.S. is estimated to be about $37 billion[4].

Like in other application methods utilized in agriculture, emerging technologies have improved manned aerial application. The availability and implementation of Aircraft Integrated Meteorological Measurement System (AIMMS) that provides real-time onboard weather data, including wind speed and direction, temperature, and humidity is a specific example; this technology coupled with the historical deployment of smoke (e.g., use of a smoker that injects a small amount of vegetable oil into the aircraft exhaust system that creates smoke, allowing the pilot by observing smoke movement to determine the wind direction and an estimate of wind speed) allows the applicator to adjust application swaths to more precisely deliver the application to the target and to respect no-spray buffer zone requirements.

Within the context of manned aerial application and this charge question, a focus on the exposure component of *'updating risk assessment practices, &/or SOPs'* has been highlighted within the discussions of the ETWG. Specifically, the models utilized by EPA OPP to predict off-site movement from manned aerial application of pest management products have not been adapted to current use conditions of manned aerial application. For example, Tier 1 in AgDRIFT (the exposure model utilized by EPA OPP in environmental / ecological risk assessment) was established based on analysis and considerations by EPA OPP from manned aerial application data generated by the Spray Drift Task Force; the data generated by this task force for manned aerial application was summarized in a document produced in 1997 (Appendix 1). While the underlying data generated by the Spray Drift Task Force is still a valued and sound resource for regulatory risk assessment, some of the associated assumptions used by EPA OPP in Tier 1 of AgDRIFT do not reflect current use conditions for manned aerial application of pesticides according to members of the ETWG. A detailed explanation of the assumptions in the Tier 1 AgDRIFT model has been provided to EPA OPP as part of specific product comment periods, along with a request for EPA OPP to employ the existing assumptions that are currently part of the Tier 3 AgDRIFT model on a more routine basis. The need to update the EPA OPP exposure estimates for manned aerial application was also noted in the December 2020 CERSA Virtual Workshop entitled *Advances in Regulatory Risk Assessment of Pesticide Drift from Unmanned Application Systems (UAS) and Manned Aerial Application* (https://cersauas.wordpress.ncsu.edu/).[5] The ETWG does note that EPA OPP has been changing some assumptions in exposure modeling – in particular nozzle type / particle size distributions – in some recent product specific risk assessments, a very positive step forward in reflecting current use conditions for manned aerial applications.

Recommendations:

Given that EPA OPP has not yet initiated the suggested changes mentioned above in manned aerial application exposure modeling, the ETWG assumes that there have been some barriers to addressing these past requests to change risk assessment assumptions. Given the importance to make changes to

[4] Dharmasena, S. 2021. "Value of the Agricultural Aerial Application Industry in the United States" Research presented at the 2021 Ag Aviation Expo, Savannah, GA. https://www.agaviation.org/2021aatresearchpapers

[5] A special thanks to the National Agricultural Aviation Association (NAAA) for their contribution to this section of the report.

EPA OPP exposure and risk assessment practices and assumptions, the ETWG recommends that EPA OPP conduct a LEAN analysis to work toward improved method for adapting to assure that representative use conditions and assumptions are included in all environmental and ecological assessments, especially those for manned aerial application. Given that additional data generation is not needed to support such a manned aerial application review and an existing higher tier model exposure model reflects current practices, the ETWG believes that a LEAN analysis will help EPA OPP discover better pathways toward making the suggested changes that have been proposed for regulation of manned aerial pesticide application.

UAV Application (off-site movement, BMPs / Use Conditions)

Uncrewed Aerial Spray Systems (UASS) are being adopted at a rapid pace in agricultural applications. The data required to effectively regulate their use must be gathered to position UASS in terms of equivalency with other conventional practices and where not available, other avenues to generate increased understanding need to be pursued. In Fall 2021, as a follow-up activity to the published recommendation from the Organization for Economic Co-operation and Development Working Party on Pesticides (WPP) UAV (Unmanned Aerial Vehicle)/Drone Subgroup's report, the CropLife America (CLA) Drones Working Group initiated an effort to collect published information in a systematic and curated database to compare equivalency of UASS to other conventional application types from a spray drift perspective. Based on the published literature assessed in this CLA project initial indications support the assumption that from a spray drift perspective, UASS off-site movement curves are somewhere between aerial and ground-based methodologies, comparing closest to orchard air blast applications. Although spray drift was primarily considered, elements of operator exposure, crop residue, and efficacy were also included in the report generated in this project. For operator exposure, the conclusions from this report support the current consensus that application with UASS has less potential for exposure in some respects (e.g., compared to backpack applications), but for other job steps that are unique to UASS (such as mixing/loading) more information is needed. With respect to crop residue under conditions where UASS applicators follow the label for conventional application techniques with the same rates, number of applications and preharvest intervals, there is no evidence to date that pesticide residues are any different to conventional application counterparts such as manned aerial application, despite the lower volume applications normally associated with aerial application (and thus higher concentration of chemical in the spray tank).[6] In terms of efficacy, applications with UASS tend to be equivalent to conventional methods; however specific cases reported in literature need to be understood better (e.g., lack of coverage contributing to lower efficacy). The assessment and comparison of published literature of UASS demonstrates potential equivalency in certain key areas and supports the responsible use of this emerging technology, while more information gathering on spray distribution within the target zone, off-target droplet movement, operator, and bystander exposure, and pesticidal efficacy continues to be generated and while best management practices are established. A presentation providing an overview from this project is available (Bonds, J., Pai, N. , Hovinga, S., Haynie, B., Bui, T., Flack, and Stump, K. Uncrewed aerial spray systems and equivalency with conventional techniques: spray drift, operator exposure, crop residue, and efficacy [Conference Presentation]. ACS Fall 2002, Chicago, IL, United States.

[6] While outside of the remit of this report, it is worth noting that the Canadian government via an Agriculture and AgriFood project is sponsoring work in the field crop residue space; members of the Unmanned Aerial Pesticide Application Task Force are supporting this effort.

https://acs.digitellinc.com/acs/sessions/512038/view) and publication for submission to a peer reviewed journal is in preparation.

EPA OPP has been closely following the developments in these efforts, particularly through active engagement and support for the OECD Drone Subgroup and the Unmanned Aerial Pesticide Application Task Force (UAPASTF) which is part of the industry response to the calls for development of additional regulatory data and information called for in the aforementioned OECD WPP report. The ETWG continues to support EPA OPP in this effort and recommends that exposure and risk assessment approaches and label language that is appropriate for this application method continue to be developed and considered for implementation.

Targeted Application (a case study)

Increasing global demand for food supply requires that agricultural production and practices increase over the next half century. At the same time, it is crucial that this production delivers on sustainability and climate change goals by optimizing agronomic inputs and increasing efficiency while maintaining or improving protection of human health and the environment. Emerging technologies such as satellite-driven technology, big data analytics, autonomous vehicles, UAVs (Uncrewed Aerial Vehicle), sensors, robotics, and artificial intelligence are part of the approach to achieving these goals.

One approach using emerging technologies is the concept of "Targeted Application", also referred to in some contexts as precision application or site-specific mitigation, where the right product, at the right time, in the right place, and using the right amount is employed. For the purposes of this report, targeted application is application equipment agnostic and can be defined as: "an application method linked to a prescription, scouting and/or sensing result, including real-time (e.g. while the application is in progress), which improves delivery of a pesticide(s) to target the intended pest (e.g. weed, insect, fungus, etc.) in small or irregular areas within a larger use area (section of a field, fairways at a golf course, etc.). This contrasts with broadcast applications, which treat the entire area, or strip/band applications, which treat a narrow continuous area within the larger use area. Targeted application technologies are often designed to directly target a pest or a section of the intended application area where the pest is located, further outlining the need to assess such technologies independently of traditional application equipment. It should be noted that while variable rate technology could also be incorporated alongside targeted application if approved label rates are followed, this is not a topic covered in this report. Further, there are examples of design features that have been used historically that are aimed at increasing precision of applications (e.g., hooded sprayers), and these are not specifically addressed in this report.

A primary goal of using a targeted application approach can be as a mitigation tool to achieve protection goals (e.g., to limit potential exposure to sensitive areas, such as habitat or range for species with protection goals or wetlands and surface water). It is therefore essential that the Environmental Protection Agency (hereafter referred to as EPA or the agency) Office of Pesticide Programs (OPP) must account for targeted application in their exposure and risk assessment process to encourage adoption of this approach. Without a change in risk assessment approach from EPA OPP, environmental and ecological benefits of targeted application will be unaccounted for and/or ignored.

To consider what targeted application from emerging technologies entails, it is useful to consider real-world examples and EPA's current risk assessment process to assess what changes need to be made.

Use case examples that need consideration when employing Targeted Application (not exhaustive)

Nozzles, spray tips, and droplets: Nozzles play an important role in targeted applications in that they can be specifically designed to direct the spray to the target and have a different purpose than nozzles in conventional broadcast applications. Conventional nozzles are typically designed to create a spray pattern that is uniformly dispersed (e.g., hollow cone and flat fan spray pattern) to maximize coverage, while targeted application nozzles need to dispense spray more directly to a target (e.g., a stream or soaker spray pattern to target an individual emerged weed). EPA has long recognized the role of spray droplet size in predicting off-target drift potential, further highlighting the need to evaluate targeted applications independently of conventional, non-targeted applications. The important considerations for spray tips, nozzles, and droplets for targeted applications are listed below:

- **Tip Spacing:** Tip spacing for targeted spray might be narrower than typical 15" spacing.
- **Spray Angle:** Targeted plants will be at different distances from the tips depending on the height of the crops. Tipping the nozzle rearward can reduce time of flight, reduce drift, and increase accuracy of achieving target.
- **Droplet Size:** The droplet size is determined by the label requirements for the chemical being applied and the need for drift control. It should be noted that since it is expected that targeted application would decrease the potential for off-site movement, changes to droplet size label language may be needed for this type of application.
- **Thickness of Spray Pattern:** A thicker spray pattern in the direction of travel improves coverage.
- **Clean On/Off:** As with any pulse width modulation (PWM) system, targeted spray systems require the tips to develop a full spray pattern when the control valve is opened and a clean shut-off when the valve shuts off.
- **Droplet Penetration:** The droplet size and tip design need to produce droplet sizes with the mass to penetrate through the canopy to contact the target plants at the height of the tip and reduce drift.
- **Shape of Spray Pattern:** The shape or type of spray pattern, flat fan or even, needs to fit the spray system. When the targeted tips are used as part of a broadcast application, the standard flat fan spray pattern will provide even coverage for the length of the boom and only the targeted tips are used for the spot spraying. An even spray pattern will have better coverage when the target tips are on different tip spacings than the other tip spacings or are on an additional boom line.
- **Tip Height from Target:** The height of the tip above the target influences tip selection for spray pattern, droplet size and spray angle (Managing Drift with Nozzles and Boom Height – Pesticide Environmental Stewardship (pesticidestewardship.org)).

UAVs: The use of spray UAVs for targeted application are another important use case. This technology lends itself to many different application types from small acreage - high value crops, such as vineyards and orchards, to larger tracts with traditional row-crops, with the advent of UAV swarms; there are also places where UAVs may be able to replace hand-held or backpack applications, or in hard-to-reach application sites (e.g., sloped areas; see last year's report for additional information). Given access-limiting growing conditions, such as muddy fields and/or areas with physical impediments such as power lines, UAVs offer a complimentary approach to, rather than a replacement of, conventional methods of plant protection product (PPP) application such as manned aerial and ground applications. Additionally, when compared to larger traditional application equipment, and with business models such as custom application, UAVs offer an affordable option for crop protection, increasing the availability of digital technologies to even small operations. Besides crop protection, UAVs are also used in vector control and industrial vegetation management, each of which often require application to remote and/or difficult-to-access terrain.

For the Agency, continuing to be engaged in the Organization for Economic Cooperation and Development (OECD) Working Party on Pesticides (WPP) Unmanned Aerial Spray System (UASS)/Drone Subgroup, Unmanned Aerial Pesticide Application System Task Force, and CropLife America Drones Working Group activities will be key for maintaining momentum in the UAV space as a potential tool for targeted application (https://www.oecd.org/chemicalsafety/pesticides-biocides/literature-review-on-unmanned-aerial-spray-systems-in-agriculture.pdf; https://static1.squarespace.com/static/5faeee45a363746603d1c6e1/t/62b60d48e322ba4449334fb4/1656098121598/2022-03-23_Trilateral+Stakeholder+Workshop_CLA+Update+Drones+Working+Group+Final.pdf; https://www.morressier.com/o/event/62daeef3a6fd3a00196fa00a/article/630fcb607e215f5e7f375c62).

Optical/Targeted/Precision/Selective Application Equipment: Though the development of this technology is still nascent in terms of covering all uses of pesticides for all crops, with initial offerings just now being made available to growers (e.g. weed control in soy, corn, and cotton: https://www.deere.com/en/sprayers/see-spray-ultimate/), optical targeted/precision application technology can also be considered as targeted applications and certain criteria should be considered from a PPP perspective; with possible benefits like PPP savings due to reduced volume usage and more cost-efficient use of premium chemicals targeted for specific modes-of-action. This technology usually involves a combination of section control units, artificial intelligence, lighting, and imagery identification to identify and detect targets. For example, when using herbicides with optical targeted/precision application technology, the ability to detect emerged weeds and apply with thorough spray coverage can be influenced by a variety of factors, including but not limited to: weed detection sensitivity level, sprayer speed, wind speed/direction, weed size/growth stage, weed species, location of the target weed, crop row spacing, nozzle type, tillage type, crop residue, weather, and time of day. These factors may result in lack of or incomplete spray coverage and reduced weed control.

As with any planned PPP application, it is recommended to scout prior to application and account for variables that influence pest detection and effective spray coverage. Regular and planned field scouting provides information on pest pressure, crop injury, crop growth staging, and soil and plant nutrient conditions, and then using this information to make pest control decisions. Field scouting is a vital part of a farm's IPM program. IPM techniques acknowledge "economic thresholds": the cost of the pest damage is weighed against the cost of the pest treatment in the decision-making process. Potential problems often are identified early and managed, thereby reducing the control costs and crop losses. Scouting prior to application could also potentially help with better estimations of total PPP needed in optical targeted/precision application approaches. As this technology advances, it will be important for considering how to incorporate both manual and emerging scouting approaches to achieve the best prescription and thus outcome for the grower.

Accessibility of targeted application and emerging technology for all communities

Detailed crop and site information that was previously inaccessible and/or expensive to acquire, is becoming more available due to advancements in hardware, communications, geospatial technology, and software (https://www.nifa.usda.gov/grants/programs/precision-geospatial-sensor-technologies-programs). Also, federal programs targeted at rural connectivity, for example the Precision Ag Connectivity Task Force lead by the Federal Communications Commission and supported by the Farm Bill, and grants such as the recently announced USDA $71 million grant to support underserved communities continue to support this expansion (https://www.usda.gov/media/press-releases/2022/10/14/usda-announces-more-71-million-support-underserved-communities?utm_content=&utm_medium=email&utm_name=&utm_source=govdelivery&utm_term=; https://www.fcc.gov/task-force-reviewing-connectivity-and-technology-needs-precision-agriculture-united-states). Growers and natural resource managers can now collect, analyze, and use vast amounts of detailed information which allows for more adoption. While these initiatives to improve infrastructure (e.g., access to broad band), there is a risk that small and medium-sized growers could face larger barriers compared to large growers when adopting these emerging technologies, such as initial cost, uncertain economic returns, and technology complexity. One possible way for smaller producers to overcome these barriers to adoption could be to utilize unique markets where their small size is an advantage. Value-added products expand the profit margin for producers who are positioned to provide enhanced value to consumers—which is more often the case for small producers who deal with small quantities of raw products and have more direct access to consumers. Another approach could be to spread the initial cost of the technology over many users. This is done in Asia, for example, where smallholders often share the cost and use of one UAV (see the UAV use case for more benefits to smaller growers). Additionally, university extension programs provide valuable educational and application assistance to help producers become more familiar with, and use, new technologies, and provide unique forums for exchange of information and shared learnings within smaller communities. (https://www.nifa.usda.gov/grants/programs/precision-geospatial-sensor-technologies-programs/adoption-precision-agriculture). Finally, medium, and small growers will likely benefit from contract service providers, as such firms would likely have expertise and experience that may not be available to an individual small or medium grower; for example, by using a service provider the grower will not have to spend time to obtain additional licenses or permits (e.g., state specific or for UAV use FAA licenses or exemptions).

Current risk and exposure assessment process and assumptions

EPA currently takes the maximum application rate for the crop, assumes a maximum rate for run-off, and that worst case scenario is utilized to derive exposure estimates for off-site movement (e.g., drift). While this approach is intentionally conservative, it will very likely overestimate exposure from targeted application (e.g., overly conservative exposure assumptions). For example, research has shown that that site specific spraying can reduce herbicide usage by up to 70% while maintaining 100% weed control.[7]. Other research has shown that some locations in a field may require a range of zero or less than 10% of the length of sprayer boom during an application, and that using targeted application technologies can reduce pesticide usage from 12 to 96% and from 17 to 85% in applications to soybean and maize fields.

[7] T., van Henten, E., Booij, J., van Boheemen, K. & Kootstra, G. Application-specifc evaluation of a weed-detection algorithm for plant-specifc spraying. Sensors 20, 7262 (2020)

In this latter study, in soybeans the desiccation and pre-planting applications showed the highest averages of pesticide reduction (76.0% and 72.1%, respectively) with later in-season applications in the soybean crop having an average reduction of 51%; the study authors concluded that the higher canopy size of plant foliage that impacted reaching the targeted pest was the major factor driving these differences in average reduction. In this same study the average range in pesticide reduction in maize ranged from 53.7 to 36.6%. Overall, this study concluded that the targeted application cost was 2.3 times less compared with associated with pesticide application over the entire field area using a conventional sprayer.[8] Regarding herbicide applications, several studies that have evaluated the utility of targeted applications to manage weeds have achieved a significant reduction in herbicide usage levels ranging from ~30–40%.[9] As for insecticide applications, a study in cereals indicated that site specific spraying with sensor technology could reduce insecticide use by 13% on average.[10]

EPA OPP defines spot application as being limited to 1000 square feet/acre – not spraying more than 2.29% of that acre. Additionally, there is EPA language regarding termiticide use that defines spot treatments as being approximately 20% of the area to be treated (https://www.epa.gov/pesticide-labels/pesticide-labeling-questions-answers). In both cases, this is somewhat arbitrary and is not a good precedent to set for all targeted applications that will enable the mentioned benefits that stand to be gained. Using the current EPA definitions because these spot applications result in a partial treatment or decreased proximity to edge of the treatment area, EPA does not assume any offsite movement from spot applications. Therefore, this current approach does set a precedent that targeted applications, which by definition treat less than 100 percent of the area, should also result in decreased offsite movement and therefore potentially have environmental and ecological mitigation benefits.

There also is a California definition for spot applications (3 CCR 6000): "Spot treatment" means an application to limited areas that will not exceed two square feet on which pests are likely to occur or have been located during the process of monitoring or inspection. Section 4.20 Spot Treatment Interprets FAC section 12973: The use site "spot treatment" in the institutional setting means an application limited to areas on which insects are likely to occur, but which will not be in contact with food or utensils and will not ordinarily be contacted by workers. These areas may occur on floors, walks, and bases or undersides of equipment. For this purpose, a "spot" will not exceed two square feet. In the outdoor setting, including agricultural, a spot treatment would be an application where small irregular areas are treated, usually specific areas of pest infestation within a more general area." (From DPR's *Pesticide Use Enforcement Program Standards Compendium Volume 8, Guidelines for Interpreting Pesticide Laws, Regulations, and Labeling*, May 2009)

These standard assumptions could be revised based on proportionality to the total treated area or limitations on edge of treatment area (e.g., no full edge of field swaths). This is an important consideration because current EPA exposure models for off-site movement assume at least 3 field swaths, adding to the active loading that has the potential to move off-site.

[8] Zanin ARA, Neves DC, Teodoro LPR, da Silva Júnior CA, da Silva SP, Teodoro PE, Baio FHR. Reduction of pesticide application via real-time precision spraying. Sci Rep. 2022 Apr 4;12(1):5638. doi: 10.1038/s41598-022-09607 .
[9] Takács-György, K. Economic aspects of chemical reduction in farming—Future role of precision farming. Acta Agric. Scand. Sect. C Food Econom. 5, 114–122. https://doi.org/10.1080/16507540903093242 (2008).
[10] Pedersen, S. M. & Lind, K. M. Precision Agriculture: Technology and Economic Perspectives 1–20 (Springer, 2017)

How current exposure assessment could change considering targeted application

Targeted application is assumed to be a percentage of an area that will be treated when a prescription and/or scouting report leads to <100% of an area to be treated and therefore exposure estimates would always be reduced proportionally to current exposure assumptions. Note use of this definition means that a prescription or scouting report that leads to 100% of the area to be treated is not a targeted application.

Additionally, labels may need to reflect the changes that emerging technology brings, including, but not limited to:

- Personal Protective Equipment (PPE): Definitions should be appropriate and relevant for the use condition. For example, do operators not directly encountering pesticides nor their application need PPE (such is the case with UAV pilots and teleoperators (e.g., that do not mix or load the product for application) of equipment, or with autonomous ground application equipment). There are existing examples of language under the Worker Protection Standard (as well as affiliated state regulations such as California's Pesticide Worker Safety regulation) that could be utilized as a basis for these circumstances: 'Work clothing may be worn instead of personal protective equipment, including when required by pesticide product labeling, when occupying an enclosed aircraft cockpit. Respiratory protection is not required to be worn when occupying an enclosed aircraft cockpit' (3 CCR 6738.4(f) (PPE Exemptions)). Another place where relevant label language that could be utilized is closed mixing regulations, as many targeted application technologies are utilizing closed or near-closed mixing systems; for example California's closed system regulations (3 CCR 6746(e)) requires all PPE required by label, permit condition or law to be available at the worksite when mixer/loaders are using closed mixing systems to isolate the hazard (e.g., having the PPE on site allows the operator to utilize proper PPE before responding to equipment failure that could lead to a spill or leak leading to potential exposure to the product mix).
- General Use Requirements: thinking about targeted application, lower carrier volumes may be advantageous or better economically for the farmer due to not needing to apply to the entire field; however current limits on the minimum total volume needed for application due to field crop residue data requirements could limit adoption of targeted applications that fall below these criteria (e.g. for row crops, applying in a minimum of 2 gallons per acre by air or 10 gallons per acre by ground and for orchard and vine crops: applying by ground in a minimum of 50 gallons per acre or by air in a minimum of 10 gallons per acre). Additionally, it should be considered that with lower volume application technology will eventually come formulations and adjuvants developed specifically for this use.
- Resistance Management: when used appropriately (e.g., using the full recommended application rate), this technology could potentially reduce the risk of resistance development by treating pests where they emerge as this should reduce the pest population being exposed. The basic principles of resistance management should still be adhered to reap this potential benefit.
- Spray Drift Precautions/Buffer Zones: Large buffer zones may not be necessary with targeted application due to less than whole field applications; as mentioned above, the potential elimination of full application swaths at the edge of the field in exposure models should also lead to reduced buffer zones. Additionally, coarser nozzles intended for a more directed rather than

broadcast application profile may reduce the need for large buffer zones. These coarser nozzles would ideally increase on-target application and mitigate drift. This aspect of reducing the buffer zones could be another benefit to the grower/applicator to encourage adoption of targeted application.

- Additional Requirements for Aerial Application: currently, for manned aerial applications standard label language states that the minimum practical boom length should be used, and that boom length must not exceed 75% of the wingspan or 80% rotor diameter. However, in the case of technologies like multi-rotor UAVs, it will need to be seen how (if at all) this should be considered and/or changed due to the different turbulences created.

Recommendations:

Our high-level recommendation is that EPA OPP must account for targeted application in their exposure and risk assessment process to encourage adoption of this technology. Without a change in risk assessment approach from EPA OPP, environmental and ecological benefits of targeted application will be unaccounted for and/or the benefits and/or potential risks associated with these technologies will not be characterized.

An example encouraging targeted application to gain environmental and ecological benefits that could ultimately be reflected on labels could be done in a similar fashion as is currently done with mitigation measures and corresponding credits to be earned from certain agronomic practices such as cover cropping and including vegetative filter strips. For example, a targeted application mitigation measure could read: "Reduce total sprayed area per application of 'product X' using precision application technology. Application to no greater than 70% of field = 2 credits. Application to no greater than 40% of field = 4 credits". Another tangible way the agency can continue to support emerging technologies like targeted application and digital connectedness is via additional PPDC efforts such as digitalizing labels.

We recommend EPA:

1.) Consider that the risk from targeted applications would be reduced proportionally when considering exposure in the risk assessment process
2.) Understand that targeted applications can help protect endangered species by programming in exclusion zones which would prevent spray applications in protected areas
3.) Consider targeted applications in current no-spray buffer zones due to reduced risk of off-site movement
4.) The above points should be reflected in label language to encourage adoption and use

To achieve the potential long-term benefits of targeted application, along with the development of emerging technologies, we also recommend that EPA OPP consider establishing a mid to long term goal of establishing a regulatory approach for a connected digital system. Such a digitally connected system would hopefully connect the label, application machinery, application location & site, factor in endangered species act (ESA) location & mitigation needs, SURGO maps, & real-time measurement of application conditions (e.g., wind speed and direction), along with other parameters (e.g., site specific needs like buffer zones, run-off models [see Agricultural Policy Environmental eXtender, or "APEX"], other models such as some of those discussed at the Environmental Modeling Public Meeting [EMPM] on Endangered Species, etc.). The fact that prototype application systems (see 'DriftRadar', Bayer receives

Future Prize | LECTURA Press) are starting to emerge demonstrates that this digitally connected and autonomous application system approach is already in development.

Chapter 3 – Charge Question 3: Establishing a Digital Mindset

Digital Tools Could Enable Local / Site-Specific Use Directions

The inclusion of site-specific or field level use conditions in regulatory decisions has been and continues to be a challenge for EPA OPP, as registration and regulatory risk assessment is predominately done at a national level; because of the national focus of their decisions historically EPA OPP has utilized conservation exposure assumptions that reflect a reasonable worst case in the risk assessment process. There are approaches that EPA OPP utilizes to take a more regional or watershed level approach: exposure scenarios in surface water assessment that take regional watershed level conditions and potential vulnerabilities into account are used to inform regulatory decisions (https://www.epa.gov/sites/default/files/2020-01/documents/creating-new-scenarios.pdf). However, utilizing a national or regional approach may overestimate exposures in some more localized site-specific conditions leading to overly protective use restrictions; the opposite could also be true (e.g., use restrictions may underestimate exposures under certain site-specific uses). Further, EPA OPP has spent a lot of time and resource building toward fulfilling its obligations under the Endangered Species Act (EPA's Workplan and Progress Toward Better Protections for Endangered Species | US EPA); consideration of endangered species is a quintessential site-specific focused assessment as these species generally are limited in their geographic distribution due to specific habitat or other requirements for completion of their life cycle. Peer review publications have raised concerns about the state level exposure assessments currently being utilized by EPA OPP in endangered species assessments, making the case that exposure at the township / more localize level is more appropriate for endangered species assessment.[11]

One way of building a digital mindset within EPA OPP could be to consider how to incorporate site-specific and field level considerations in risk assessments and regulatory decisions; such an approach would allow EPA OPP to investigate how to incorporate a 'bottom up' (e.g., start with actual use sites) approach in contrast to the 'top down' approach (e.g., use scenarios that are intended to be representative of use sites). An intriguing possibility toward a site-specific approach was presented at the August 2022 ACS meeting; the slides utilized in this presentation are provided in Appendix 2 (American Chemical Society AGRO Division Presentation; August 23, 2022. B. Engel, F. Pan, Z. Tang, R. Sur, H. Yen, and D. Ren. Web-based, Site-specific Exposure Modeling for Endangered Species Assessment; please note that a similar presentation from this research group was given at the June 23, 2022 Environmental Modeling Public Meeting). This presentation provided an overview of an internet-based tool that could enable site specific assessment for endangered species, particularly for species in aquatic environments. Instead of utilizing the current approach (e.g., using conservative exposure scenarios that are meant to be representative of regional or national use conditions), a digital mindset might lead EPA OPP to use a tool like the one in this presentation to estimate exposures using a population of established crop / farm sites; this population of specific use sites would then allow regulatory decisions informed by a range of actual site-specific use sites (e.g. from the most vulnerable to the less vulnerable) depending on the properties of the active ingredient, the proposed use pattern, the characteristics of the specific use sites, and the nontarget species with protection goals in proximity to the use site. The next step in the site-specific assessment

[11] Murphy, E. L., Eikenberry, S., Iacona, G., Watson, G., & Gerber, L. R. (2021). The value of increased spatial resolution of pesticide usage data for assessing risk to endangered species. Conservation Science and Practice, 3(12), e551. https://doi.org/10.1111/csp2.551

process could be estimating the effect of conservation measures or other changes in use conditions (for example, sites that have a potential exposure overlap with an endangered species) that could be employed to decrease off-site movement particularly in vulnerable use sites; an example of a tool that could accomplish this was presented at the June 2022 Environmental Modeling Public Meeting facilitated by EPA OPP (See Appendix 3). To enable use of a site-specific approach for endangered species assessment – again which is the quintessential site-specific risk assessment - the overlap of refined species range or habitat maps for a specific segment of use sites could be the next step in the process; a tool to enable this type of assessment has also been subject of a previous presentation (See Appendix 4). Using this sequence of tools to help develop a digital mindset within EPA OPP could be scaled to enable case studies or pilots to develop a digital mindset; for example, a population of actual use sites could be limited geographically (e.g., to an individual state), by cropping system (e.g., an orchard crop), or by a grouping of endangered species (e.g., as in the on-going EPA OPP endangered species pilots).

Coupling the site-specific tools mentioned above with digital infrastructure that autonomously delivers use instructions to application equipment has the potential to provide a more precise and protective regulatory system. Even if tools like the ones listed above were utilized in additional to the current assessment approach utilized by EPA OPP, more appropriate directions for use could be developed when local conditions are the goal of the assessment and regulatory decisions (e.g., when considering endangered species). In short, we recommend that EPA OPP consider using site-specific tools such as the ones described in this presentation using case studies or pilots as a method to develop a digital mindset.

Building a Digital Infrastructure for Delivering Directions for Use

For most of us in the United States observations from time in public settings would lead to the conclusion that the majority of the US population has a mobile phone; the near ubiquitous nature of mobile phones has led to the use of digital tools to navigate our daily lives whether looking for navigation help while driving, paying for our groceries, or attending an entertainment event (e.g., many stadiums, arenas, and theaters have moved to a digital ticketing / access system). Current estimates of smartphone (e.g., a phone that can make calls but also perform tasks like a computer) ownership demonstrate a doubling of smartphone use in the US over the last decade, with 294.15 million smartphone users and 85% of US adults now using a smartphone. Population demographics provide additional information on the distribution of smartphone use:

- Income: 76% of people who earn less than $30,000 a year own a smartphone compared to 96% of people who earn $75,000 or more each year.
- Ethnic background: 85% of both White and Hispanic people and 83% of Black people own a smartphone
- Location: 89% of individuals in urban areas, 84% of people in suburban areas, and 80% of people in rural areas own a smartphone. [12]

While the ETWG is not aware of research that provides information on smartphone use by US farmers, there is information from Germany regarding smartphone use by farmers. A survey was undertaken by researchers in 2019 that showed that 95% of the surveyed farmers use a smartphone, but only 71% of

[12] "U.S. Smartphone Industry Statistics [2022]: Facts, Growth, Trends, And Forecasts" Zippia.com. Jan. 30, 2022, https://www.zippia.com/advice/us-smartphone-industry-statistics/, and https://www.statista.com/statistics/219865/percentage-of-us-adults-who-own-a-smartphone/

these farmers used a crop protection smartphone application or 'app'. The research team speculated on the reasons for this difference in smartphone access and crop protection apps including the need for applications more user-oriented information based on the crop specialization of the farm and incorporation of farm (e.g., site specific) needs. It is not an overstatement that having digital access to pesticide directions for use would be one of the most important crop protection applications of interest to farmers.[13]

It is not only a dramatic increase in smartphone access that has occurred over the last decade, but the evolution of the capacity of these computers that fit in a pocket has also dramatically increased; a common comparison to give context to this dramatic increase is the smartphone in your pocket has over 100,000 times the processing power and > 32,600 times faster processing of the NASA Apollo computer that was used to land a manned spacecraft on the moon and return the crew safely to earth.[14]

In contrast to the emergence of smartphone access and computing power and the impacts of this on the use of digital tools as part of everyday life, the EPA OPP approach to communication of use directions for pesticides has not made significant progress in building digital infrastructure. At its essence, the current system was designed for a paper-based world and none of the steps in pesticide labels (e.g., review of proposed label wording, application of a label to a pesticide container, or enforcement of use instructions on pesticide labels) have taken advantage of the benefits that a digital infrastructure to use directions could provide.

Therefore, once again the ETWG urges EPA OPP to work to build a digital mindset for its program by establishing projects and/or pilots that work toward building a digital infrastructure for use directions; as the ETWG has stated, the development and adoption of digital labels / use instructions that can be read and acted on by autonomous machines, including robots is not just a need for the future, but is a current need. The content from the ETWG 2021 report (see Section 2, particularly Digital Label) is still very relevant, and is incorporated to this report per reference. As was stated in the ETWG 2021 report: '*To accommodate these emerging technologies, OPP's approach to pesticide labels must change. We recommend that PPDC advocate for and support a mindset of digital transformation, which supports digital labels that can be read and acted on by autonomous machines, including robots. OPP has taken small steps in label review to compare PDF files of labels, but more sophisticated capabilities are needed. Digitalization of agriculture needs to be enabled to fully implement the benefits of precision farming*.' In conclusion, we urge EPA OPP to establish a PPDC working group that will support efforts to build the much-needed digital infrastructure.

Conclusion

[13] M. Michels, V. Bonke, & O. Musshoff. Understanding the adoption of smartphone apps in crop Protection. Precision Agriculture (2020) 21:1209–1226, https://doi.org/10.1007/s11119-020-09715-5

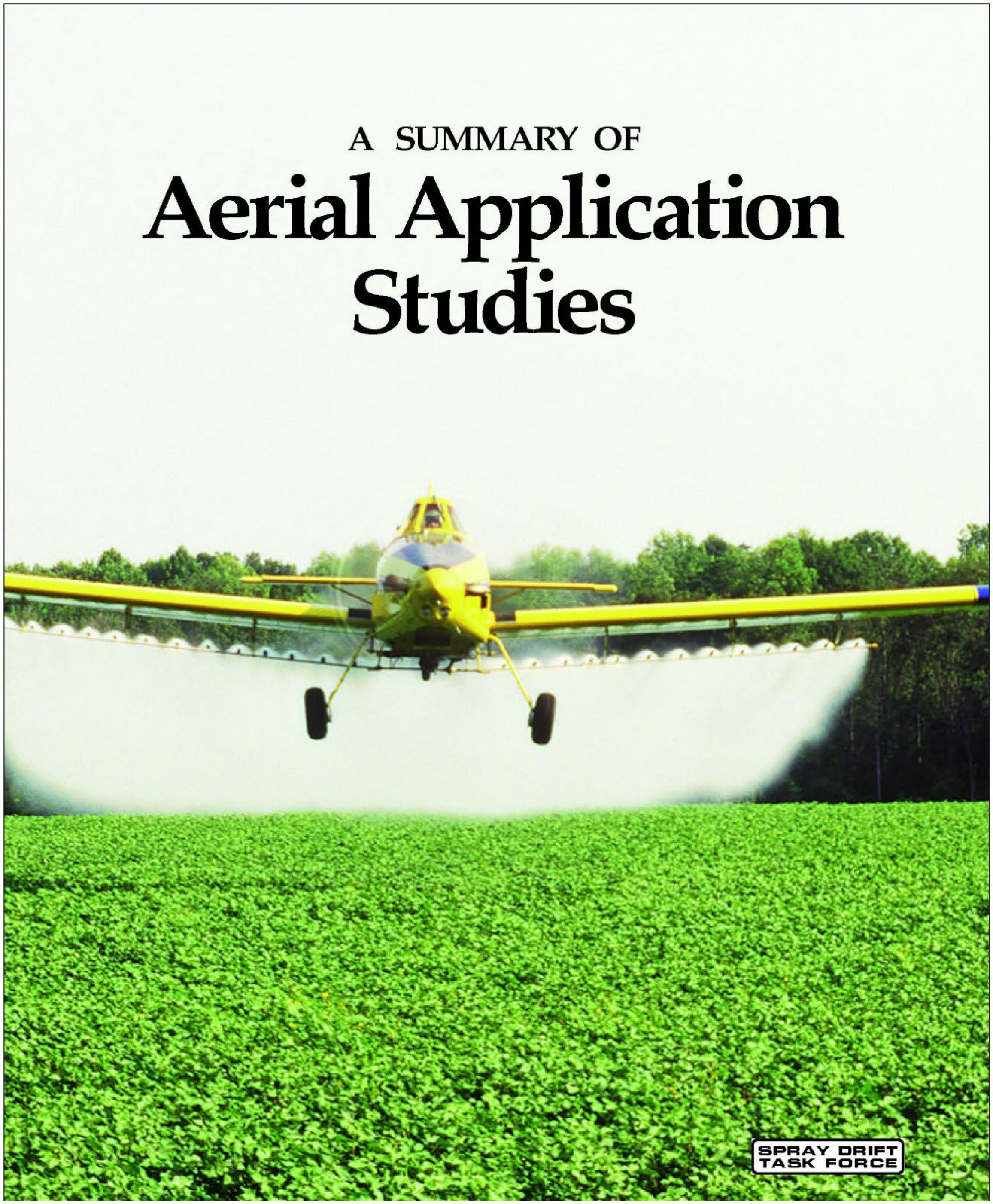
[14] https://www.realclearscience.com/articles/2019/07/02/your_mobile_phone_vs_apollo_11s_guidance_computer_111026.html and https://www.zmescience.com/science/news-science/smartphone-power-compared-to-apollo-432/

Emerging technologies using Targeted Application and other examples cited in this report are a central element to solving one of society's most pressing issues: feeding a growing population while minimizing agriculture's impact on the environment and human health. Sustainable and climate-smart production will require this to be achieved by managing the economics as well as factors such as soil health, erosion, water use, and prudent use of agricultural inputs. As with the adoption of any new technology, it will only be successful if it brings benefits to farmers, the environment, and society. It is therefore necessary to continue the engagement of diverse stakeholders as these efforts progress within transparent, science-based, and flexible regulatory frameworks that can enable these technologies to continually evolve for the future of farming.

The ETWG acknowledges that many current and future challenges exist in the pest management space in modern times. For example, for growers, besides the daily tasks involved in operating the farm and growing a crop, many open issues have the potential to greatly impact their business, such as labor, drought, and trade (https://www.fb.org/issues). Also, emerging sustainable business opportunities such as funding access via certification programs and carbon credits add opportunity, however, also increase the complexity. Additionally, increasing regulatory requirements, such as those introduced with ESA, add another element to an already complex system. In parallel, increased and more site-specific risk assessments, based on field, farm, and county requirements will be developed versus broad, national ones; this need will be driven by endangered species assessments and the evolution of conservation programs funded by USDA and others. This evolving situation requires more attention to what can be done to reduce the burden on growers to connect to all this information, most likely through digital solutions.

We recommend that EPA OPP not only look to approaches involving digital submissions and review of registrations, but also to approaches that support an overall digital infrastructure that is supportive of connecting all the complexities, in a practical way, that can be implemented by a grower, and in the future to automated machinery, to sustain and increase their business in line with environmental and human health goals.

Appendix 1. A Summary of Aerial Application Studies. Spray Drift Task Force. 1997.



Introduction

The incidence and impact of spray drift can be minimized by proper equipment selection and setup, and good application technique. Although the Spray Drift Task Force (SDTF) studies were conducted to support product registration, they provide substantial information that can be used to minimize the incidence and impact of spray drift. The purpose of this report is to describe the SDTF aerial application studies and to raise the level of understanding about the factors that affect spray drift.

The SDTF is a consortium of 38 agricultural chemical companies established in 1990 in response to Environmental Protection Agency (EPA) spray drift data requirements. Data were generated to support the rereg-istration of approximately 2,000 existing products and the registration of future products from SDTF member companies. The studies were designed and conducted in consultation with scientists at universities, research insti-tutions, and the EPA.

The purpose of the SDTF studies was to quantify primary spray drift from aerial, ground hydraulic, air blast and chemigation applications. Using a common experimental design, more than 300 applications were made in 10 field studies covering a range of application practices for each type of application.

The data generated in the field studies were used to establish quantitative databases which, when accepted by EPA, will be used to conduct environmental risk assessments. These databases are also being used to validate computer models that the EPAcan use in lieu of directly accessing the databases. The models will provide a much faster way to estimate drift, and will cover a wider range of application scenarios than tested in the field studies. The models are being jointly developed by the EPA, SDTF and United States Department of Agriculture (USDA).

Overall, the SDTF studies confirm conventional knowledge on the relative role of the factors that affect spray drift. Droplet size was confirmed to be the most important factor. The studies also confirmed that the active ingredient does not significantly affect spray drift. The physical properties of the spray mixture generally have a small effect relative to the combined effects of equipment parameters, application technique, and the weather. This confirmed that spray drift is primarily a generic phenomenon, and justified use of a common set of databases and models for all products. The SDTF developed an extensive database and model quantifying how the liquid physical properties of the spray mixture affect droplet size.

The SDTF measured primary spray drift, the off-site movement of spray droplets before deposition. It did not cover vapor drift, or any other form of secondary drift (after deposition), because secondary drift is pre-dominantly specific to the active ingredient.

Prior to initiating the studies, the SDTF consulted with technical experts from research institutions around the world and compiled a list of 2,500 drift-related studies from the scientific literature. Because of differing techniques, it was difficult to compare results across the studies. However, the information from these references was useful in developing test protocols that were consistently followed throughout the field studies.

The objective of the aerial field studies was to quantify drift from the range of application practices common in the early 1990s. Since some practices may have changed since then, it is important to recognize that the aerial model will use inputs based on current practices.

The information being presented is not an in-depth presentation of all data generated by the SDTF. Use of pesticide products is strictly governed by label instruc-tions. Always read and follow the label directions.

Procedures

Test site location and layout

Two sites were chosen in Texas because they provided open expanses, up to one-half mile downwind from the application areas, and a wide range of weather conditions. Wind speeds varied from 2 mph to 17 mph, with an average of 10 mph across all applica-tions. Air temperatures varied from 32˚F to 95˚F and relative humidity varied from 7% to 94%.

Aerial View of Test Site

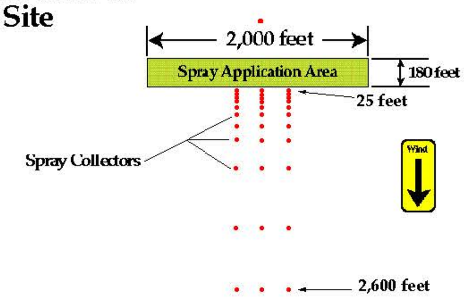


figure 1

The test application area measured 2,000 feet in length and 180 feet in width (figure 1). Four, 45-foot wide parallel swaths were sprayed going from left-to-right and right-to-left. Three lines of horizontal alpha-cellulose cards (absorbent material similar to thick blotting paper) were placed on the ground at 12 selected intervals from 25 feet to 2,600 feet downwind from the edge of the application area. These collectors simulated the potential exposure of terrestrial and aquatic habitats to drift. Acollector was also positioned upwind from the application area to verify that drift only occurs in a downwind direction.

Relating droplet size spectra to drift

All agricultural nozzles produce a range of droplet sizes known as the droplet size spectrum. In order to measure the droplet size spectrum that was applied in each field study treatment (and that represent those produced from commercial applications), the critical application parameters (nozzle type, orifice size, pressure, angle, and air speed) were duplicated in an extensive series of atomization tests conducted in a wind tunnel. The controlled conditions of the wind tunnel allowed the droplet size spectrum to be accurately measured using a laser particle measuring instrument.

The volume median diameter (VMD) is commonly used to characterize droplet size spectra. It is the droplet size at which half the spray volume is composed of larger droplets and half is composed of smaller droplets. Although VMD is useful for characterizing the entire droplet spectrum, it is not the best indicator of drift potential.

A more useful measure for evaluating drift potential is the percentage of spray volume consisting of droplets less than 141 microns in diameter. This value was selected because of the characteristics of the particle-measuring instrument, and because it is close to 150 microns, which is commonly considered a point below which droplets are more prone to drift.

The cut-off point of 141 microns or 150 microns has been established as a guide to indicate which droplet sizes are most prone to drift. However, it is important to recognize that drift doesn't start and stop at 141 microns. Drift potential continually increases as droplets get smaller than 141 microns, and continually decreases as droplets get bigger.

The wind tunnel atomization tests verified that a broad range of droplet size spectra was applied in the field study treatments. These measurements were critical to understanding the differences in spray drift that were measured for each field study treatment.

Other factors affecting drift

Other variables that were tested include: nozzle heights from 6 feet to 31 feet above the ground; boom lengths of 69% and 84% of the wingspan; oil as a carrier for the ultra low volume (ULV) applications; the effects of liquid physical properties of the pesticide spray mixture; and the effects of crop canopy.

Weather-related factors including wind speed and direction, and air temperature were recorded during the field trials at four separate heights between 1 and 30 feet. Relative humidity, solar radiation, barometric pressure, and atmospheric stability were also recorded.

Experimental design

The varying weather conditions encountered during multiple-application field studies presented a good opportunity to evaluate their effects on drift. However, these variations complicated efforts to measure the effects of equipment-related factors. For example, if a treatment using 8002 nozzles (producing a fine droplet spectrum) was run during low wind speeds, and then a treatment using D8 nozzles (producing a coarse droplet spectrum) was run during high wind speeds, the amount of drift would have been affected both by the change in droplet size and the wind speed.

To factor out the meteorological effects, the SDTF used a covariate experimental design, which is a commonly accepted statistical technique for this type of study. The design entailed a control treatment that was always applied immediately after an experimental treatment. The control treatment was a medium droplet size spectrum produced with D6-46 nozzles at a 45° angle on a fixed-wing airplane traveling at 110 mph. It was always applied in exactly the same manner. The experimental treatment differed from application to application in nozzle type, nozzle orifice size, aircraft speed, etc.

The primary test airplane, a Cessna Ag Husky®, was equipped with a dual application system (tank, pump and boom) that permitted successive applications of the control and experimental treatments without landing. The two booms were never used simultaneously in order to avoid any potential interference between the sprays.

Four swaths of the experimental treatment were applied first, beginning at the downwind side. The control treatment was then immediately applied over the same area. The total elapsed time for both applications was 12 minutes. Continuous weather monitoring showed no appreciable changes in atmospheric conditions during the 12 minute periods. The downwind collectors were analyzed for both diazinon (the tracer used with the control treatment) and malathion (the tracer used with the experimental treatment).

Using this experimental design, differences between replications of the control treatments are due only to atmospheric conditions, since the application procedures were always the same. Differences between experimental treatments are due to changes in the atmospheric conditions and application procedures. Consequently, differences between experimental and control treatments are due to application procedures. This allowed direct comparisons to be made among all the experimental treatments by factoring out the effects of weather (as measured by the control applications).

Atotal of 90 experimental (45 treatments, 2 replicates each) and a corresponding 90 control applications were made. Besides providing a means of adjusting for atmospheric conditions, the 90 applications of the control treatment also provided an extensive database for evaluating the effects of meteorological parameters on drift.

Aerial drift model

Due to the complexity of evaluating all possible interactions of the numerous application variables, a computer model is the most practical way to conduct spray drift risk assessments. For aerial application, a highly sophisticated simulation model had been developed previously by the USDA Forest Service for forestry applications. The SDTF, EPAand USDA worked together to adapt and validate this model for agricultural applications using the data generated in the SDTF field and atomization studies. After final review and acceptance by the EPA, this model will allow evaluation of a much wider range of applications than those tested in the field studies. Its use will help ensure that SDTF assessments reflect current application practices.

Because so many interacting factors affect aerial spray drift, this report only offers examples of how the major variables affect drift.

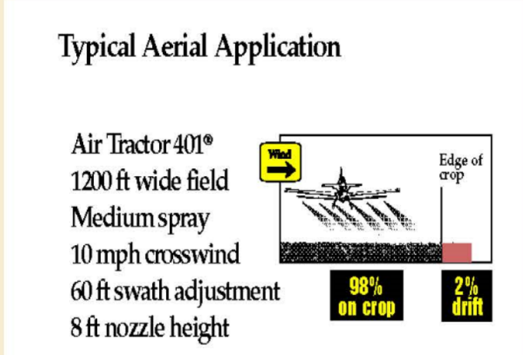


figure 2

Findings

Typical drift levels from aerial application

The goal of aerial applicators is to protect crops from diseases, insects and weeds while keeping drift as close to zero as possible. The SDTF studies show that drift can be kept very low by using good application procedures.

Based on data generated by the SDTF, in a typical full field aerial application, 98% of the total applied active ingredient stays on the field and only 2% drifts (figure 2). Atypical application was defined as a 1200-foot wide, 20-swath field (suggested by EPA) using an Air Tractor 401® set-up to produce a medium droplet spectrum, in a 10 mph crosswind (typically the maximum allowable wind speed), a 60-foot swath adjustment, and 8-foot nozzle height (application height).

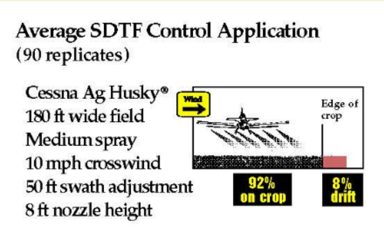


figure 3

Although aerial applications typically consist of twenty or more swaths, using fields of this size was not practical. Instead, a four-swath (180 feet wide) application area was used in the field studies. This design generated data that represented drift from a
20-swath field since most drift originates from the farthest downwind swaths.

Because the application area was smaller than is typical for commercial applications, and because most drift comes from the outer swaths of the field, the percentage of the active ingredient leaving the field in the SDTF studies was 8% rather than 2% (figure 3). This percentage of drift is artificially high due to the relative size of the application areas. The 8% drift is the average of the 90 applications of the control treatment. The SDTF control application differed from the typical application only in the aircraft used, swath width, and the size of the application area.

Figure 4 shows how the 8% of the control treatment that left the field deposited downwind. The amount of material that deposits on the ground decreases rapidly with distance and is already approaching zero at 250 feet downwind. Ground deposition was measured out to one-half mile downwind, but the amount of material was normally too low beyond 250 feet to illustrate any differences between treatments.

Drift from the SDTF Control Application

1.0 = 1.2 oz per acre

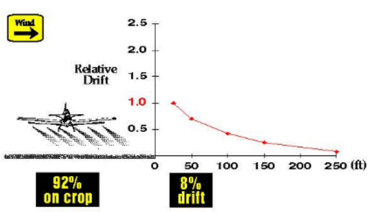


figure 4

Ground deposition measurements began 25 feet downwind, which represents a reasonable distance from the edge of a crop to the effective edge of a field where drift would begin to be of concern.

A scale of Relative Drift is used in this and all subsequent graphs to facilitate comparisons among treatments. Since the control treatment will be used as a standard of comparison, it was set to 1.0 at 25 feet. For an application of one pound of active ingredient per acre, this represents 1.2 ounces per acre deposited on the ground at 25 feet. A Relative Drift value of 0.5 indicates that one-half as much was deposited. A value of 2 would indicate twice as much was deposited. In subsequent graphs the deposition profile for the control treatment is shown in red in order to facilitate comparisons.

How swath adjustment reduces drift

When the wind is low, virtually all of the spray is deposited directly under the aircraft allowing the pilot to fly close to the edge of the field (figure 5a). With a crosswind, the spray swath is displaced downwind (figure 5b). Pilots typically compensate for this swath displacement by adjusting the position of the aircraft upwind (figure 5c). The amount of swath adjustment can vary from one half, to more than two swath widths, depending upon wind speeds and proximity to sensitive areas.

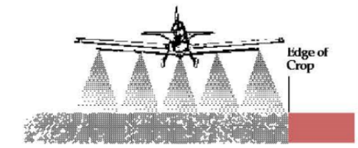


figure 5a

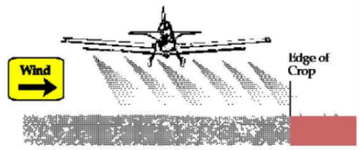


figure 5b

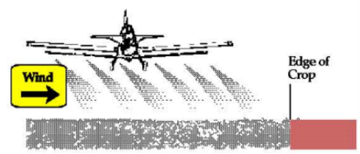


figure 5c

In order to maintain consistency across all applications in the SDTF field studies, the pilot made no swath adjustment. However, in this report a swath adjustment was applied by mathematically shifting the deposition curve upwind by 50 feet. This would be a typical swath adjustment in a 10-mph crosswind, the average wind speed in the field studies.

The effects of swath adjustment are illustrated in figure 6 for no adjustment, a half swath adjustment, and a full swath adjustment as applied for the control treatment. With no swath adjustment, the amount of spray material depositing at 25 feet downwind is approximately three and a half times that from a full swath adjustment. Swath adjustment substantially reduces drift, especially in the first 100 feet. These results are for a medium droplet size spectra from the control

How swath adjustment affects drift

Control Application

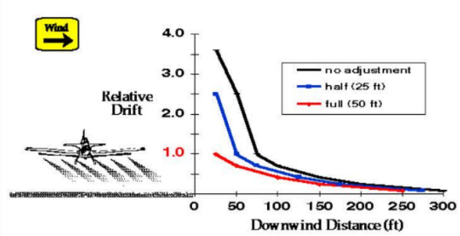


figure 6

treatment. The effects would be even more dramatic with a finer droplet spectrum.

How nozzle and droplet size affect drift

The effect of droplet size on downwind ground deposition is illustrated in figure 7. It shows that drift decreases dramatically as the percent of volume in droplets smaller than 141 microns decreases due to the use of different nozzles, nozzle angles, and/or air speeds.

The control treatment had 15% of the spray volume in small droplets (less than 141 microns). The smaller D4-45 nozzle at the same angle produced twice the volume of small droplets and twice the amount of drift at 25 feet. The solid stream nozzle (D8) at a 0° angle produced a much lower volume of small droplets and substantially less drift than the control.

How nozzle and droplet size affect drift

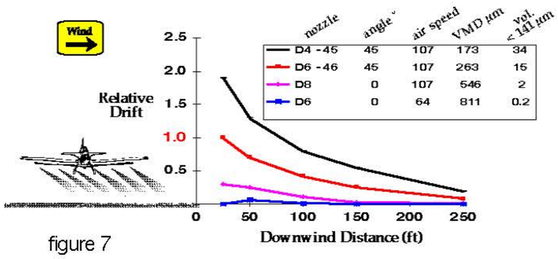


figure 7

Although droplet size was the primary factor affecting drift, the data for the D6 at 64 mph are not directly comparable because they were obtained with a helicopter instead of a fixed wing airplane. The helicopter data are included to illustrate that it is possible to reduce the percentage of small droplets to very low levels with a corresponding decrease in drift. The results show that pilots can minimize drift by managing the factors affecting droplet size.

How air shear affects droplet size and drift

Air shear across the nozzle tip, which is a function of both nozzle angle and aircraft speed, significantly affects droplet size. When nozzles are pointed toward the back of the plane, air shear is less than when the nozzles are pointed downward (figure 8). Air shear across the nozzle tip also increases with faster aircraft speeds, resulting in smaller droplets. The effect of air shear on droplet formation and drift was studied by

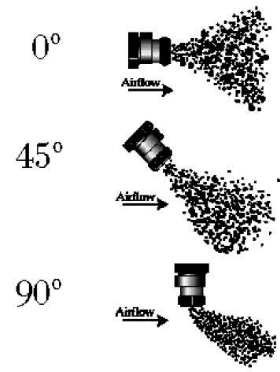


figure 8

setting up identical nozzles and nozzle angles on three aircraft: a helicopter, which flew at 64 mph; a piston-powered, fixed-wing airplane at 107 mph; and a turbine-powered, fixed-wing airplane at 156 mph. The nozzle height was 8 feet.

When the same nozzles (D6-46) were positioned at a 45° angle on all three aircraft, there were differences in drift due to air shear (figure 9). At 156 mph, 39% of the droplet volume was less than 141 microns. As speed and subsequent air shear decreased, the volume percent less than 141 microns decreased to 6% with a corresponding decrease in drift.

It must be emphasized that figure 9 illustrates the effect of air shear on droplet size and drift. It does not indicate that these are typical droplet spectra for each aircraft. Normally the sizes and/or angles of the nozzles are changed to compensate for the air shear at higher speeds.

How air shear affects drift

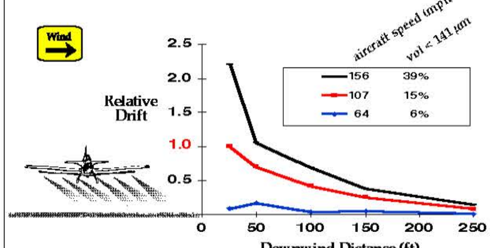


figure 9

How nozzle height affects drift

In aerial applications over agricultural crop areas, spray is typically released when the nozzles are about 8 feet above the ground or crop, compared with forestry and rangeland applications which are sometimes made at 20 feet or higher. Figure 10 compares drift from the control treatment when the nozzle height is changed from 8 feet to 22 feet. It shows that the higher nozzle height results in approximately 2.5 times more drift at 25 feet downwind.

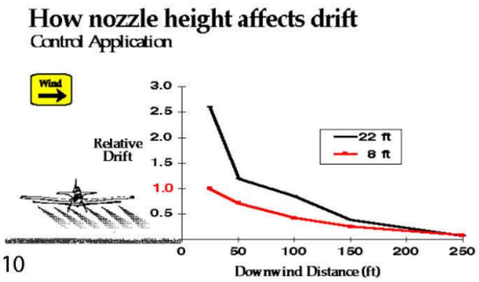


figure 10

With a finer droplet spectrum, this difference would have been greater; with a coarser droplet spectrum, the differences would have been less.

How boom length affects drift

Turbulent air, referred to as vortices, is created by the wings. Wing or rotor tip vortices exist on all aircraft. When the length of the boom is too long, spray droplets are caught in these vortices. The smaller droplets follow the air movement up and over the wing or rotor which effectively increases the application height and increases the potential for drift. When boom lengths are shortened, fewer droplets enter the vortices and drift is reduced.

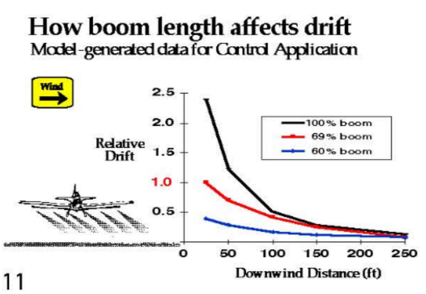


figure 11

Although the SDTF did not extensively test the effects of boom length on drift, the computer drift model affirms that the common practice of maintaining boom length at 70% or less of the wingspan minimizes drift (figure 11). The effect of boom length is more important when spraying a fine versus coarse droplet size spectrum.

How dynamic surface tension affects drift

Physical properties of the tank mixture can influence the formation of droplets by agricultural nozzles, although this effect is most important at higher levels of air shear.

The SDTF examined dynamic surface tension, shear viscosity, and extensional viscosity. Of these three physical properties, dynamic surface tension usually has the greatest influence on droplet size. Figure 12 represents the maximum range of drift attributable to dynamic surface tension for the SDTF control treatment. The
72 dynes/cm represents water, 32 dynes/cm represents the most extreme case, and 45 dynes/cm represents a large percentage of commercial pesticide tank mixtures.

These curves were generated by the computer drift model. Field study data confirmed that for the control treatment, physical properties had a very small effect on drift compared to equipment and application procedures.

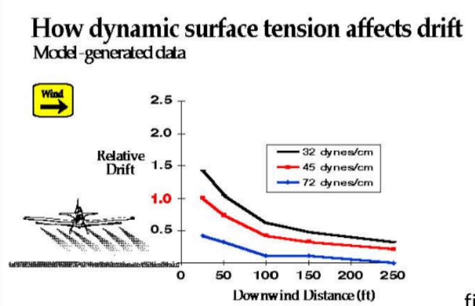


figure 12

How wind speed affects drift

The 90 replicates of the control applications clearly established that wind speed was the most important atmospheric factor affecting drift (figure 13). Although it is commonly accepted that hot, dry conditions accelerate droplet evaporation, which results in smaller droplets, this was not found to be as important as wind speed.

How wind speed affects drift

Control Application

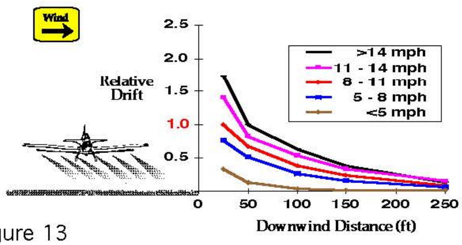


figure 13

How crop canopy affects drift

Ground cover in the application and drift collection areas consisted of short grass. Alimited number of treatments were conducted over cotton to determine if there was a significant effect due to the presence of a more developed canopy. These treatments indicated a small decrease in downwind ground deposition over cotton.

Because the effect of canopy was extremely small, and because it was not practical to evaluate the infinite number of canopy shapes, heights, and densities, additional testing was not conducted. However, the treatments on cotton suggest that the SDTF field studies may slightly over-estimate drift for applications that are typically conducted over a well developed canopy.

Conclusions

The results from the SDTF studies confirm present knowledge concerning the role of factors that affect spray drift. In many cases the studies quantified what was already known qualitatively. As expected, droplet size was shown to be the most important factor affecting drift from aerial applications. Logically, the results also confirm that drift only occurs downwind. Waiting until the wind is blowing away from sensitive areas is an effective application practice. Although drift cannot be eliminated totally with current technology, there are many ways to minimize drift to levels approaching zero. The SDTF studies confirm that when good application practices are followed, all but a small percentage of the spray is deposited on target.

Drift levels can be minimized by:

a. Applying the coarsest droplet size spectrum that provides sufficient coverage and pest control.

b. Continuing the standard practice of swath adjustment.

c. Controlling the application height.

d. Using the shortest boom length that is practical.

e. Applying pesticides when wind speeds are low.

Except at high levels of air shear, the physical properties of the spray mixture have only a minimal effect on drift. The SDTF studies show that the pattern and magnitude of drift results from a complex interaction of many factors. The drift model is an effective means of predicting aerial spray drift and permits the evaluation of a much broader range of variables than those tested by the SDTF.

When accepted by the EPA, the SDTF model and databases will be used by the agricultural chemical industry and the EPAfor environmental risk assessments. Even though active ingredients do not differ in drift potential, they can differ in the potential to cause adverse environmental effects. Since drift cannot be completely eliminated with current technology, the SDTF database and models will be used to determine if the drift from each agricultural product is low enough to avoid harmful environmental effects. When drift cannot be reduced to low enough levels through altering equipment set up and application techniques, buffer zones may be imposed to protect sensitive areas downwind of applications.

Mention of a trademark, vendor, technique, or proprietary product does not constitute an endorsement, guarantee, or warranty of the product by the authors, their companies, or the Spray Drift Task Force, and does not imply its approval to the exclusion of other products or techniques that may also be suitable.

For more information contact David Johnson at Stewart Agricultural Research Services, Inc., P.O. Box 509, Macon, Missouri 63552. (816) 762-4240 or fax (816) 762-4295. (Area code changes to 660 after 11-97)

Appendix 2. American Chemical Society AGRO Division Presentation; August 23, 2022. B. Engel, F. Pan, Z. Tang, R. Sur, H. Yen, and D. Ren. Web-based, Site-specific Exposure Modeling for Endangered Species Assessment.

Web-based, Site-specific Exposure Modeling for Endangered Species Assessment

Bernie Engel*, Feng Pan*,
Zhenxu Tang**, Robin Sur**,
Haw Yen** and Dongyang Ren*
*Purdue University; **Bayer Crop Science

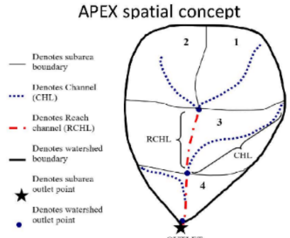
August 23, 2022
engelb@purdue.edu

PURDUE UNIVERSITY | Agricultural & Biological Engineering | BAYER Crop Science

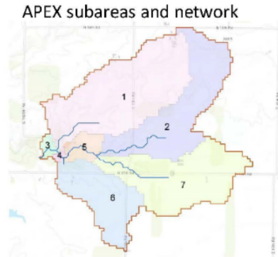
APEX Model Concept — Slide 4

- APEX developed to extend EPIC model capabilities to whole farms and small watersheds by:
  - Dividing watershed into homogeneous subareas in terms of physical characteristics for individual field simulation
  - Connecting subsurface hydrologic and water quality processes of each subarea based on topography
  - Routing water, sediment, and pesticides across complex landscapes and channel systems

APEX spatial concept



APEX subareas and network



✦**Objectives** Slide 3

- GeoAPEX-P (**Geo**graphic Information-based **APEX** for **P**esticides), a web-based, spatial exposure modeling tool is developed built on the Agricultural Policy Environmental eXtender (APEX) model to quantify runoff exposure for site-specific evaluation
  - Build national level database including spatial data, pesticide info, weather data, and management operations
  - Develop the tool with pesticide modeling capability at field/small watershed scale
  - Conduct rapid site-specific evaluations by guided button-clicks and automatic setup

Feng, Q.; Flanagan, D. C.; Engel, B. A.; Yang, L.; Chen, L., GeoAPEXOL, a web GIS interface for the Agricultural Policy Environmental eXtender (APEX) model enabling both field and small watershed simulation. Environmental Modelling & Software 2020, 123, 104569.

✦**Objectives** Slide 3

- GeoAPEX-P (**Geo**graphic Information-based **APEX** for **P**esticides), a web-based, spatial exposure modeling tool is developed built on the Agricultural Policy Environmental eXtender (APEX) model to quantify runoff exposure for site-specific evaluation
  - Build national level database including spatial data, pesticide info, weather data, and management operations
  - Develop the tool with pesticide modeling capability at field/small watershed scale
  - Conduct rapid site-specific evaluations by guided button-clicks and automatic setup

Feng, Q.; Flanagan, D. C.; Engel, B. A.; Yang, L.; Chen, L., GeoAPEXOL, a web GIS interface for the Agricultural Policy Environmental eXtender (APEX) model enabling both field and small watershed simulation. Environmental Modelling & Software 2020, 123, 104569.

✦**Comparison of APEX and PRZM simulated results with EMVTF field data** Slide 7

- Data used previously by EPA for PRZM evaluation

Data Set	Area (ha)	Slope (%)	Soil Type	Crop	Application Method[1]	Half-Life[2] (d)	Kd[2] (ml/g)
IA2R	7.0	4.3	Silt loam	Corn	T-Band, foliar, and broadcast (G, L)	30	121
IA3R	0.065	5.6	Silt loam	Corn	T-Band, foliar, and broadcast (G, L)	30	121
IA4R	1.21	2.9	Silt clay loam	Corn	T-Band (G)	52	4200
					T-Band (G)	121	12
IA5R	0.065	2.8	Silt clay loam	Corn	T-Band (G)	52	3200
					T-Band (G)	121	10

Data and documents used:

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Environmental Model Validation Task Force Final Report (EMVTF). American Crop Protection Association, 1156 Fifteenth Street, NW, Suite 400, Washington, DC 20005.

Singh, P. and R. L. Jones (2002). "Comparison of pesticide root zone model 3.12: Runoff predictions with field data." Environmental Toxicology and Chemistry 21(8): 1545-1551.

✦APEX Model Overview

Slide 6

- Pesticide module in EPIC, APEX, and SWAT are all derived from GLEAMS so their methods to track movement of pesticides with percolated water, runoff, and sediment are very similar
- APEX functions on daily time step and can simulate hundreds of years for approximately one hundred crops
- APEX has unique capability of simulating effects of BMPs and conservation practices
- APEX serves as a main nationwide environmental assessment tool in USDA-NRCS Conservation Effects Assessment Project (CEAP) since 2003

Key references:

Agricultural policy/environmental eXtender model theoretical documentation version 0806. agri life research, Texas A&M, Blackland Research and Extension Center, 720 East Blackland Road Temple, Texas.

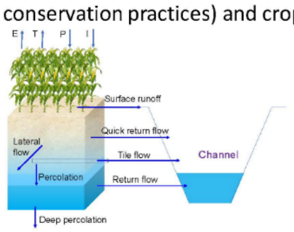
Wang, X., Williams, J. R., Gassman, P. W., Baffaut, C., Izaurralde, R. C., Jeong, J., & Kiniry, J. R. (2012). EPIC and APEX: Model use, calibration, and validation. Transactions of the ASABE, 55(4), 1447-1462.

✦PRZM Versus APEX

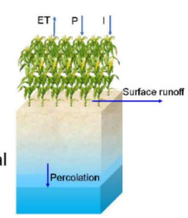
Slide 5

- APEX and PRZM both calculate runoff and erosion based on NRCS curve number method and Modified Universal Soil Loss Equation.
- APEX includes more hydrologic components (tile flow, subsurface flow, return flow).
- APEX pesticide module uses more empirical method to quantify pesticide transport, which needs fewer parameters and is computationally efficient .
- APEX has more details than PRZM for simulating management (including BMPs and conservation practices) and crop growth.

APEX subarea hydrological concept



PRZM hydrological concept

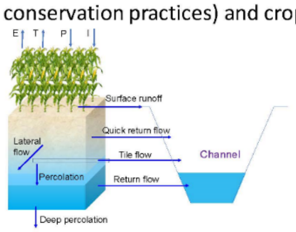


✦PRZM Versus APEX

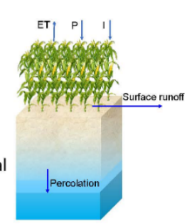
Slide 5

- APEX and PRZM both calculate runoff and erosion based on NRCS curve number method and Modified Universal Soil Loss Equation.
- APEX includes more hydrologic components (tile flow, subsurface flow, return flow).
- APEX pesticide module uses more empirical method to quantify pesticide transport, which needs fewer parameters and is computationally efficient .
- APEX has more details than PRZM for simulating management (including BMPs and conservation practices) and crop growth.

APEX subarea hydrological concept



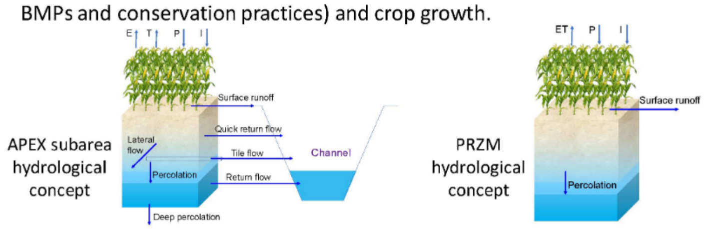
PRZM hydrological concept



✦PRZM Versus APEX

Slide 5

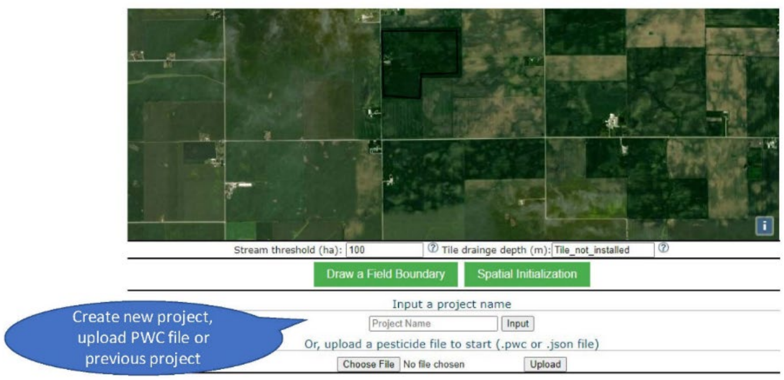
- APEX and PRZM both calculate runoff and erosion based on NRCS curve number method and Modified Universal Soil Loss Equation.
- APEX includes more hydrologic components (tile flow, subsurface flow, return flow).
- APEX pesticide module uses more empirical method to quantify pesticide transport, which needs fewer parameters and is computationally efficient .
- APEX has more details than PRZM for simulating management (including BMPs and conservation practices) and crop growth.



✦The Interface

Slide 13

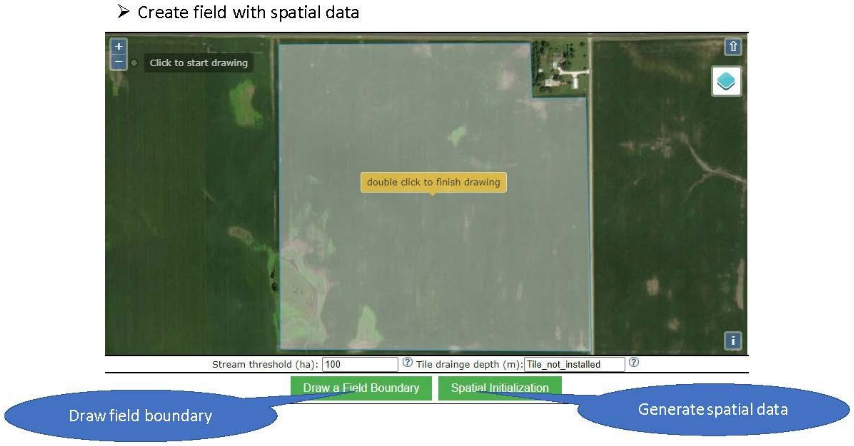
- Initiate the project



✦The Interface

Slide 12

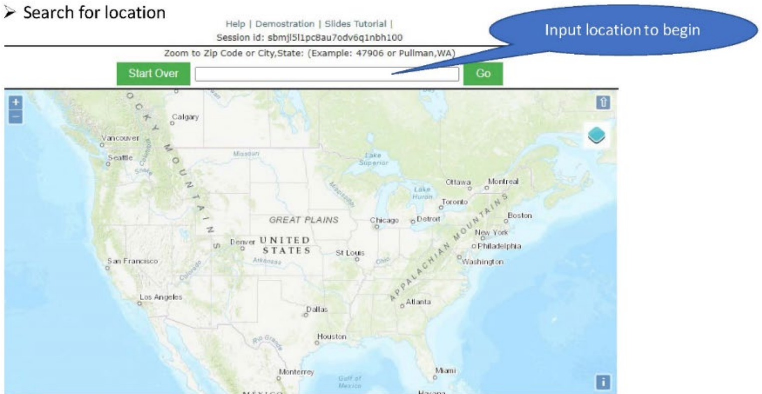
- Create field with spatial data



The Interface

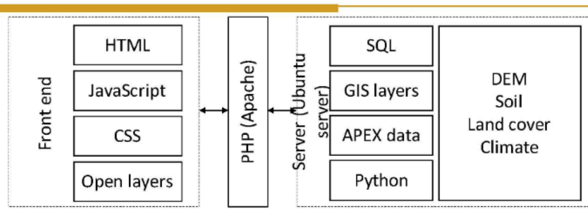
Slide 11

- Search for location

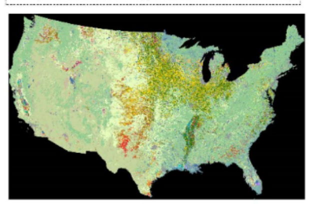


Conceptual System and Database

Slide 10



National Soil Map (SSURGO)



National Cropland Layer (NASS)

Results

Slide 17

- Simulation example

Location: 8 soybean fields in LaSalle County, Illinois representing high soybean production area with endangered plants in the county

Chemical Compound: 2,4-D

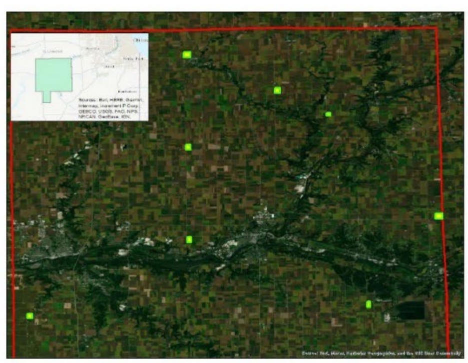
Application Timing:

(1) Apr 26 (12 days before emergence)

(2) May 8 (emergence day)

(3) May 20 (12 days after emergence)

Application Rate: 1.12 kg/ha

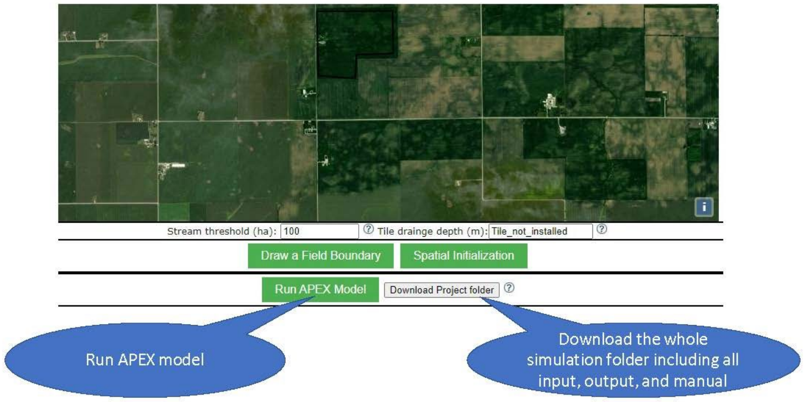


Model input data is from "2022 Ecological Risk and Endangered Species Assessment for Use on Genetically-Modified Herbicide-Tolerant Corn, Soybean, and Cotton in Support of Registration Renewal Decision for Enlist One and Enlist Duo Products" (EPA-HQ-OPP-2021-0957-0008_content)

✦The Interface

Slide 16

- Simulate and download results



✦The Interface

Slide 15

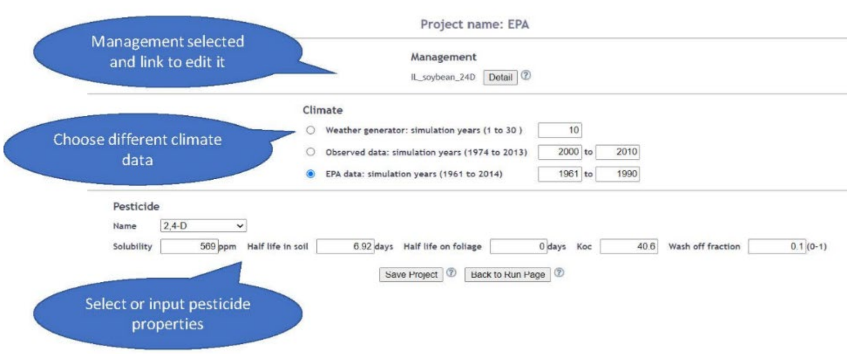
- Select or edit management operations

Y	M	D	Operation	Type	Crop	Fertilizer or pesticide name/ Time to maturity(for crop)	Amount(kg/ha)/ Potential heat units(for crop)
1	4	22	Plow cultivate other	Row cultivator			0.0
1	4	25	Plow cultivate other	Field cultivator			0.0
1	4	26	Apply pesticide	Aerial application insecticide		2,4-D	1.2
1	5	1	Plant in rows	Planter regular 12 row	Soybeans	0	1200.0
1	5	8	Apply pesticide	Aerial application insecticide		2,4-D	1.2
1	5	20	Apply pesticide	Aerial application insecticide		2,4-D	1.2
1	5	30	Plow cultivate other	Field cultivator			0.0
1	7	15	Plow cultivate other	Row cultivator			0.0
1	10	10	Harvest without kill	Harvest			0.0
1	10	11	Kill crops	Kill			0.0

✦The Interface

Slide 14

- Edit text format data

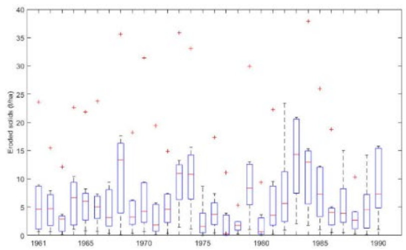


✦Results

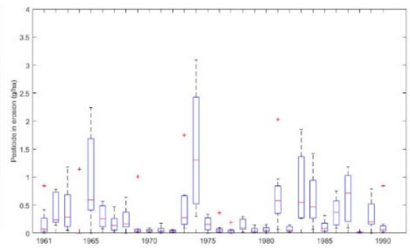
Slide 20

➢ Simulation example

Annual results (continued)



Annual total erosion (t/ha)



Annual total 2,4-D in erosion (g/ha)

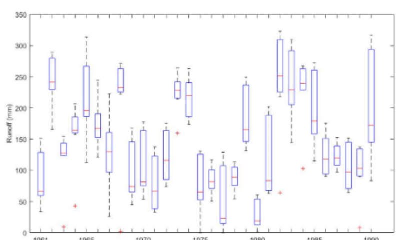
✦Results

Slide 19

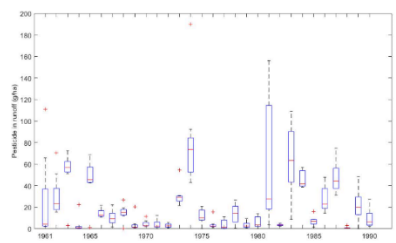
➢ Simulation example

Annual results (each boxplot shows the data range of 8 fields for that year)

Years 1961 to 1990



Annual total runoff (mm)



Annual total 2,4-D in runoff (g/ha)

✦Results

Slide 18

➢ Simulation example

Spatial variability of results were demonstrated by applying the model to 8 soybean fields in LaSalle County, Illinois with different soil types and slopes

Individual field results display temporal variability

- Annual results of 30 years for 8 fields
- Daily results of 50 days from first application date in 1962

Major soil types for 8 fields:

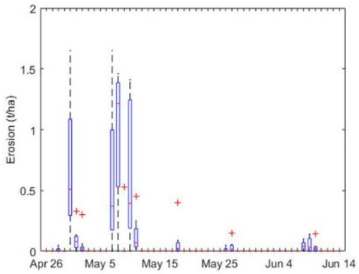
Soil name	Slope
Drummer silty clay loam	0 to 2 percent slopes
Elpaso silty clay loam	0 to 2 percent slopes
Sable silty clay loam	0 to 2 percent slopes
Muscatune silt loam	0 to 2 percent slopes
Rutland silty clay loam	2 to 5 percent slopes
Muscatune-Buckhart silt loams	0 to 3 percent slopes
Flanagan-Catlin silt loams	0 to 3 percent slopes
Streator silty clay loam	0 to 2 percent slopes

✦Results

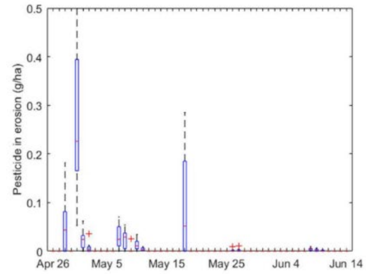
Slide 22

➢ Simulation example

Daily results (continued)



Daily total Erosion (t/ha)



Daily total 2,4-D in erosion (g/ha)

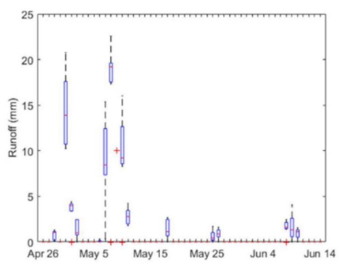
✦Results

Slide 21

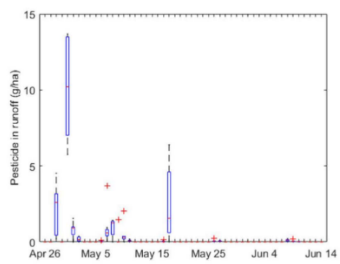
➢ Simulation example

Daily results of year 1962 (each boxplot shows the data range of 8 fields for the day)

50 days from the first application date (Apr 26)



Daily total runoff (mm)



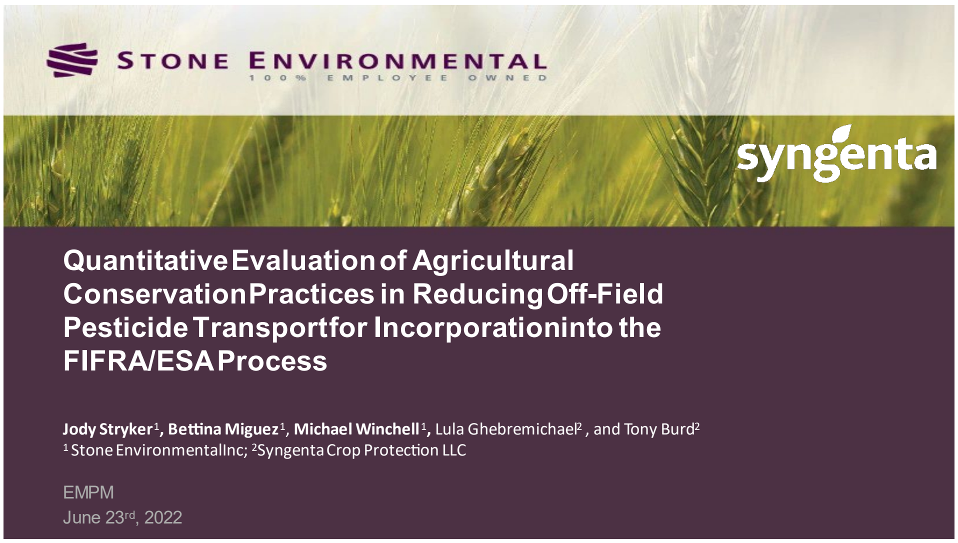
Daily total 2,4-D in runoff (g/ha)

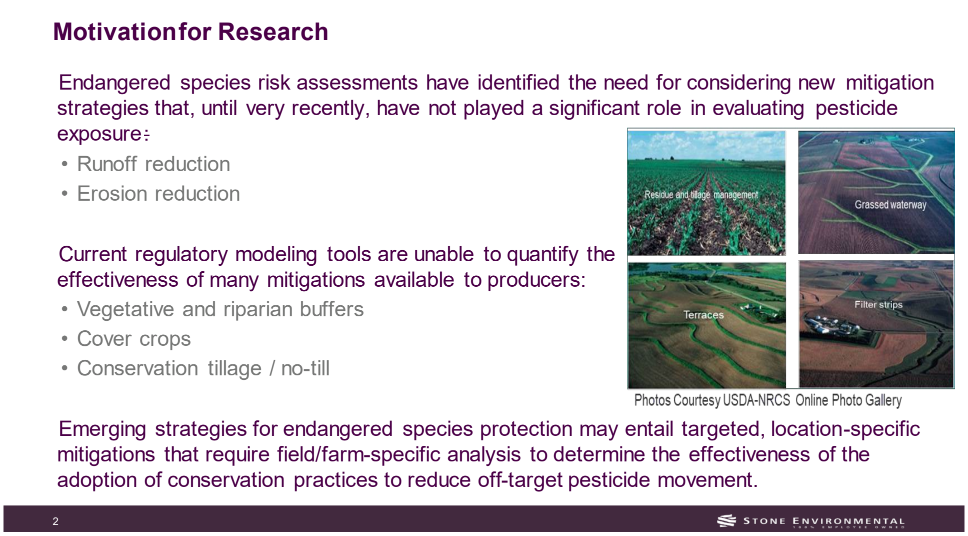
✦Conclusions

Slide 23

- ➢ APEX is a proven field-scale simulation framework and used by USDA CEAP among many others.
- ➢ APEX performance acceptable for initial assessment with EMVTF field study data.
- ➢ APEX web interface supports rapid, site-specific modeling of pesticide losses and conservation practices in continental US by using nationally available data.
- ➢ The future of regulatory risk assessment and management is site-specific for improved environmental protection.
- ➢ The APEX web tool lays the foundation towards this very vision.
- ➢ Ongoing research includes validation of APEX results with observed data and comparison between PRZM and APEX.

Appendix 3. Environmental Modeling Public Meeting June 23, 2022. J. Stryker, B. Miguez, M. Winchell, L. Ghebremichael, and T. Burd/ Quantitative Evaluation of Agricultural Conservation Practices in Reducing Off-Field Pesticide Transport for Incorporation into the FIFRA/ESA Process





Overview and Objectives

This talk will introduce an effort underway to develop a web-based tool, based on the APEX model, capable of evaluating the impacts of site-specific field and farm-level conservation practices on off-field pesticide runoff transport and resulting surface water concentrations.

Project Objectives:

- Develop a modeling framework:
  - Model parameterizations for pesticide transport processes
  - Comparisons with current regulatory models
  - Design and evaluate conservation practice effects on off-field pesticide runoff losses
- Develop a prototype web-based BMP tool that allows users to quantitatively estimate the effects of site-specific conservation practice implementation on pesticide runoff losses and resulting surface water concentrations

3 STONE ENVIRONMENTAL

Modeling Framework

Modeling will be based on the US Department of Agriculture (USDA) supported Agricultural Policy / Environmental eXtender Model (APEX)

- APEX is a physically-based model that predicts the short-term and long-term impacts of agronomic management decisions on environmental quality
- Inputs include daily climate time series, soil characteristics, topographic information, and agronomic management information
- Outputs include pesticide edge-of-field losses, nutrient and sediment edge-of-field losses, runoff rates, crop yields, biomass accumulation, and soil carbon stores

Allows configuration of various land management practices (e.g., buffers, tillage) and can simulate relative changes of runoff and associated water quality between scenarios with and without conservation practices.

4 STONE ENVIRONMENTAL

Modeling Framework

Initial model evaluation included:

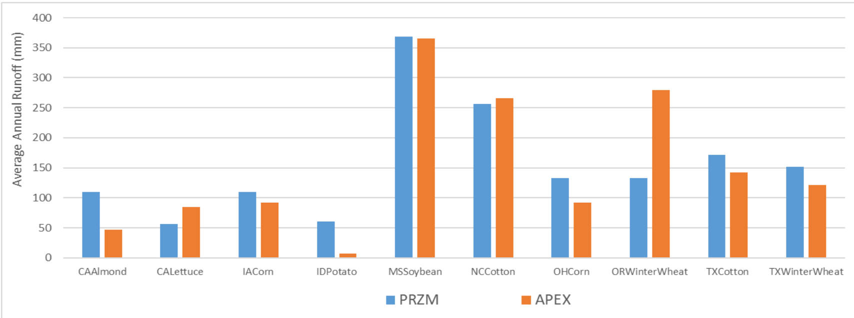
- Development of 'baseline' APEX scenarios based on subset of standard PRZM scenarios
- High level comparison of pesticide outputs from APEX and PRZM for baseline scenarios
- Evaluation of conservation practices compared to baseline scenarios in APEX
- Simulation of 2 pesticides, one relatively soluble and one relatively insoluble

Region	State	Crop	Associated PRZM Scenario	Hydro Group	Surface OM (%)	Slope (%)
Midwest	OH	Corn	OHCornSTD.scn	C	2.00	6
Midwest	IA	Corn	IAcornstd.scn	B	1.60	6
Southeast	MS	Soybean	MSsoybeanSTD.scn	C	2.20	2
Southeast	NC	Cotton	NCcottonSTD.scn	D	3.99	6
Northwest	OR	Winter Wheat	ORwheatOP.scn	D	7.98	6
Northwest	ID	Potato	IDNpotato_WirrigSTD.scn	C	1.50	4
Central Plains	TX	Winter Wheat	TXwheatOP.scn	C	1.26	3
Central Plains	TX	Cotton	TXcottonOP.scn	C	1.26	5
California	CA	Almonds	CAalmond_WirrigSTD.scn	C	1.39	2
California	CA	Lettuce	CAlettuceSTD.scn	D	1.25	6

5 STONE ENVIRONMENTAL

Modeling Framework: Runoff Simulation

Preliminary APEX and PRZM Runoff Comparison

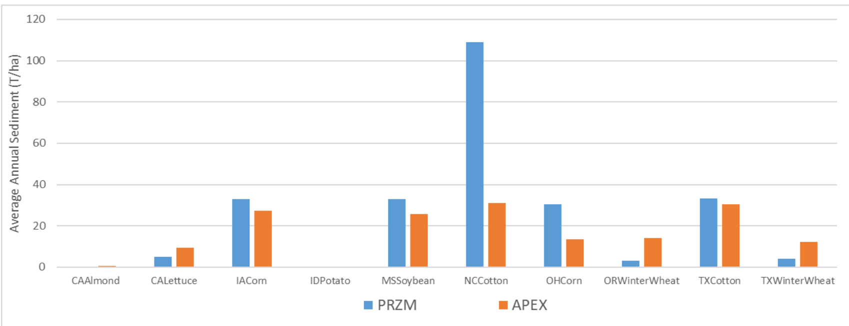


Averaged statistics across sites: PBIAS: -7 % Abs(PBIAS): 39% Mean Absolute Error: 42 mm

6 STONE ENVIRONMENTAL

Modeling Framework: Erosion Simulation

Preliminary APEX and PRZM Sediment Erosion Comparison

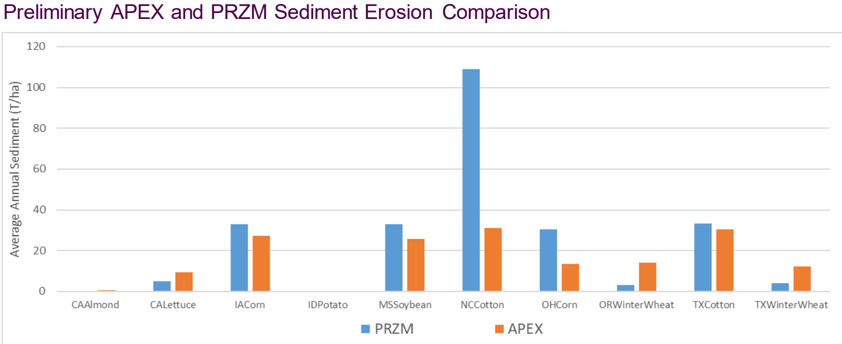


Averaged statistics across sites: PBIAS: 49% Abs(PBIAS): 88% Mean Absolute Error : 13 T/ha

7 STONE ENVIRONMENTAL

Modeling Framework: Erosion Simulation

Preliminary APEX and PRZM Sediment Erosion Comparison

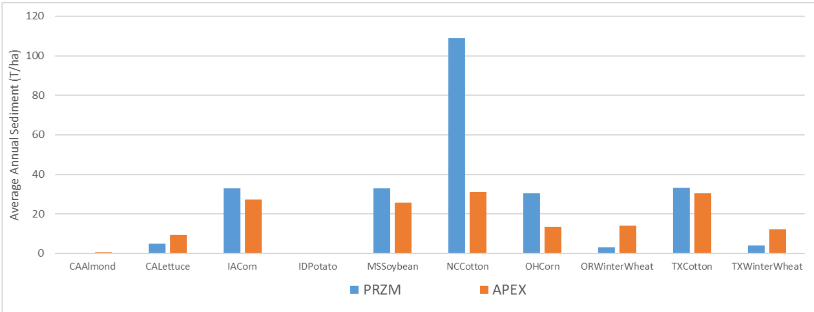


Averaged statistics across sites: PBIAS: 49% Abs(PBIAS): 88% Mean Absolute Error : 13 T/ha

7 STONE ENVIRONMENTAL

Modeling Framework: Erosion Simulation

Preliminary APEX and PRZM Sediment Erosion Comparison



Averaged statistics across sites: PBIAS: 49% Abs(PBIAS): 88% Mean Absolute Error : 13 T/ha

Prototype Web-Based BMP Tool

The Prototype Tool will:

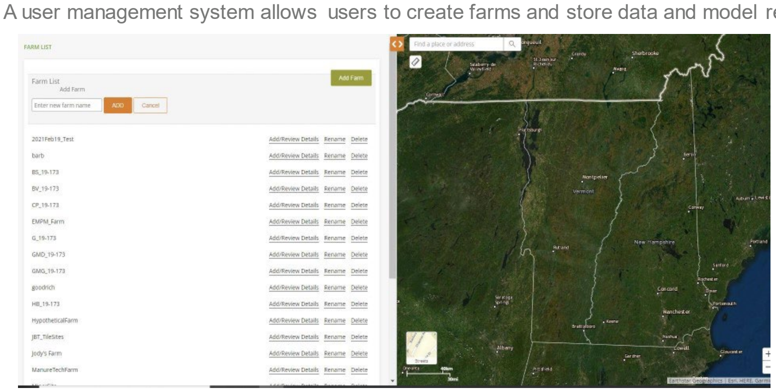
- Utilize APEX as the background model
- Have a user management system that allows users to create farms and store data and model results
- Automatically derive physical field characteristics, soil properties, and appropriate weather
- Interactively:
  - Upload shapefiles or draw fields in a web-based interface
  - Provide information about field management, including conservation practices
  - Run an optimization assessment, designed to simulate combinations of practices to reach a targeted reduction of chemical loss, where users can prioritize or exclude practices

The prototype tool will have a workflow similar to that shown in the following slides

Prototype Web-Based BMP Tool– Example Concept Demonstration

Farm-Specific Modeling Tool Development – Farm Management

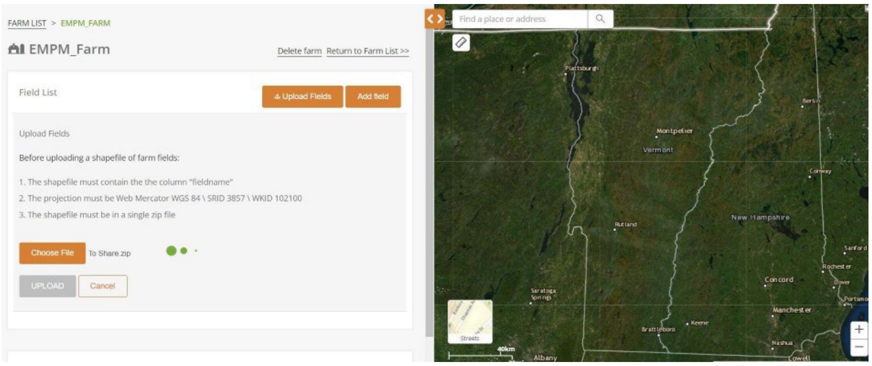
- A user management system allows users to create farms and store data and model results



Prototype Web-Based BMP Tool– Example Concept Demonstration

Farm-Specific Modeling Tool Development – Field Delineation

- Users upload shapefiles or draw fields in a web-based interface

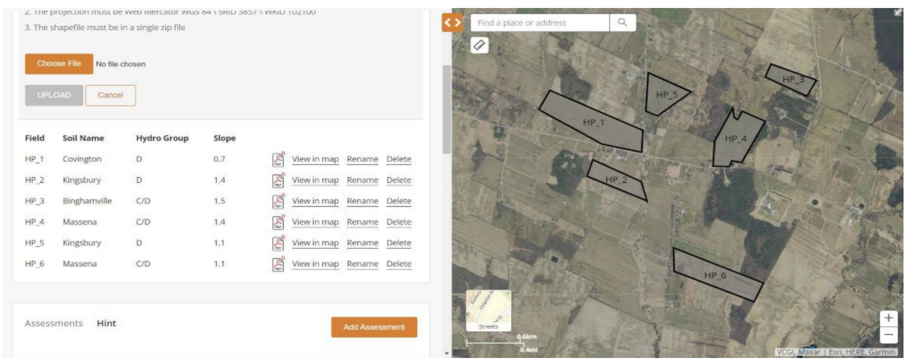


12 STONE ENVIRONMENTAL

Prototype Web-Based BMP Tool– Example Concept Demonstration

Farm-Specific Modeling Tool Development – Field Characterization

- Physical field characteristics are automatically determined, weather stations identified

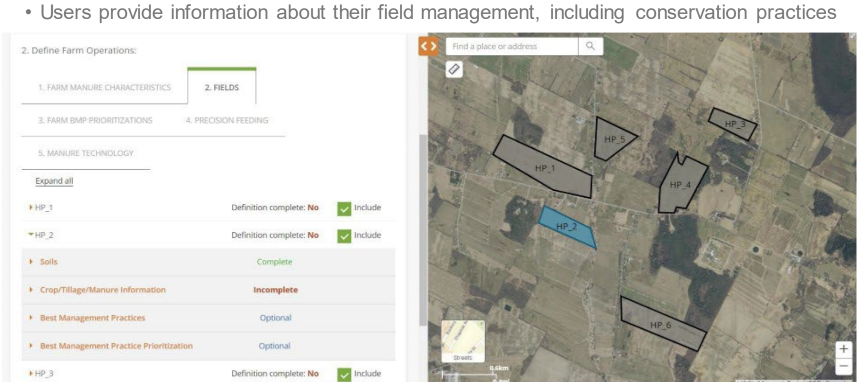


13 STONE ENVIRONMENTAL

Prototype Web-Based BMP Tool– Example Concept Demonstration

Farm-Specific Modeling Tool Development – Crops and Management

- Users provide information about their field management, including conservation practices

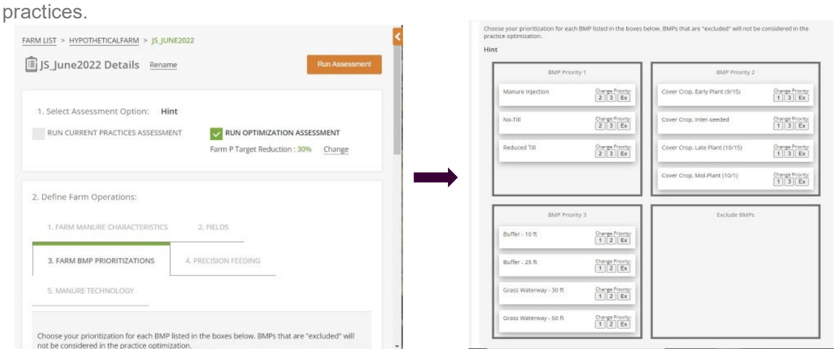


14 STONE ENVIRONMENTAL

Prototype Web-Based BMP Tool– Example Concept Demonstration

Farm-Specific Modeling Tool Development – Mitigation Optimization/Prioritization

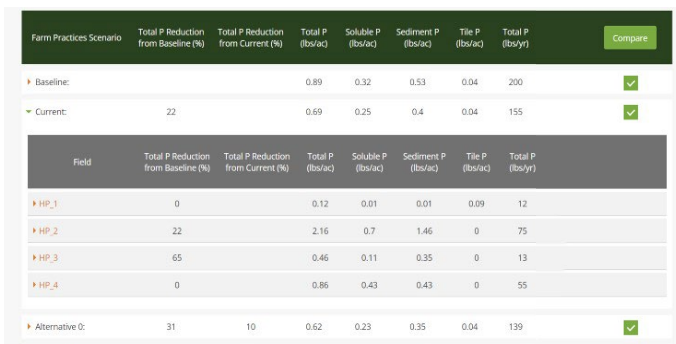
- Users can run an optimization assessment, designed to simulate combinations of practices to reach a targeted reduction of chemical loss, where users can prioritize or exclude practices.



Prototype Web-Based BMP Tool– Example Concept Demonstration

Farm-Specific Modeling Tool Development – Output Analysis

- Model results help identify feasible mitigation options that achieve water quality goals



Farm Practices Scenario	Total P Reduction from Baseline (%)	Total P Reduction from Current (%)	Total P (lbs/ac)	Soluble P (lbs/ac)	Sediment P (lbs/ac)	Tile P (lbs/ac)	Total P (lbs/yr)	Compare
Baseline:			0.89	0.32	0.53	0.04	200	✓
Current:	22		0.69	0.25	0.4	0.04	155	✓
Field	Total P Reduction from Baseline (%)	Total P Reduction from Current (%)	Total P (lbs/ac)	Soluble P (lbs/ac)	Sediment P (lbs/ac)	Tile P (lbs/ac)	Total P (lbs/yr)	
HP_1	0		0.12	0.01	0.01	0.09	12	
HP_2	22		2.16	0.7	1.46	0	75	
HP_3	65		0.46	0.11	0.35	0	13	
HP_4	0		0.86	0.43	0.43	0	55	
Alternative 0:	31	10	0.62	0.23	0.35	0.04	139	✓

Conclusions

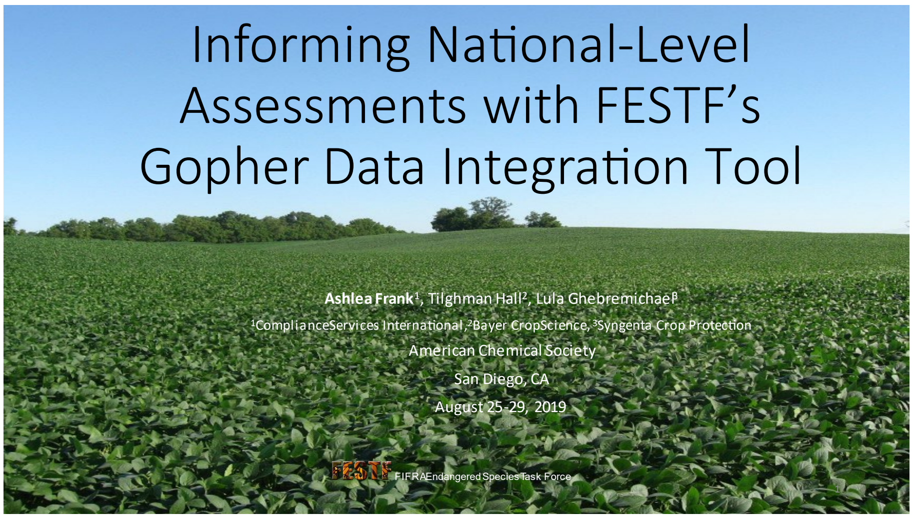
APEX model evaluation component has shown general consistency with PRZM; ongoing work will further refine the parameterization

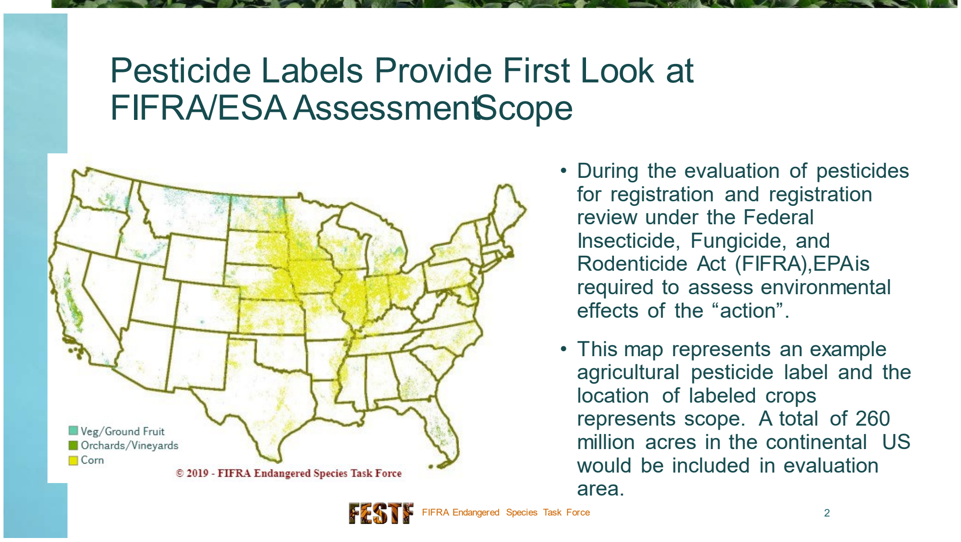
Trends in model simulated runoff and erosion losses across scenarios where conservation practices were implemented appear consistent with known trends

The BMP tool will provide an easily applied and scientifically defensible approach to quantify the impacts of farm and field-level conservation practices on reducing pesticide runoff losses and surface water concentrations

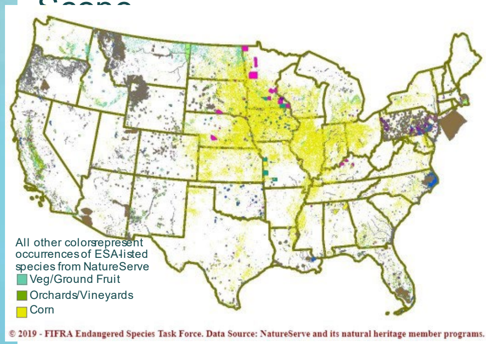
Tool will support evaluation of conservation practices tailored to specific fields/farms, thereby returning feasible, custom practice and management options to improve water quality outcomes necessary for endangered species protection

Appendix 4. American Chemical Society AGRO Division Presentation August 25-29, 2019. A. Frank, T. Hall, L. Ghebremichael. Informing National-Level Assessments with FESTF's Gopher Data Integration Tool.





Location of ESA-listed Species Focuses Scope



- Under Section 7(a)(2) of the Endangered Species Act (ESA) EPA must ensure that the "action" is not likely to jeopardize federally listed species or adversely modify designated critical habitat.
- For a national-scale assessment, this could lead to 1,640 ESA-listed needing to be evaluated via EPA's Biological Evaluation and FWS/NMFS's Biological Opinion process.

Proposed Revisions to the FIFRA/ESA Process

- EPA has proposed revisions to the methods used for conducting national-level Biological Evaluations and to inform FWS/NMFS Biological Opinions in the FIFRA/ESA process.

Table 1. Overview of the 3-Step Section 7 Endangered Species Act Consultation Process

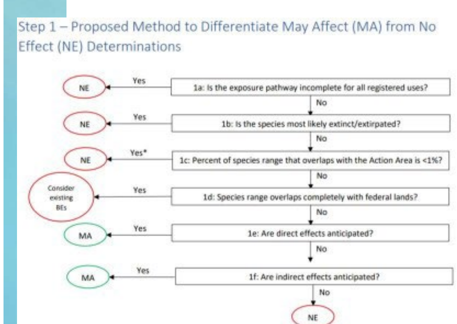
TOPIC	STEP 1	STEP 2	STEP 3
Assessment	Biological Evaluation	Biological Evaluation	Biological Opinion
Scale[1]	Individual/field	Individual/field and landscape	Population/landscape/watershed
Determination	No Effect/May Affect	Not Likely to Adversely Affect/Likely to Adversely Affect	No Jeopardy/ Jeopardy[2]

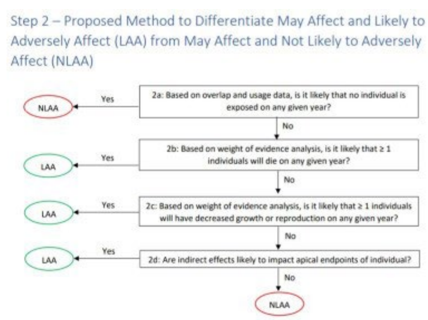
[1] Although Step 1 and Step 2 are conducted at an individual level, consideration is given to the likelihood that exposure is reasonably certain to occur in Step 1 and the potential consequence of that exposure in the effects determination in Step 2.
[2] This is the determination for listed species. The determination for designated critical habitats is "No Adverse Modification/Adverse Modification".

**Table taken from pg. 5 of EPA's proposed revised method, https://www.epa.gov/sites/production/files/2019-05/documents/epa- revised-interim-esa-methodology.pdf

- Revised methods are designed to identify species that may be affected by the subject registration action and whether they are likely to be adversely affected.

Proposed FIFRA/ESA Method Overview



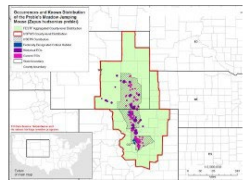


**Taken from Figures 2 and 4 from pg. 6-7 and 18-19 of EPA's proposed revised method https://www.epa.gov/sites/production/files/2019-05/documents/epa-revised-interim-esa-methodology.pdf

Data Integration Needs

- Addressing each step in the FIFRA/ESA process requires many inputs.
- Since its formation in 1996, the FIFRA Endangered Species Task Force (FESTF), a consortium of 18 companies, has been providing data to the EPA for their evaluation of the effects of pesticides on ESA-listed species and has seen the process evolve. FESTF work products include:

- Species locations, including licensed dataset from NatureServe
  - Range maps for FWS using aggregated data
- Spatial and tabular data representing pesticide use locations
  - Licensed dataset from ADCi
- Species attributes, local data and conditions
  - Status of Species (SOS) files for FWS, and from NMFS OP BiOp
  - EPA's attributes from the OPBE
  - NatureServe data

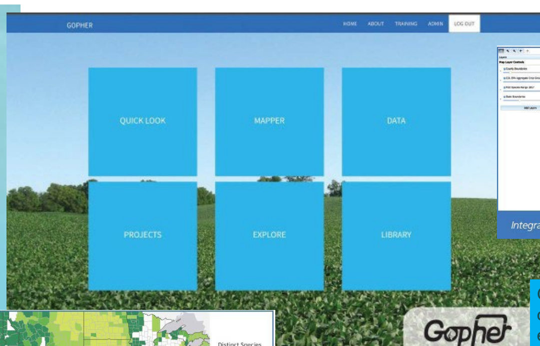


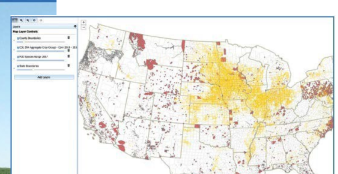
FESTF FIFRA Endangered Species Task Force 6

Data Integration Needs

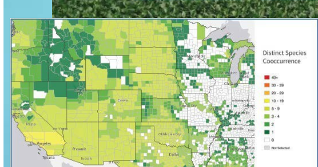
- FESTF also learned what is necessary for data aggregation and delivery.
- FESTF first designed an Information Management System in early 2000s. The next generation, Gopher, brings a spatial platform and flexibility to inform this proposed revised process.
- Gopher brings local and field-scale data to the national- level.

FESTF FIFRA Endangered Species Task Force 7





*Integration of CDL EPA Crop Group & MJD Species Range**



Species/Usesite co-occurrences using advanced proximity analysis

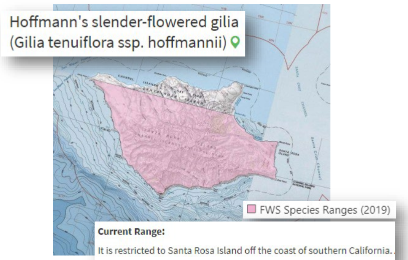
Gopher, a tool developed by FESTF, can be used to compile, apply, and evaluate components that feed into the likelihood of exposure evaluation and risk/jeopardy determinations for pesticide registration actions and T&E species in a **well-documented and transparent manner**

FESTF FIFRA Endangered Species Task Force

Gopher Houses Data Regarding the Exposure Pathway

1a: Is the exposure pathway incomplete for all registered uses?

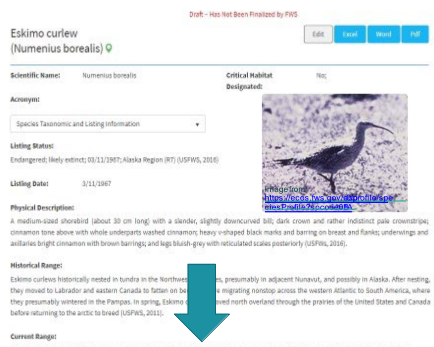
- Maps of range and attributes describe locations where applications and/or exposures are unlikely to occur



1b: Is the species most likely extinct/extirpated?

Gopher Houses Data Regarding Current Status and Presence Information (1)

- Status of Species information from FWS and NMFS provides current status and range details for each species


Draft – Has Not Been Finalized by FWS

Eskimo curlew
(Numenius borealis)

Edit Excel Word Pdf

Scientific Name: Numenius borealis

Critical Habitat Designated: No;

Acronym:

Species Taxonomic and Listing Information

Listing Status:
Endangered; likely extinct; 03/11/1967; Alaska Region (R7) (USFWS, 2016)

Listing Date: 3/11/1967

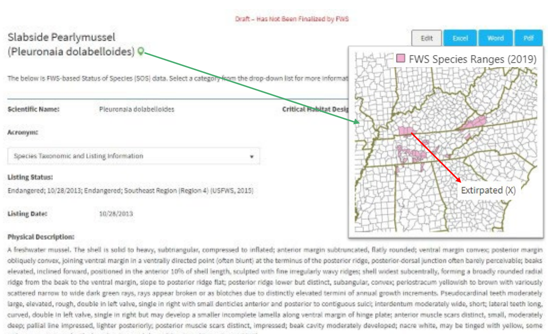
Physical Description:
A medium-sized shorebird (about 30 cm long) with a slender, slightly downcurved bill; dark crown and rather indistinct pale crownstripe; cinnamon tone above with whole underparts washed cinnamon; heavy v-shaped black marks and barring on breast and flanks; underwings and axillaries bright cinnamon with brown barrings; and legs bluish-grey with reticulated scales posteriorly (USFWS, 2016).

Historical Range:
Eskimo curlews historically nested in tundra in the Northwes[...]es, presumably in adjacent Nunavut, and possibly in Alaska. After nesting, they moved to Labrador and eastern Canada to fatten on be[...]e migrating nonstop across the western Atlantic to South America, where they presumably wintered in the Pampas. In spring, Eskimo c[...]oved north overland through the prairies of the United States and Canada before returning to the arctic to breed (USFWS, 2011).

Current Range:
See historical range/distribution. The last record confirmed by physical evidence is a specimen collected in Barbados in 1963 (USFWS, 2011).

1b: Is the species most likely extinct/extirpated?

Gopher Houses Data Regarding Current Status and Presence Information (2)


Draft – Has Not Been Finalized by FWS

Slabside Pearlymussel
(Pleuronaia dolabelloides)

Edit Excel Word Pdf

The below is FWS-based Status of Species (SOS) data. Select a category from the drop-down list for more informat

Scientific Name: Pleuronaia dolabelloides

Critical Habitat Desig

Acronym:

Species Taxonomic and Listing Information

Listing Status:
Endangered; 10/28/2013; Endangered; Southeast Region (Region 4) (USFWS, 2015)

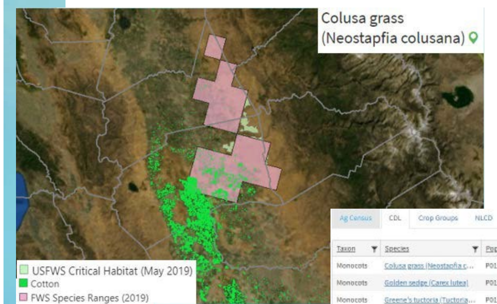
Listing Date: 10/28/2013

Physical Description:
A freshwater mussel. The shell is solid to heavy, subtriangular, compressed to inflated; anterior margin subtruncated, flatly rounded; ventral margin convex; posterior margin obliquely convex, joining ventral margin in a ventrally directed point (often blunt) at the terminus of the posterior ridge, posterior-dorsal junction often barely perceivable; beaks elevated, inclined forward, positioned in the anterior 10% of shell length, sculpted with fine irregularly wavy ridges; shell widest subcentrally, forming a broadly rounded radial ridge from the beak to the ventral margin, slope to posterior ridge flat; posterior ridge lower but distinct, subangular, convex; periostracum yellowish to brown with variously scattered narrow to wide dark green rays, rays appear broken or as blotches due to distinctly elevated termini of annual growth increments. Pseudocardinal teeth moderately large, elevated, rough, double in left valve, single in right with small denticles anterior and posterior to contiguous sulci; interdentum moderately wide, short; lateral teeth long, curved, double in left valve, single in right but may develop a smaller incomplete lamella along ventral margin of hinge plate; anterior muscle scars distinct, small, moderately deep; pallial line impressed, lighter posteriorly; posterior muscle scars distinct, impressed; beak cavity moderately developed; nacre white, may be tinged with yellow, some iridescence posteriorly. The length is 6cm and the width is 3cm. (NatureServe, 2015)

- Location-specific information from NatureServe can be used to determine where within range species is extirpated

Gopher Houses Species Ranges and Use Sites (1)

1c: Percent of species range that overlaps with the Action Area is <1%?



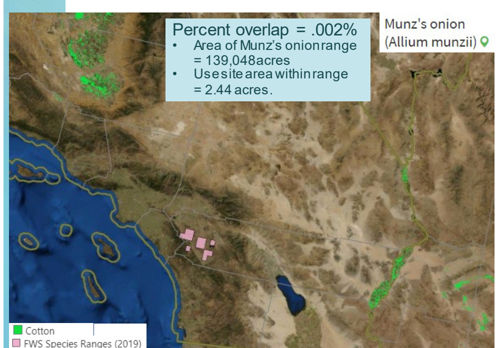
- Gopher houses over 20 tabular and spatial datasets, pre-calculating millions of possible species-use site relationships and proximities.

Ag Census | CDL | Crop Groups | NLCD | ADCI

Taxon	Species	Population	Status	Lifeform	ST	County	Use Site	Speci...	Dist
Monocots	Colusa grass (Neostapfia c...	P01	T	Both	CA	Merced	Cotton	USFWS Cri...	0
Monocots	Golden sedge (Carex lutea)	P01	E	Both	NC	Onslow	Cotton	USFWS Cri...	2372.268
Monocots	Greene's tuctoria (Tuctoria...	P01	E	Both	CA	Merced	Cotton	USFWS Cri...	0
Monocots	Hairy Orcutt grass (Orcutti...	P01	E	Both	CA	Merced	Cotton	USFWS Cri...	2117.12
Monocots	San Joaquin Orcutt grass (...	P01	T	Both	CA	Merced	Cotton	USFWS Cri...	0

Gopher Houses Species Ranges and Use Sites (2)

1c: Percent of species range that overlaps with the Action Area is <1%?



- FESTF is exploring enhancements to automate creation of Action Area and calculate overlaps as described in EPA's revised process.

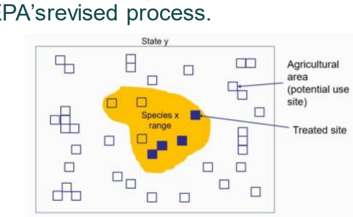
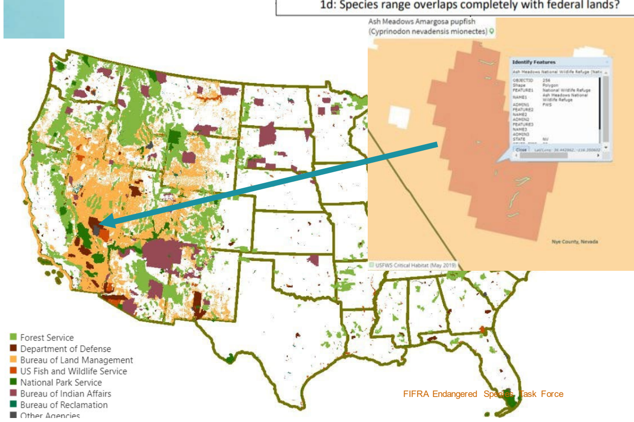


Figure 5. Conceptual illustration of approach for assigning treated acres to area relative to species range. In this example, PCT for the potential use site is 10%.

**Taken from Figures 5 from pg. 22 of EPA's proposed revised method https://www.epa.gov/sites/production/files/2019-05/documents/epa-revised-interim-esa-methodology.pdf

Gopher Contains Information about Land Ownership

1d: Species range overlaps completely with federal lands?



- ~30% of the US is federally owned/Indian lands, concentrated in the Western states where 46.4% is federally owned.
- Upwards of 50% of all ESA-listed species reside on these lands, with the most residing on USDA FS and DOD lands.
- Spatial and attribute data in Gopher can be used to determine which species reside wholly within federal lands, and land ownership details.

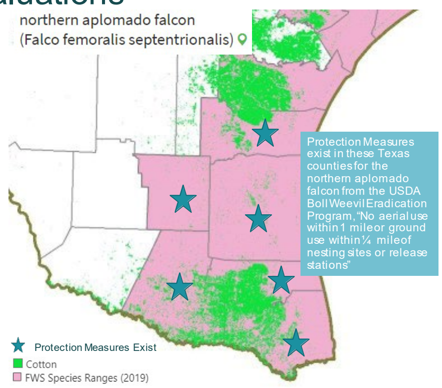
Consider existing BEs

Yes

1d: Species range overlaps completely with federal lands?

Making Use of Prior Evaluations

- Federal agencies must ensure their activities on federally-owned lands do not cause jeopardy to ESA-listed species. Protections from prior consultations can be used in the FIFRA/ESA process.
- Gopher can provide this information and be used to track consultations.

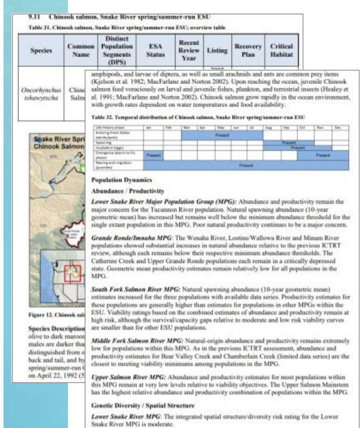


FESTF FIFRA Endangered Species Task Force 15

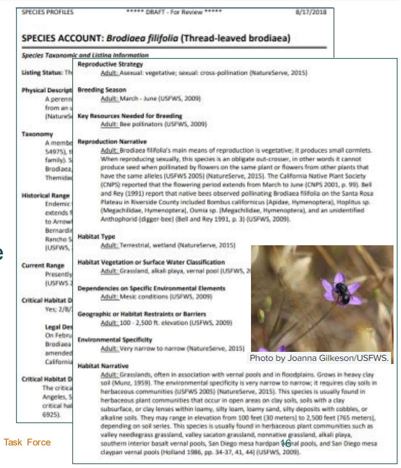
Species Attributes

1e: Are direct effects anticipated?

1f: Are indirect effects anticipated?



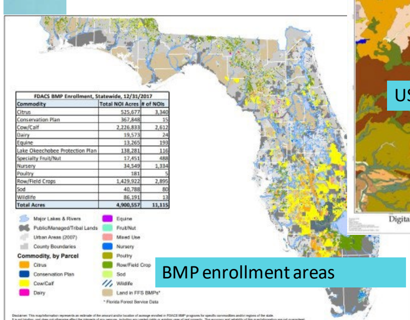
- Attribute information housed in Gopher can be used to investigate components of species behavior and habitat that are relevant to analysis of potential effects



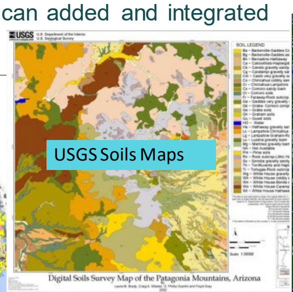
FESTF FIFRA Endangered Species Task Force 16

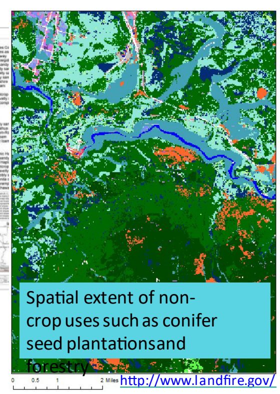
Gopher – Additional Data Layers

Additional datasets, can added and integrated



FDACS BMP Enrollment, Statewide, 12/31/2017		
Commodity	Total NOI Acres	# of NOIs
Citrus	525,677	3,340
Conservation Plan	367,848	15
Cow/Calf	2,226,833	2,612
Dairy	19,573	24
Equine	13,265	193
Lake Okeechobee Protection Plan	138,281	116
Specialty Fruit/Nut	17,451	488
Nursery	34,549	1,334
Poultry	181	5
Row/Field Crops	1,429,922	2,896
Sod	40,788	80
Wildlife	86,191	13
Total Acres	4,900,557	11,115





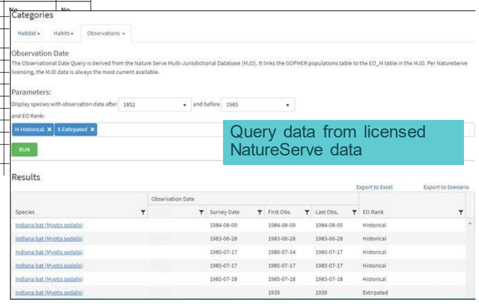
FESTF FIFRA Endangered Species Task Force 17

Gopher – Query Attributes

Table A 1-20.7. Diets of listed terrestrial invertebrates: terrestrial animals or soil.

Scientific Name	Common Name	Terrestrial Inverts	Soil dwelling inverts	Soil[1]	Mammals	Birds	Reptiles	Amphibians (terrestrial)	Carrion
Anaea troglodyta floridalis	Florida Leafwing Butterfly	No	No	Yes	No	No	No	No	No
Batrisodes texanus	Beetle, Coffin Cave mold	No	No	Yes	No	No	No		
Cicindela dorsalis dorsalis	Tiger beetle, Northeastern beach	Yes	Yes	No	No	No	No		
Cicindela nevadica lincolniana	Tiger beetle, Salt Creek	Yes	Yes	No	No	No	No		
Cicindela ohlone	Tiger beetle, Ohlone	Yes	Yes	No	No	No	No		
Cicindela puritana	Tiger beetle, Puritan	Yes	Yes	No	No	No	No		
Cincindelidia floridana	Tiger beetle, Miami	Yes	No	No	No	No	No		
Cincindelidia highlandensis	Tiger beetle, highlands	Yes	No	No	No	No	No		
Dinacoma caseyi	June Beetle, Caseys	No	Yes	Yes	No	No	No		
Elaphrus viridis	Beetle, delta green ground	Yes	Yes	No	No	No	No		
		Yes	No	No	No	No	No		
		Yes	No	No	No	No	No		
		No	No	No	No	No	No		

Query data from EPA's ESKB and additional attributes



Query data from licensed NatureServe data

Gopher – Dataset Download

DATA

New Data Upload

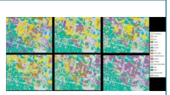
Datasets

DisplayName	Description
▴ Species	
NMFS Salmon - Atlantic (SR-5)	Spatial data files containing Atlantic Salmon range from NMFS
FWS Species Range Maps (SR-6)	Spatial data containing species range maps from FWS via the FWS ECOS bulk download.
FWS ECOS County (f)	Tabular data containing Species by County list for all Threatened, Endangered, Candidate and Proposed Species from FWS ECOS. Query provided by FWS ECOS staff from help desk request.
TESS List ()	Most Recent TESS List reflecting species nomenclature and status currently in Gopher.
MJD-EO (c)	Tabular data containing species location data by county as reported by Natural Heritage Programs to NatureServe and included in FESTF's licensed dataset.
MJD-GIS (d)	Tabular data containing species location data by county based on overlay of spatial data on county boundaries conducted by NatureServe, and included in FESTF's licensed dataset.
NatureServe County (g)	Tabular data containing species location data by county from NatureServe's main database (includes data for states not contributing to FESTF's licensed dataset).
NMFS County (h)	Tabular data containing species locations by county based on overlay of spatial-based salmon range data provided by NMFS on county boundaries.
FESTF-MJD (SR-1)	Spatial data files (shapefiles) provided by state and taxon as a part of FESTF's licensed dataset from NatureServe. Contains element occurrences representing reported locations.
FWS Species Range Maps - Hawaii (SR-2)	Spatial data files representing range of species in Hawaii and Pacific Islands prepared by FESTF under direction of the Pacific Islands Fish and Wildlife Office.
NMFS Salmon - Pacific (SR-4)	Salmon/Steelhead range from NMFS.

- Datasets in system can be downloaded by users with proper access
- Users can upload datasets to be added to the system
- Uploaded datasets go to a Data Steward for review and validation before being added to system

Gopher, a system to…address the primary challenges to meeting national level risk assessment data needs

Data change over time



TEMPORALITY

COMPLEXITY

Dissimilar elements describe one attribute

What is authoritative source?

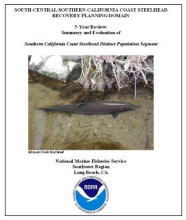
CONSENSUS

Gopher, a system to…consider all available lines of evidence for an accurately informed assessment of likelihood of effect

http://newsroom.ucr.edu/573

- Information on species size, behavior, diets, habitats and temporal presence and the relationship of those attributes to pesticide use and toxicity

- Regulatory reports on primary stressors and factors critical to survival and reproduction



- Expert knowledge on local conditions and interactions

Gopher – Take-away

- Gopher is a web-based, password-protected software system developed by FESTF; provides a platform to access and spatially interact with best available datasets related to pesticides and ESA-listed species
- Gopher's spatial and tabular data can be viewed, mapped, queried, and exported in various formats to inform EPA's revised process
- Gopher can lift species-specific attributes and local/regional knowledge to the national-level to identify species that may be affected by the subject pesticide and whether they are likely to be adversely affected

- With data integration platform, Gopher can explore opportunities to enhance species recovery while minimizing over-regulation and adverse grower impact in a way that provides transparency

FESTF FIFRA Endangered Species Task Force 22

Thank you for this opportunity and please contact me with any questions!

Ashlea Frank
Principal Consultant, Compliance Services International
Technical Consultant, FIFRA Endangered Species Task Force

7501 Bridgeport Way West – Lakewood, WA
98499 253-473-9007
AFrank@ComplianceServices.com

COMPLIANCE SERVICES INTERNATIONAL
FESTF FIFRA Endangered Species Task Force 23