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Environmental Monitoring Branch
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Study # 305: Measurement of airborne drift of the fungicide Captan as applied by an unmanned aerial vehicle

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1 Introduction

Unmanned Aerial Vehicles (UAVs) are remotely-piloted aircraft with no pilot on board. Section 333 of the Federal Aviation Administration's (FAA) Modernization and Reform Act of 2012 allows for UAV manufacturers to petition the agency for exemption from several elements of the Federal Aviation Regulations prior to the introduction of broader regulation governing the certification and operation of UAVs in national airspace. The Yamaha Corporation's R-MAX® II remotely-operated helicopter was approved under Section 333 in May 2015, making it the largest and heaviest UAV approved for civilian use so far, and the first with the ability to perform aerial applications of pesticide (U.S. FAA 2015). UAVs such as the R-MAX® II may eventually be used to perform aerial applications in situations where the use of traditional aircraft is infeasible, or where ground-based means of application are undesirable (e.g. due to soil compaction) or dangerous (e.g. due to steeply sloped land).

Airborne drift refers to the downwind deposition of particulates resulting from an aerial spray. Despite a 20-year history of agricultural UAVs in Japan, there are few peer-reviewed studies that characterize drift from UAV applications or compare the drift characteristics of UAVs to those of larger aircraft. Several of the most important factors affecting drift (such as droplet size and application height) will remain consistent between larger aircraft and UAVs, other factors such as swath size and aircraft speed will differ substantially from those typical of a larger aircraft. These factors are known to affect spray drift (Hewitt et al. 2002), and suggest that UAV applications may be less subject to drift than other aerial applications. While modeling can often accurately spray drift based on aircraft characteristics and environmental conditions, several parameters of UAVs (such as size, weight, and air speed) fall outside range of existing drift models and model performance is unknown under these conditions. Collection of downwind air and deposition samples will provide data necessary to evaluate the performance of the current drift models.

The Department of Pesticide Regulation (DPR) proposes to take part in a pilot study to assess the airborne drift characteristics resulting from UAV aerial applications. Data collected in this study will support pesticide drift modeling efforts. The pilot study will also inform the design of future UAV drift studies. This broader series of studies may eventually be useful in informing the development of new regulatory standards for the use of UAVs in agricultural contexts.

2 Objectives

This pilot study will focus on the measurement of primary spray drift resulting from an aerial spray application delivered by the Yamaha R-MAX UAV, using both mass deposition sheets and air samples.

3 Personnel

The Environmental Monitoring Branch (EM), under the supervision of Edgar Vidrio, project supervisor, will conduct this study. The study will be carried out concurrently with a worker exposure study conducted by DPR's Worker Health and Safety division. Members of DPR's Enforcement and Human Health Assessment branches may also advise and review. Dr. Ken Giles of University of California at Davis will advise and assist in the logistics of the R-MAX® II aerial spray, including the use of the R-MAX® II and the services of a certified pilot and spotter.

- Project supervisor: Edgar Vidrio
- Project leader: Colin Brown
- Field Coordinator: Chris Collins
- Staff: EM Staff
- Other: Dr. Ken Giles (UC Davis), DPR Worker Health and Safety Branch, DPR Enforcement Branch, DPR Human Health Assessment Branch

All questions concerning this project should be directed to Edgar Vidrio at (916) 323-2778 or Edgar.Vidrio@cdpr.ca.gov.

4 Study Plan and Sampling Methods

We will conduct air and mass deposition monitoring using methods developed by our partner laboratory at the California Department of Agriculture (CDFA) Center for Analytical Chemistry. Methods for air monitoring are similar to those used in previous DPR studies measuring aerial concentration of pesticides near fumigated fields. The methods for mass deposition have been widely employed in the broader scientific literature for similar studies of drift in airplane, helicopter, and ground applications.

4.1 Site Description

The study will take place on land owned by the University of California Nickels Soil Laboratory located in Arbuckle, CA. There is an approximately 3-acre parcel of flat, open, bare ground available for the study (Figure 1). The site is positioned immediately adjacent to 2 acres of asparagus, and bordered by almonds to the north, west, and south. Uncultivated grassland is located to the east of the proposed study site.

The study site will allow a fetch, or upwind spray zone, of 180 feet, and a length of 230 feet. This fetch matches that of the Spray Drift Task Force studies, an extensive collection of drift studies performed by registrants in the 1990s that helped characterize the factors

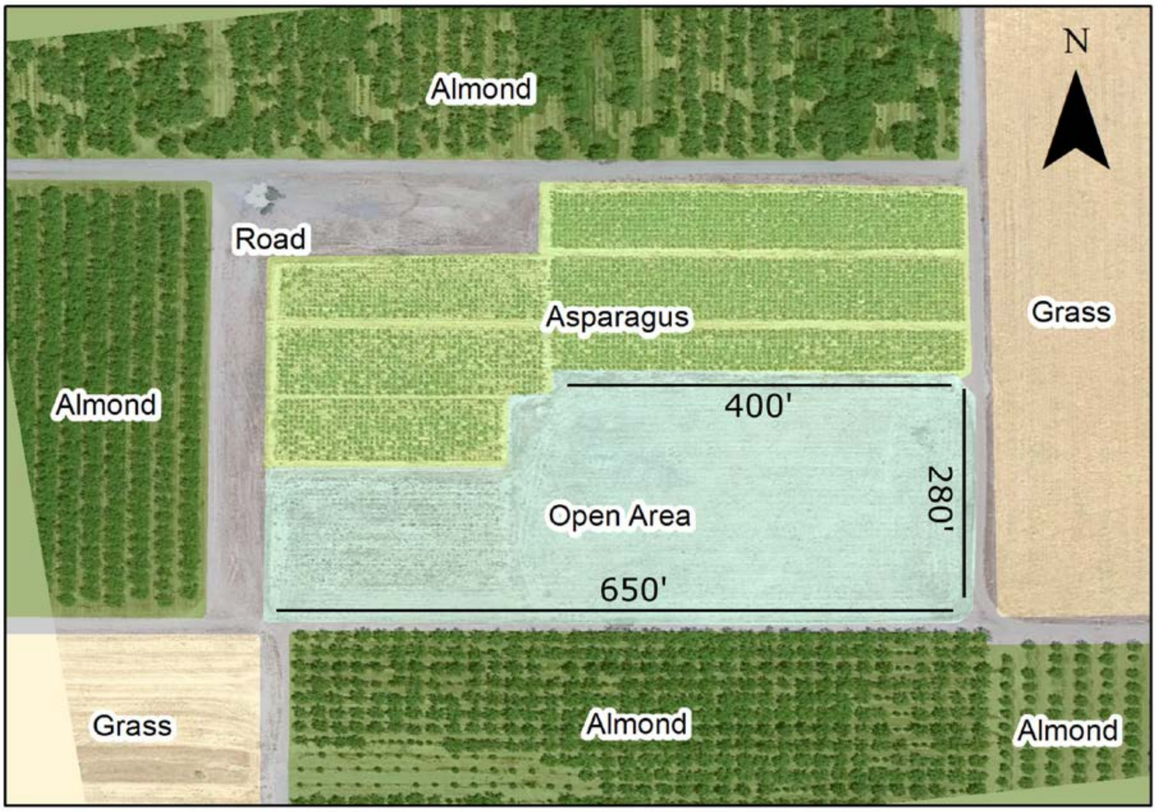

Figure 1: Site layout and approximate field dimensions of the study plot in Arbuckle.

4.2 Application Equipment and Methodology

The pilot study will focus on the use of the active ingredient (AI) Captan, a fungicide. Fungicides are typically sprayed with a medium droplet spectrum and nozzle selection will reflect this specification. Captan was chosen for reasons including its low human toxicity, low phytotoxicity, and low toxicity to honeybees. Honeybees will be active in the area during the study period. The use of Captan may necessitate additional lead-in time to the study for development and validation of laboratory methods for mass deposition and air sampling, in addition to methods for measurement on clothing for the purpose of worker exposure studies.

Dr. Ken Giles and the UAV piloting team will be responsible for the operation of the UAV and related logistics. One possible flight plan will involve the UAV will first completing two initial passes ('pillow passes') perpendicular to the planned spray flight line, after which the passes will proceed along the planned path. The estimated flight time for aerial spraying of a 1-acre plot is 15 minutes. Details regarding the configuration of the R-MAX® II are described in Table 1.

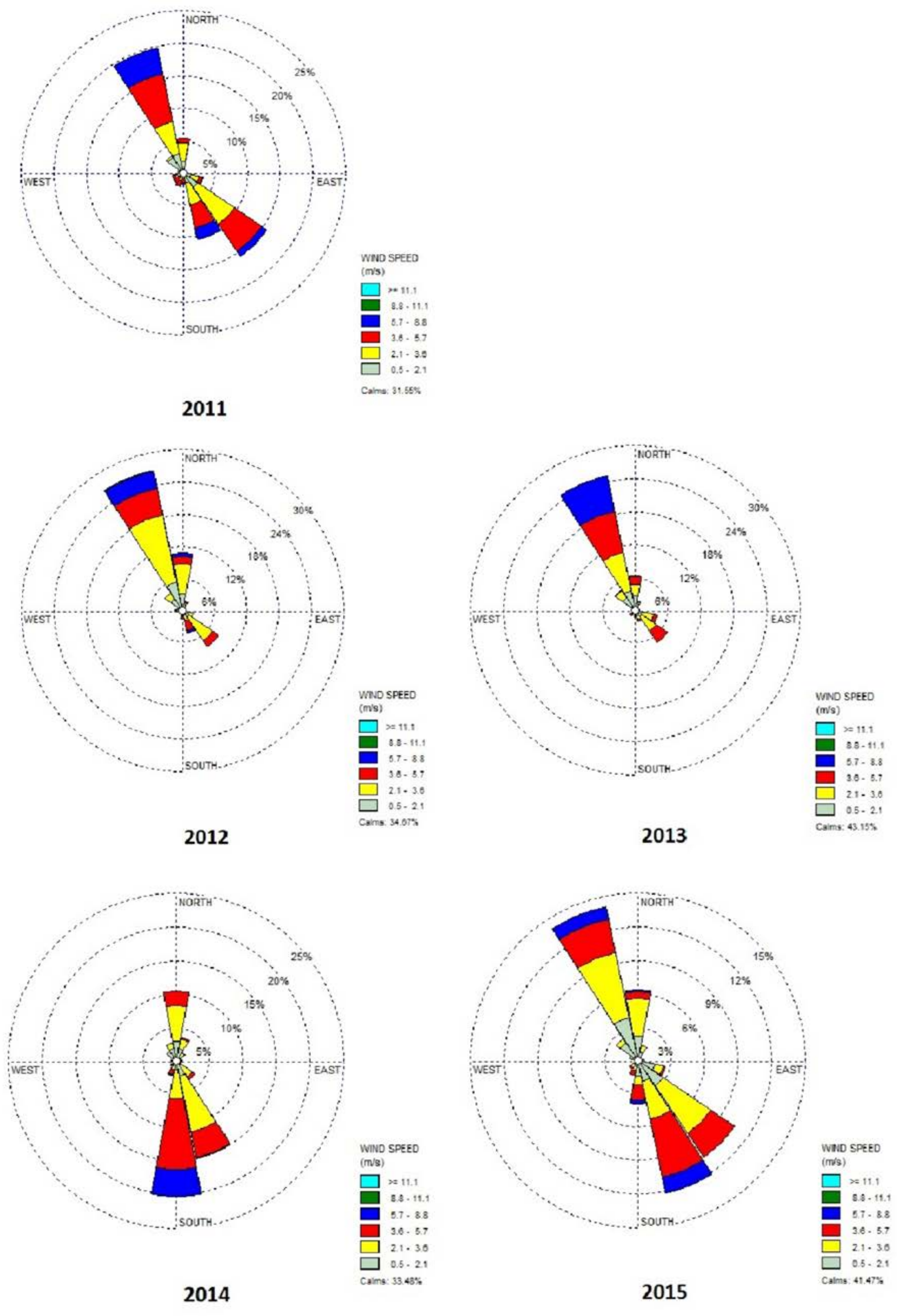

Figure 2: Wind roses for February wind patterns at the Colusa CIMIS weather station, located approximately 17 miles north of the study site in Arbuckle.

Table 1: Summary of UAV and application characteristics for use in the proposed study.

Characteristic	Specification
UAV Model Type	Yamaha R-
MAX Nozzle Flow Rate	1
ga/min Application Height	10 feet above
ground Swath width	6 feet
Application A.I.	
	Captan
Application Product	Drexel Captan
80W Application Rate	5.6 lb/acre

4.3 Air Sampling

We will place 16 air sampling stations in two concentric circles surrounding the margins of the treatment plot (Figure 3). Each air sampling station will consist of a battery-operated personal sampler pump (SKC # PCXR8 or PCXR7), attachment hardware, plastic tubing, a pre-packed XAD-4 resin sample tube, and a stake to secure the assembly to the ground. XAD-4 resin sample tubes will be pre-labeled and their location recorded on the day of the application. Stakes for each air assembly will be placed on the day prior to the study to minimize setup time on the morning of the aerial spray. Sampling stations will be stationed at distances of 25 and 50 feet from the plot margin and will be co-located with mass deposition sheets. Air sampling assemblies will collect air from 5 feet above ground level. Air samples will be collected in two intervals: a 24-hour background sampling phase, and an application sampling phase. A total of 18 air samples will be collected: 1 for background air quality prior to the study, and 17 for the actual pesticide application. One each of a co-located, blank, and spiked sample (trip spike) will be added for quality assurance and quality control (QA/QC) purposes. The co-located sample will be placed in the downwind direction of the UAV application.

Operation and calibration of the sampling equipment will follow those procedures outlined in Standard Operating Procedure (SOP) EQAI001.00 (Wofford 2001). Calibration of each pump will take place in the days prior to the study using a blank resin tube not intended for analysis; this is due to the need to minimize pump run time before and after the study. The flow rate on each unit will be calibrated to 2L/min, which was the highest rate of flow that could be reliably achieved on these pump units. The actual calibrated rate of flow for each unit will be recorded and related to each air sample.

We will prepare and affix sample labels to each sorbent tube prior to the beginning of the study. Labels will indicate the study number and the sample identification number. We keep records matching each sample identification number to its location in the study plot on the site schematic (Figure 3). DPR's SOP FSAI001.01 (Ganapathy 2003) describes the methods associated with the preparation of sorbent tubes and the chain of custody (COC) forms associated with their use, and SOP ADMN006.01 (Ganapathy 1997) more generally describes the COC methods for field samples.

Figure 3: Proposed site design for measurement of drift from UAV aerial application of Captan on bare ground at the UC Nickels Soil Laboratory in Arbuckle.

We propose to use a delayed start function and a pump timer function on the PCXR8 and PCXR7 units to synchronize the start and stop of all samplers to within a narrow window of time that includes the beginning and end of the aerial spray. This approach will require setting timers on all 16 pumps prior to affixing the pumps to their respective stakes on the morning of application, and as a result will necessitate a delay of sufficient time to complete setup and begin the aerial spray. The primary benefit of this approach is the possibility of more precise results that minimize the issue of background contamination, differences in elapsed pump run time, and differences in pump start and stop times. The primary drawbacks are the need to precisely coordinate the timing of the aerial spray several hours in advance, the difficulty in resetting the system if the window is missed, and less feedback to the sampling crew as to whether the sample pumps are running (as compared to a manual start). An alternative approach involves the manual actuation and shutdown of each pump; this approach will minimize the complex coordination involved in the timer approach, but may result in reduced data quality due to the factors described above.

We will cap sorbent tubes upon removal from the sample pumps. Each tube will be protected by bubble wrap or another protective material and stored on dry ice in an insulated container. Additional details regarding the packing and transport of field samples are detailed in SOP QAQC004.01 (Jones 1999). Samples will follow chain of custody (COC) procedures described in SOP ADMN006.00 (Ganapathy 1997) and receipt log-in and verification procedures described in SOP QAQC003.02 (Ganapathy 2005).

4.4 Mass Deposition Sampling

We will perform deposition sampling using a 1000 cm^2 mass deposition sheets (MDS) cut to a size of 40 cm by 25 cm. MDS construction consists of plastic-backed paper towels attached to a corrugated cardboard mount, which is then weighted to the ground using a bungee cord and cinder block with the absorbent material facing upwards. Additional details regarding the construction, use, and transport of MDS are described in DPR's SOP FSOT005.00 (Walters 2003), and COCs will be completed following the directions specified in SOP ADMN006.01 (Ganapathy 1997).

Our mass deposition sampling protocol will utilize 3 concentric rings surrounding the plot margins, each consisting of 8 MDS, plus 2 MDS in the application area (26 MDS total). MDS within each circle will be positioned at distances of 10, 25, and 50 feet from the plot margin (Figure 3). MDS at 25 ft and 50 ft will be co-located with air sampling assemblies. Each MDS will be labeled with a unique identifier that will allow tracking of its location relative to the field and its relation to any co-located air samples. We will also submit one each of a blank and trip spike MDS for QA/QC purposes.

The cinder blocks that serve as the foundation in each MDS assembly will be placed on the day prior to the aerial spraying. MDS will be attached to each cinder block on the morning of aerial spraying, and collected following completion of the application. Each collected MDS will be wrapped in aluminum foil and placed into a pre-labeled envelope prior to storage in an ice chest with dry ice. Samples will be held in cold storage until delivery to the CDFA laboratory for analysis.

4.5 Meteorological Data

We will assemble a MetOne® meteorological station adjacent to the study plot at least one day prior to the beginning of the aerial spraying, with the main instrument assembly at a height of 30 feet. This mobile weather station collects data on wind direction, wind speed, temperature, solar radiation, and relative humidity. We will pair each weather station instrument to a Campbell Scientific CR 21X data logger, which will record data as a 1-minute average of 1-second instantaneous readings for all instruments excluding wind direction, which will instead use instantaneous measurements once every minute. In addition, EM Staff will assist Dr. Giles with the installation of a sonic anemometer at the site, which will assist in characterizing atmospheric stability. Two suitable sites have been identified for the positioning of the weather station, as indicated in Figure 3.

4.6 Chemical Analysis

Air and mass deposition samples will be analyzed by the CDFA Center for Analytical Chemistry (CAC). Quality assurance and quality control for laboratory methods will follow the standards outlined in SOP QAQC001.00 (Segawa 1995). CDFA CAC is in the process of developing and validating methods to analyze air and mass deposition for Captan. CDFA CAC is also developing methods to analyze cloth samples, which is relevant for the completion of a worker exposure study conducted concurrently with the present study.

Meteorological data collected during the UAV application period will inform which samples will be submitted to CDFA CAC for processing. Only those samples located downwind of the application will be submitted. Limiting the number of samples to be analyzed will reduce the costs associated with the pilot study while expediting the speed at which the laboratory can return air concentration and mass deposition data for analysis by DPR staff. Analysis of the downwind subset of data will help characterize the worst-case scenario for primary drift from UAV applications.

CDFA CAC may choose to include a trip spike as part of the methodology. A trip spike is a sorbent tube to which a known quantity of a known AI has been added in the laboratory. The trip spike will be excluded from the field sampling period (it will not be attached to a sampling pump), but will otherwise receive identical treatment to the field samples with respect to storage, transportation, and analysis procedures.

5 Data Analysis

5.1 Air Concentration and Mass Deposition Calculations

Chemical analysis of field samples provides a result of weight of pesticide analyte per sample (sorbent tube). We will determine the air concentration of AI resulting from downwind primary drift by multiplying the weight of analyte per sample by the volume of air pulled through the sample medium over the duration of the sampling period. Concentrations will be reported in nanograms per cubic meter (ng/m^3).

5.2 Drift Transport Modeling

Data collected in this study will be analyzed using the AGDISP® aerial application model. AGDISP® is a physics-based model designed purposely for the prediction of spray drift from aerial applications.

6 Timetable

We estimate up to an additional nine months will be required to take the study from the end of the field sampling phase to the end of the report preparation phase. An estimated time table is displayed in Figure 4.

2016										
	Feb	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**
Field work					**Data Analysis**					
Laboratory analysis								**Report Preparation**		

Figure 4: Estimated timeline for the UAV Pilot Study in Arbuckle, CA

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