Predicting Air-Borne Droplet Drift from Agricultural Areas

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Introduction

Application spray drift represents an important pathway for pesticides to enter the environment, where they can contaminate air, water, and soil, and harm off-target organisms[1]. Although drift reduction strategies have been researched and are documented in the scientific literature, the overall impact of their adoption on overall drift losses remains unclear. This study was initiated to quantify spray drift losses across western Canada by linking spray applicator surveys with empirical spray drift loss data.

Under the National Agri-Environmental Health Analysis and Reporting Program (NAHARP)[2], Agriculture and Agri-Food Canada is developing a number of agri-environmental indicators. These indicators assess:

i) how well agriculture and agri-food systems manage and conserve natural resources and
ii) how compatible these systems are with natural systems and processes in the broader environment.

As part of this program, the Indicator of Risk of Water Contamination by Pesticides (IROWC-Pest) is being developed to provide information on spatial and temporal changes in the risk of pesticide contamination of ground and surface waters on a national basis.

Two main factors are used to calculate this risk:

i) how much pesticide is applied and
ii) what proportion moves into the surrounding environment.

The proportion of pesticide transported in surface runoff as well as pesticide leached through soil to a 1-m depth is estimated using the Pesticide Root Zone Model[3]. However, a portion of each pesticide application is lost to the atmosphere as application drift that may subsequently impact water quality via atmospheric deposition. Consequently, the incorporation of the effect of application drift from ground sprayers on the risk of water contamination by pesticides is required.

Objective

The objectives of this study were to (a) develop models that can be used to calculate air-borne drift in agricultural areas from survey data in order to improve estimation of the risk of water contamination by pesticides using IROWC-Pest.

Methods

Survey Data

Sprayer configuration data were extracted from the Prairie Weed Management Surveys of spring-seeded cereal, oilseed and pulse crops in 2001 in Alberta, 2002 in Manitoba and 2003 in Saskatchewan. In each of these surveys, ground sprayer configuration was identified for herbicide applications. In total, this information for all three surveys was available for 1,563 fields and included nozzle type (from which spray quality was inferred), boom height, travel speed and presence of shrouds or cones. Categorization within these four model variables resulted in a total of 225 possible unique combinations. Of these, 73 combinations were present in the survey data.

Model Variables

Each of the four variables were divided into several categories as determined by the questionnaire used in the weed surveys. Spray Quality (Q) had five categories (Very Fine, Fine, Medium, Coarse and Very Coarse). Boom Height (H) had three categories (30 to 50 cm, 51 to 100 cm and >100 cm). Travel Speed (T) had five categories (5 to 8 km h^{-1}, 9 to 16 km h^{-1}, 17 to 24 km h^{-1}, 25 to 32 km h^{-1} and >32 km h^{-1}). Boom Shrouding (S) had three categories (none, cone and shroud).

Spray Drift Data

Spray drift data were taken from trials conducted in Saskatchewan from 1986 to 2004 with "initial airborne drift" as the dependent variable. "Initial airborne drift" is the amount of airborne drift 5 m downwind of the downwind end of the boom. For each trial, application parameters were assigned to categories used for survey data. Additionally, wind speed (W) was included as a variable.

Model Development

Simple multiple regression analysis was conducted on the drift data with spray quality, boom height, travel speed, boom shrouding and wind speed as independent variables.

Results

Pesticide labels differ in which wind speeds they permit application. As a result, two example wind speed ranges were used to develop the models, representing low wind speeds (10 to 20 km/h) and intermediate wind speeds (15 to 25 km/h). Other models, for wind speed ranges that fall within the 10 to 35 km h-1 boundaries of the original dataset, can be developed in the future.

Low wind speed Model (10 to 20 km h^{-1}, n = 62, r^2 = 0.62)

$$\text{Drift (\%)} = 0.20W - 1.63Q + 1.57H + 1.03T - 0.63S + 0.35 \qquad \textit{Equation 1}$$

Intermediate wind speed Model (15 to 25 km h^{-1}, n = 53, r^2 = 0.59)

$$\text{Drift (\%)} = 0.10W - 1.78Q + 2.12H + 1.06T - 1.09S + 1.86 \qquad \textit{Equation 2}$$

The models accounted for 62 and 59% of the spray drift variation in the original dataset for the low and medium wind speed models, respectively. Based on the p-values for the estimated coefficients, spray quality was the most important variable in predicting the percent drift during pesticide applications using ground sprayers at either low or intermediate wind speeds. For the low wind speed model, wind speed and travel speeds also had significant effects. For the intermediate wind speed model, the presence of shrouds and the travel speed had significant effects.

For both wind speeds, the relationship between observed and predicted drift was linear, with a tendency to under-estimate drift (Figures 1 and 2).

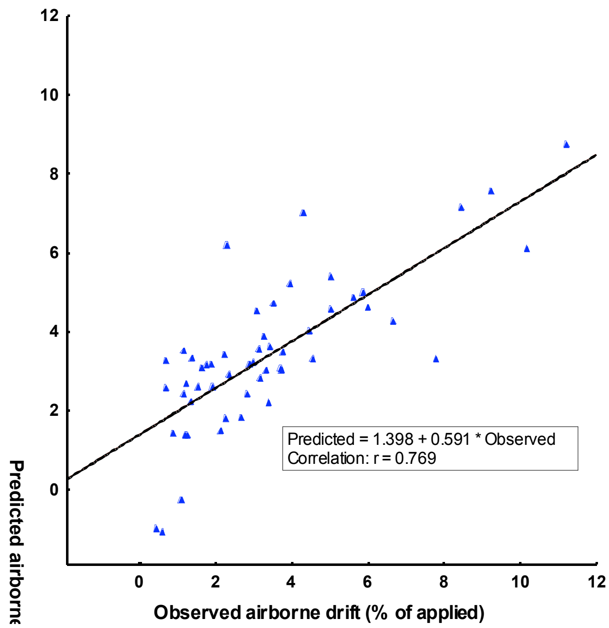


Figure 1. Relationship between observed and predicted drift values for low wind speed model

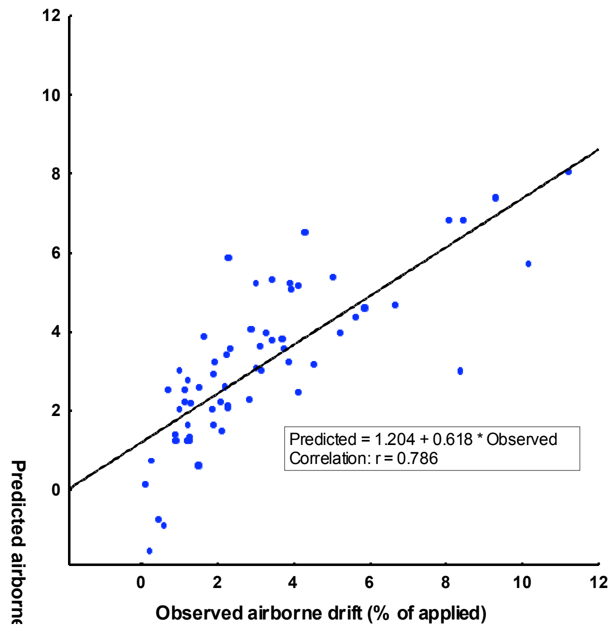
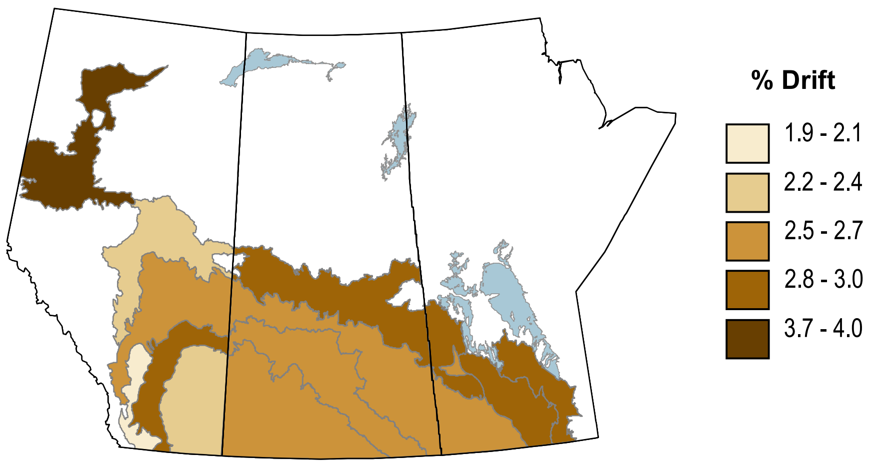


Figure 2. Relationship between observed and predicted drift values for medium wind speed model

Model Application – An Example

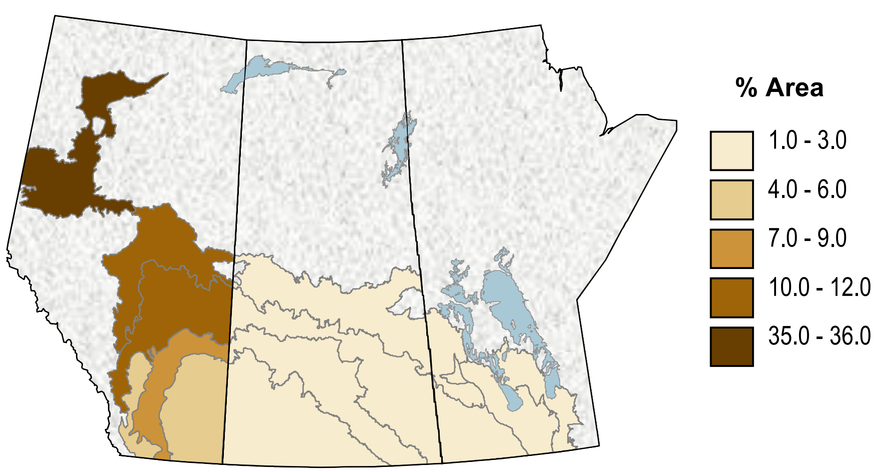
Predicted airborne drift (as a percent of the applied amount) was calculated based on application data reported in the Prairie Weed Management Surveys. These data were used to predict the drift in each intensively farmed ecoregion[4] within each province. Ecodistricts with survey data but relatively low cultivated area were combined with adjacent ecoregions[5]. Maps were produced with ArcView GIS 3.2 from Environmental Systems Research Institute, Inc. based on ecodistict and ecoregion boundaries available from Agriculture and Agri-Food Canada[6].

Using the intermediate wind speed model, the predicted drift at the time the surveys were conducted is illustrated in Map 1. Using the low wind speed model, predicted drift was lower with a similar distribution, as expected (map not shown).



Map 1. Predicted airborne drift with 20 km h^{-1} wind

The high risk of drift for the Peace River Ecoregion in northwest Alberta was related to the proportionately higher use of Very Fine and Fine spray qualities in that region (Map 2).



Map 2. Use of Very Fine and Fine spray quality nozzle types

Discussion

These models demonstrate how experimental spray drift data from ground application of herbicides and analogous sprayer configuration survey data can be integrated to predict pesticide application drift. The robustness of these models will allow the quantification of air-borne drift with sprayer configuration data sets from areas other than the Canadian Prairies. In addition, these models can be used to predict the impact of the adoption of new application technology (nozzle type and use of shrouds or cones) and changes in practices (boom height, travel speed, and wind speed at spraying time) by regulators, policy makers, and producers on the magnitude of application drift. In Canada, greater than 90% of agricultural pesticides are applied with ground sprayers.

Pesticides that enter the atmosphere via application drift increase the risk of water contamination through the processes of wet (precipitation) and dry (particulate) atmospheric deposition that remove pesticides from the atmosphere. Consequently, these models, which predict application drift at low and intermediate wind speeds, will be incorporated into the IROWC-Pest agri-environmental indicator to improve estimates of risk of water contamination by agricultural pesticides. This will ensure that estimates of risk of water contamination by pesticides using IROWC-Pest will also be responsive to changes in application technology and spray practices. A similar methodology could be employed to estimate the magnitude of drift from aerial, orchard and vineyard applications of pesticides.

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