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Modeling Glyphosate aerial spray drift at the Ecuador–Colombia border

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ABSTRACT

We propose a mathematical model for the Glyphosate aerial spray drift at the Ecuador–Colombia border. Glyphosate is one of the herbicides used by the Colombian government to spray coca fields close to the Ecuadorian border. The model considers known parameters of the sprays in three zones of interest at the border. As many details of the actual spray procedures are not known, our model is chosen as a simple scalar PDE, characterising qualitatively and quantitatively the spray drift. This back-of-an-envelope model can be used as a starting point for more accurate models of the phenomena. Two dimensional simulations are shown.

1. Introduction

Glyphosate is one of the herbicides used by the Colombian government to spray coca fields close to the Ecuadorian border. The sprays have taken place for a number of years and have been more frequent after 2000, when Plan Colombia started.

Spray drifts into Ecuadorian territory became a big issue for people living close to the border. Their negative impact on health and agriculture have been observed and confirmed by intensive studies, e.g., [1]. Hence, in 2005 Ecuador and Colombia signed an agreement to stop the sprays in a 10 km corridor along the border. However, measurements on Ecuadorian territory indicated that significant amounts of Glyphosate spray have still drifted into Ecuador. The sprays stopped in 2007 and a trial in the International Court of Justice started. In September 2013 the case was settled with an agreement that “sets out operational parameters for Colombia’s spraying programme, records the agreement of the two Governments to ongoing exchanges of information in that regard, and establishes a dispute settlement mechanism” [2]. In the settlement Colombia also agreed to pay 15 million US dollars to Ecuador [3].

The herbicide/pesticide aerial spray drift is a big concern in agricultural communities. Most studies of spray drift so far have focused on the extent of near-field drift under varying meteorological conditions and application methods [4–6]. Application procedures and general guidelines have been proposed in the context of agriculture, in order to maximize the effectiveness of plant protection products and minimize risks to public health and the environment, see e.g. in [7]. All the models in the literature assume that these procedures and guidelines are followed. However, for the sprays at the Ecuador–Colombia border some of these guidelines either cannot be followed, e.g. the maximum aircraft spray height

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due to the topography of the zone, or they were not followed, e.g., the droplet size, see [1] and references therein. These result in demands for a new model that considers the available information on the particular spray procedures at the border and deals with technical difficulties, like the size of the spray zones and the accuracy required.

In this paper we propose a mathematical model and perform two-dimensional numerical simulations of the spray drift in specific zones at the border. Even though the Ecuador–Colombia case was settled for now, similar issues may arise elsewhere. Our model is not specific to the herbicide, it could be applicable even in very different situations.

The paper is organized as follows. First, we briefly study the physical phenomena of the aerial spray drift in two zones: close to the nozzle and distant from the nozzle. Then, we review the existing models that have been proposed in the literature and state the aerial spray guidelines. After that, we describe the particular procedures of the sprays at the Ecuador–Colombia border. Then, we propose our mathematical model and show some preliminary numerical simulations using data similar to the three zones of interest. Finally, some discussion of the results and conclusions are stated.

2. Physical phenomena

The aerial spray can be seen as two-phase fluid flow, where liquid droplets are released into an air flow. In order to model this situation it is necessary to determine both the air flow in the system and the spray movement in the prevailing air flow. The spraying process can be divided into two zones: close to the nozzle, where droplet movement is influenced by the sprayer and at distance from the sprayer where droplet movement is controlled by prevailing meteorological conditions, see Fig. 1.

Models of droplet movement in the near nozzle region are often ballistic or particle trajectory models. Close to the spray nozzle the spray is relatively dense and the droplets can influence the local air turbulence [8]. The fact that droplets are being propelled from the nozzle in a certain direction causes surrounding air to be entrained into the spray plume [9]. The combination of the high droplet concentration, initial spray sheet and entrained air can provide a blockage to cross flowing air, resulting in regions of low and high air pressure, leading to the creation of spray induced vortices [10,11]. The spray vehicle, e.g., aircraft, and spray structures, e.g., booms, can also create additional turbulence in the region where the spray is being produced. The modeling near to the nozzle has been studied extensively [12–15]. The main difference between these models relate to how air flow is characterized in the near nozzle region.

On the other hand, once a droplet moves far enough from the spray nozzle it will move entirely under the influence of the prevailing meteorological conditions. At this stage the spray concentration in the air is low so the influence of the droplets on the local air turbulence is negligible [8]. The main purpose of models of droplet movement at distance from the spray nozzle is to determine the amount of spray drift moving away from treatment areas. For our problem we are particularly interested in modeling this phenomenon. Two main approaches that have been used for these models are Gaussian diffusion theory and random walk. We will briefly review these approaches in the next section.

3. Review of existing models

A number of models have been developed to predict the drift and deposition from aerial spray applications [16–25]. These aerial spray models fall into two general categories: empirical and mechanistic. The empirical models do not take into account any physical basis for the spray drift and are generally applicable only to situations very similar to those for which they were developed, e.g., [22,23].

Mechanistic models are based on Gaussian dispersion equations and particle tracking models (Lagrangian particle trajectory) [26]. Gaussian modeling [16,18,19,24] is a classical approach used in atmospheric dispersion modeling of releases from tall stacks and line, area, and volume sources and is well suited for modeling moderately long-range drift (0.5 km) and

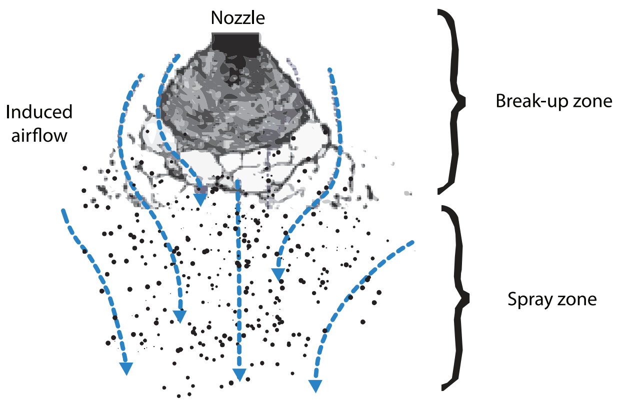

Fig. 1. Diagram of the airflow near and distant to the nozzle [7, Section 2.1].