Local Dust Emission Factors for Agricultural Tilling Operations

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Abstract: Dust emission factors for regional- and local-scale simulations of particulate matter with diameters less than or equal to 10 μm (PM_{10}) dispersion from agricultural operations are not generally available. This article presents a modification of the U.S. Environmental Protection Agency AP-42 approach to better calculate aerosol emission factors of PM_{10} for agricultural tilling operations. For the modification, we added the variables soil moisture, operation type, and crop type based on experimental and literature data to estimate local emission factors. Field experiments to measure the PM_{10} emissions from rolling, disking, listing, planting, and harvesting cotton (*Gossypium hirsutum L.*) were conducted. Data from these field experiments plus literature data were used to isolate the effects of soil moisture and operation type on the emissions. Literature data were then used to add different crop and operation types.

Key words: Agricultural operation, AP-42, emission factor, PM_{10}, source strength, tilling.

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The U.S. Environmental Protection Agency (EPA) defines an *air emission factor* as "a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant" (EPA, 1985). Emission factors are generally used to estimate the long-term ensemble (or population) emissions of a specific activity by multiplying the emission factor by the rate of the pollution-emitting activity. These general emission factors are not sufficient to estimate local agricultural emission rates where operation type, crop type, and soil moisture variations can affect the emissions of individual operations by orders of magnitude. This article considers these variations in the case of agricultural tilling operations.

The EPA specifies the calculation of PM_{10} (particulate matter with diameters ≤10 μm) emission factors for agricultural tilling operations as a power function of soil texture only:

$$E = 112.98\ s^{0.6} \tag{1}$$

where E is the PM_{10} emission factor (milligrams per square meter) and s is the silt fraction (proportion of particles <75 μm in diameter) of surface soil (0–10 cm of depth) (proportion, grams per gram). This silt fraction's definition is different from the definition commonly used by geologists and soil scientists who usually consider silt as particles from 2 to 50 μm and clay as particles from 0 to 2 μm (EPA, 1985). This equation for fugitive dust was developed by the Midwest Research Institute in 1983 and adopted by the EPA in the fourth edition of AP-42 (EPA, 1985; Cowherd and Englehart, 1984).

The California Air Resources Board (CARB) has adopted empirical PM_{10} emission factors for several types of agricultural operations (Flocchini and James, 2001). The CARB emission factors separate agricultural operations into categories. For example, disking, tilling, and chiseling are combined in one category and have one single emission factor, 1.2 (lbs acre-pass^{-1}; i.e., 134.8 mg m^{-2}); land planing and floating (leveling the tops of furrowed rows before planting) are also combined in one category with an emission factor of 12.5 (lbs acre-pass^{-1}; i.e., 1,404.5 mg s^{-2}).

We have measured (Hiscox et al., 2007) and modeled (Wang et al., 2008) the PM_{10} exposure of workers in and near fields during agricultural operations in the lower Rio Grande Valley of New Mexico. To use our model (Wang et al., 2008) broadly in other environmental conditions, we need to estimate emission rates under different conditions without making *in situ* emission factor measurements. Therefore, we have developed, and describe in this article, modifications for the method described in Eq.(1) to add the variables soil moisture, crop type, and operation type, which allow the extension of our measured emission factors to other environmental conditions.

MATERIALS AND METHODS

In 2005 and 2008, field experiments were conducted to quantify airborne particle emission factors from different agricultural operations (rolling, disking, listing, planting, and harvesting) in cotton fields at New Mexico State University Leyendecker Plant Science Center in Las Cruces, NM (32.2°N, 106.8°W; elevation, 1,180 m). To supplement the experimental data, literature data from Holmén et al. (2001) and Cassel et al. (2003) were also used.

Experiments

Rolling, listing, planting, and disking operations were conducted in March and April of 2005, and disking operations were repeated in March of 2008 in Experimental Field 1 (100 m × 246 m) in the experimental cotton fields shown in Fig. 1. The operation sequence was deliberately conducted as normal and was the same as that used every year at the New Mexico State University farm, which mimics the most common sequencing in the Mesilla Valley region of New Mexico. On November 7, 2005, a harvesting operation was conducted in Experimental Field 2 (80 m × 210 m). The soil types for both fields were a mixture of Armijo clay loam (fine, Montmorillonitic, Thermic Typic Torrerts) and Harkey loam (coarse-silty, mixed [calcareous], Thermic Typic Torrifluvents) (the fraction of >75-μm particles, 0.43; the fraction >2-μm and <75-μm particles, 0.23; the fraction of ≤2-μm particles, 0.34) (USDA, 2005).

A three-dimensional sonic anemometer (CSAT3, Campbell Scientific Inc, Logan, UT) was located at 1.5 m height at the field edge and measured, at 20-Hz sampling rates, the wind component velocities and air temperature. From these data, average

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