Proposal for 2008-2009
Northwest Columbia Plateau PM_{10} Project

Objective #2: **Measurement and Prediction of Wind Erosion and Dust Emissions**

Title: ***Tillage Tool Modifications for Reducing the Emission of Windblown Dust from Agricultural Soils***

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Project Objectives

Conservation tillage and cropping systems are sought in the low precipitation zone of the Columbia Plateau that will reduce windblown dust and PM_{10} emissions from agricultural soils. Past studies related to tillage systems in the region have focused specifically on agronomic characteristics (e.g. yield, crop cover) of those systems. Little attention has been given to characterizing PM_{10} emissions during high winds as influenced by tillage systems and to the design of tillage equipment for reducing soil erodibility.

The objectives of this research will be to:

1. Modify the rodweeder, which is conventionally used to control weeds during the summer fallow phase of a winter wheat – summer fallow rotation, that will enable armoring of the soil surface with buried crop residue and nonerodible aggregates during the rodweeding operation.
2. Determine the effectiveness of the modified rodweeder in reducing emission of windblown dust as a result of armoring the soil surface with crop residue and nonerodible aggregates in conventional summer fallow.

Recent Accomplishments

Two adjacent field sites were instrumented to continuously monitor soil erosion, PM_{10} emissions, and wind speed during the 2006 dust storm season. One site was maintained using conventional tillage practices while the other site was maintained using conservation tillage practices. Conventional tillage included spring disking, rodweeding, and sowing winter wheat while conservation tillage included undercutting, rodweeding, and sowing winter wheat. Advanced instrumentation installed at the upwind and downwind boundaries of each site included high-volume air samplers, BSNE airborne soil collectors and CREEP samplers, and various standard meteorological sensors. Real-time PM_{10} concentrations were measured at a height of 1.5, 3, and 6 m using E-samplers. Winter wheat was maintained on adjacent fields to reduce the influx of airborne or eroded sediment. Equipment placed at the upwind and downwind boundaries allowed us to calculate the loss of soil and PM_{10} from each field site. Soil and crop residue characteristics were measured throughout the summer to ascertain changes in surface conditions. Soil and crop residue properties measured included soil water content, surface roughness, aggregate size distribution, residue biomass and cover, ridge height and spacing, and soil PM_{10} content. Data from 2005 and 2006 were used to test the EROSION submodel of the Wind Erosion Prediction System (WEPS) in a region characterized by loessial soils, intense tillage systems, and poor air quality. The conservation tillage treatment, in which the undercutter was used as the primary tillage implement, resulted in a 15 to 65% reduction in soil loss and 30 to 70% reduction in PM_{10} emissions.

Planned Research

Activities planned for 2008 include 1) modifying the rodweeder that is conventionally used to control weeds during summer fallow in the Pacific Northwest and 2) collecting information on soil properties and dust emissions to ascertain the effectiveness of the modified rodweeder in reducing windblown dust emissions during summer fallow. We propose to do the following in 2008:

Rodweeder modification

The rodweeder to be modified is a Calkins Model HD212-265 end-wheel drive rodweeder. The principle component of the rodweeder is a 3.6-m long solid steel rod with square dimensions (22 mm). The square rod protrudes through bushings located at the base of the shanks which are mounted to the frame of the rodweeder. The bushings and square rod rotate using a chain drive. The length of the square rod will be reduced to 2.7 m to facilitate usage within the experiment plots. Further modifications to the rodweeder include attachment of a sieve assembly to the base of the shanks. The sieve assembly will be positioned immediately behind (50 mm) and level with the square rod. The sieve assembly consists of a solid round steel rod (19-mm diameter) that is 2.7 m long. Mounted perpendicular to the round rod will be smaller rods (6.3 mm diameter) that are 0.3 m long. One end of each small rod is welded to the 2.7-m long round rod. The spacing between centers of the smaller rods is 25 mm, thus 109 small rods are equally spaced along the length of the large-diameter round rod. The sieve assembly is bolted to the shank of the rodweeder such that the large-diameter round rod maintains a level position with respect to the square rod and the unattached ends of the smaller rods project upward at a 30° angle. This angle allows the unattached ends of the smaller diameter rods to protrude 50 mm above the soil surface.

Modified rodweeder field test

The modified rodweeder will be field tested at the Palouse Conservation Field Station in Pullman, Washington, on a Palouse silt loam and at the Lind Dryland Field Station in Lind, Washington, on a Shano silt loam. Annual precipitation at Pullman is 530 mm and at Lind is 260 mm. The performance of the modified rodweeder will be tested during the summer fallow phase of a winter wheat – summer fallow rotation.

Tillage treatments

The experimental design will be a split plot with tillage as main plot treatments and rodweeder as subplot treatments. Tillage treatments will consist of both conventional and conservation tillage.

At Pullman, WA, main plots will be 7.3 x 30 m while subplots will be 3.6 x 30 m. Conventional tillage will include: 1) mowing wheat stubble to a height of 0.1 m with a

Brillion flail mower in August after harvest of 100 bushel / acre Paladin hard red winter wheat, 2) plowing in October to a depth of 0.15 m using a John Deere 4200 rollover plow, 3) cultivating to a depth of 0.15 m the following April using a Calkins cultivator equipped with 38 mm shanks at a spacing of 0.3 m, and 3) rodweeding monthly to a depth of 0.1 m beginning in May. Conservation tillage will include: 1) mowing wheat stubble to a height of 0.1 m with a Brillion flail mower in August after harvest of 100 bushel / acre Paladin hard red winter wheat, 2) cultivating in October to a depth of 0.15 m using a Glencoe Model P-3604 Soil Saver, 3) cultivating to a depth of 0.15 m the following April using a Calkins cultivator equipped with 38 mm shanks on 0.3 m spacing, 3) and rodweeding monthly to a depth of 0.1 m beginning in May.

At Lind, WA, main plots will be either 14.6 x 30 m (conventional tillage) or 9.1 x 30 m (conservation tillage) while subplots will be either 7.3 x 30 m (conventional tillage) or 4.5 x 30 m (conservation tillage). Conventional tillage will include: 1) undercutting the soil in August to a depth of 0.13 m using a Haybuster Model 3200 Undercutter, equipped with 0.8 m wide V-blades spaced 0.7 m apart, after harvest of 40 bushel / acre Masami soft white winter wheat, 2) chiseling the soil in November prior to soil freezing to a depth of 0.25 m using a John Deere chisel plow equipped with twisted points spaced 0.3 m apart, 3) disking the soil the following April to a depth of 0.13 m using a John Deere double disk equipped with 0.56-m diameter blades, 4) and rodweeding monthly to a depth of 0.1 m beginning in May. Conservation tillage will include: 1) undercutting the soil in August after harvest of 40 bushel / acre Masami soft white winter wheat and the following April to a depth of 0.13 m using a Haybuster Model 3200 Undercutter equipped with 0.8 m wide V-blades spaced 0.7 m apart and 2) rodweeding monthly to a depth of 0.1 m beginning in May.

Subplot treatments will consist of rodweeding with either the unmodified or modified Calkins end-wheel drive rodweeder.

Measurements

The erodibility of the soil following rodweeding with the unmodified and modified rodweeder will be assessed by measuring the biomass of standing and prostrate residue, stubble height and density, percent cover of residue and nonerodible aggregates, near-surface bulk density and soil water content, aggregate size distribution and stability, and surface roughness. Biomass determinations will be made after separately drying the standing and prostrate residue collected from an area of 0.25 m^2. Stubble height will be measured using a ruler while density will be assessed from an area of 0.25 m^2. Percent cover of residue and nonerodible aggregates will be determined using a pin meter equipped with 40 pins (foot of each pin is 6 mm in diameter) equally spaced 25 mm apart. Percent cover of residue or nonerodible aggregates is calculated as the percentage of pins whose individual feet completely overlay the cross section of a residue element or do not protrude beyond the bounds of the underlying aggregate. The pin meter will also be used to calculate surface roughness, expressed as the standard deviation in elevation among the 40 pins. Near-surface bulk density will be ascertained by extracting soil core samples from the upper 30 mm of the soil profile using 70-mm diameter stainless steel tubing. The core samples will be oven dried prior to weighing and determining bulk density. Near-surface soil water content will be measured gravimetrically within the upper 5 mm of the soil profile using 70-mm diameter steel tubing. Aggregate size distribution will be determined by sieving 1 kg samples collected in the upper 30 mm of the soil profile. A rotary sieve will be used to separate the following size fractions: 0.42, 0.84, 2.0, 6.4, 19.0, 45.0, and 76.0 mm in diameter. The <0.42 mm size fraction will be further separated into 10, 45, and 100µm sizes using a sonic sieve. The 6.4-19.0 mm size fraction will be used to assess aggregate stability using an aggregate crushing meter (Hagen et al., 1995).

The influence of armoring the soil surface with buried crop residue and nonerodible aggregates using the modified rodweeder on dust emissions will also be assessed using a portable wind tunnel at Lind, WA. The assessment will be made after the last rodweeding of the summer fallow period or after sowing winter wheat in August. The wind tunnel has been previously described by Sharratt (2007). The push-type tunnel has a working section 7.3 m long, 1.0 m wide, and 1.2 m high. Winds of up to 20 m s^{-1} are generated in the tunnel by a 1.4 m diameter axivane fan powered by a 33-kW engine. The flow passes through a series of conditioning devices to reduce turbulence prior to entering the working section. At the entrance of the working section, a non-uniform grid assembly initiates the development of shear flow. A fully turbulent boundary layer characterizes the flow at a distance of 5.2 m from the shear grid assembly in the working section; wind speed and PM_{10} concentrations are measured at this position in the working section. PM_{10} concentration and wind speed are measured with Dustraks and pitot tubes, respectively. PM_{10} concentration is measured upwind at the grid assembly to assess influx of PM_{10} as well as at a distance of 5.2 m downwind from the grid assembly. An instrument rack allows placement of Dustrak inlets or pitot tubes at various heights above the soil surface. An isokinetic slot sampler is placed beside the instrument rack to measure total sediment flux.

References cited

Hagen, L., B. Schroeder, and E. Skidmore. 1995. A vertical soil crushing energy meter. Trans. Am. Soc. Agric. Eng. 38:711-715.

Sharratt, B.S. 2007. Instrumentation to quantify soil and PM_{10} flux using a portable wind tunnel. Proc. Intern. Symposium on Air Quality and Waste Management for Agriculture, Broomfield, CO. [CD-ROM]