CHAPTER 1

Purpose, Progress and Perspectives

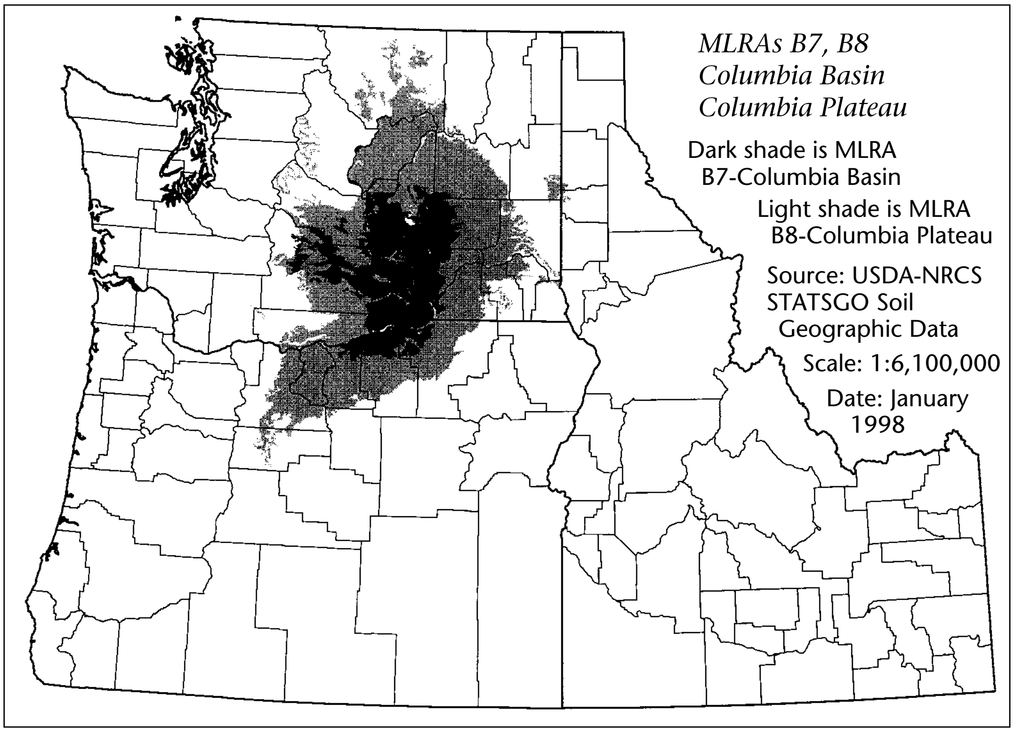

FIGURE 1.1. *The Columbia Plateau and the Columbia Basin Major Land Resource Areas shown in the three-state map of Idaho, Oregon, and Washington. Together these MLRAs comprise a land area of about 24,000 square miles and make up the core of the cropland area in the Pacific Northwest that is most susceptible to wind erosion. Nearly one-half of the Columbia Plateau is cropland most of which is dry-farmed with wheat–fallow the dominant system on about 3.84 million acres. Approximately 15% of the Columbia Basin (0.7 million acres) is irrigated where horticulture, grain and forage crops are grown under intensive management. See Figure 1.2 for the county designations of the Columbia Plateau and Columbia Basin in Washington state.*

INTRODUCTION

The Northwest Columbia Plateau Wind Erosion Air Quality Project (also known as the Columbia Plateau PM_{10} Project, or CP_3) began in 1992 through cooperative efforts by the USDA's Agricultural Research Service (ARS) and Washington State University (WSU), Pullman, Washington. Its purpose was to conduct research on practical solutions for reducing wind erosion and dust emissions from irrigated and dry-farmed croplands on the Columbia Plateau and Columbia Basin Major Land Resource Areas (Figs. 1.1, 1.2)[1]. Start-up funding to supplement in-house resources was provided by the US Environmental Protection Agency (EPA[2]) Region 10, Seattle, and the Washington State Department of Ecology (Ecology), Olympia, and since 1994, by grants from the USDA's Cooperative State Research, Education, and Extension Service. The work was prompted by mandates of the Clean Air Act Amendments of 1990 (CAAA) that included provisions in its National Ambient Air Quality Standards (NAAQS) to regulate airborne particles of 10 µm or less in aerodynamic diameter commonly referred to as PM_{10} (Fig. 1.3)[3]. This standard was based on studies indicating the adverse effects of this pollutant on human health and public welfare. In the inland Pacific Northwest, atmospheric PM_{10} concentrations at monitoring stations are often highest during major dust storms from upwind erosion on dry and irrigated croplands. In addition to air pollution, wind erosion contributes to significant loss of the region's most valuable resource for its productive agriculture, i.e., the nonrenewable topsoil.

The goal of the CP_3 from its inception in 1992 remains the same: to develop technologies for controlling wind erosion, and provide technical assistance for implementing them at the farm level to enable growers to operate profitably and minimize dust emis-

[1] Reference to the Columbia Plateau and Columbia Basin in this book refers to the Major Land Resource Areas as defined by the Natural Resources Conservation Service, US Department of Agriculture. See Web site http://www.nrcs.usda.gov/technical/land/mlra/mlranw.html.
[2] Reference to EPA in this book denotes the US Environmental Protection Agency.
[3] 1 µm = 1 micron = one-thousandth of a millimeter. It would take 2,540 PM_{10} particles side by side to cross an inch of space.

FIGURE 1.2. *Designations of counties on the Columbia Plateau and Columbia Basin Major Land Resource Areas in Washington state.*

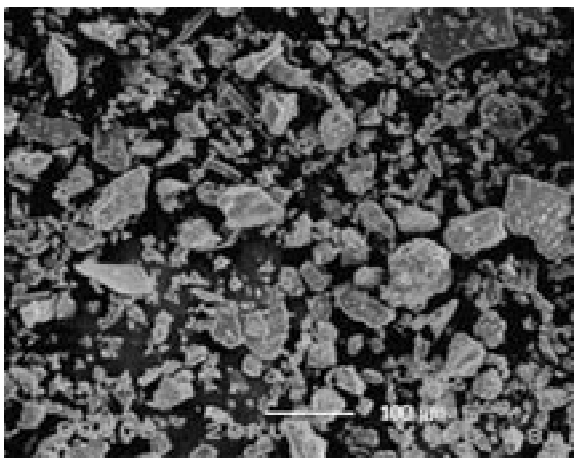

FIGURE 1.3. *Microphotograph of soil dust particulates shown on a scale of 100 microns that includes PM_{10} size that is regulated by EPA as air-borne pollutants hazardous to human and environmental health. The soil was taken directly from a tilled field and not modified in any way before photographing. These fines are directly suspendible by strong winds when they are disaggregated and exposed at the soil surface. Photography by J. Kjelgaard, WSU.*

ions from agricultural fields.[4] Though considerable research has been conducted on farmland wind erosion over the years, most of it dealt with the movement of coarse materials that comprise the greatest percentage of the soil mass eroding from fields. The CP_3 effort is considered as unique since little, if any, of the earlier research on wind erosion focused on the presence, behavior and control of extremely fine dust particles during wind erosion events.

The climate of the Columbia Plateau is characterized by cool, moist winters and dry summers with occasional drought cycles and high intensity winds from Pacific fronts that impact the area from a southwesterly direction. Because of crop adaptation and economic advantages, winter wheat (*Triticum aestivum* L.) alternating with summer fallow (one crop every two years) has dominated dryland agriculture since the early 1900s on 3.84 million acres in the low-precipitation zone (12 inches and less of average annual precipitation) (Stephens et al., 1932; Ramig, et al., 1983). The fallow year allows for storage of additional water in the soil profile that helps to reduce the risk of crop failure from drought, and ensure profitable yields. In addition to the drylands, there are about 0.6 million acres of irrigated farmlands, contained mainly in the Columbia Basin of central Washington, devoted to the production of cereal, forage, vegetable, fruit and seed crops (Figs. 1.1, 1.2). Soils on the Columbia Plateau for the most part are developed from deposits of loess comprised primarily of silt, but also with significant amounts of sand in some areas (Fig. 1.4).

Excessive soil erosion in the drylands is exacerbated by traditional summer fallow where intensive tillage creates a loose, friable soil that is very susceptible to blowing by wind at least four months each year. Similarly, under irrigation, intensive tillage used in establishing many small-seeded vegetable and cereal crops in the spring, as well as late fall harvesting of root crops leaves a bare, weakly aggregated soil that is highly susceptible to wind erosion during the non-growing season. Combinations of dry soils, high winds, drought and inadequate use of conservation practices on farmlands can lead to severe dust storms throughout the Plateau any time of the year, but with the highest probability in early spring, and late summer and fall (Figs. 1.5, 1.6)[5].

2003 UPDATE

This book follows an earlier one entitled *Farming with the Wind* that was published in 1998 by the CP_3 and emphasized best management practices for 1) controlling wind erosion, and 2) improving air quality on the Columbia Plateau (Papendick, 1998). The purpose of this publication is to report continuing progress by the CP_3 on studies to better understand the mechanics of wind erosion and dust emissions, with the overall goal of applying the results to control windblown dust from Columbia Plateau farmlands without the loss of agricultural productivity or economic profitability to the region's growers. The emphasis is on the past six years of work (1998-2003) during which time the Project has matured and been very active with research and educational programs conducted by as many as 18 project scientists. During this time the drylands experienced below normal precipitation and suffered severe drought during the 2000-01 and 2001-02 growing seasons.

Figure 1.7 shows that precipitation at the WSU Dryland Research Station at Lind, WA during 1998-2002 was

[4] See Saxton (1995) for original objections and appendix for extended objectives of the CP_3.
[5] According to the EPA, an "exceedance" in Figure 1.6 is an event when the 24-hour average PM_{10} concentration at the monitoring site is greater than 150 µg m^{-3}.

below the 1921-2002 annual average of 9.56 inches for two years, above normal one year and normal two years of the five. During the previous five years (1993-97) precipitation was above normal for four years and near normal one year. The site is a representative location in the area of the Plateau with fine loessial soils. During 1998-2002, precipitation at the Horrigan site, located in the Horse Heaven Hills in the driest farmed area of the Columbia Plateau, was below the 1989-2002 average of 6.31 inches for four years and above normal the remaining year, whereas in the previous five years it was above normal three years, normal one year and below normal one year.

Seasonal, annual and multi-year precipitation patterns can significantly affect farming practices and, concomitantly, the wind erosion hazard in the dryland areas. For example, drought leads to less soil cover and can cause growers to increase fallow acreage whereas a wet cycle produces more plant growth and encourages more intensive cropping that promotes more continuous plant and crop residue cover.

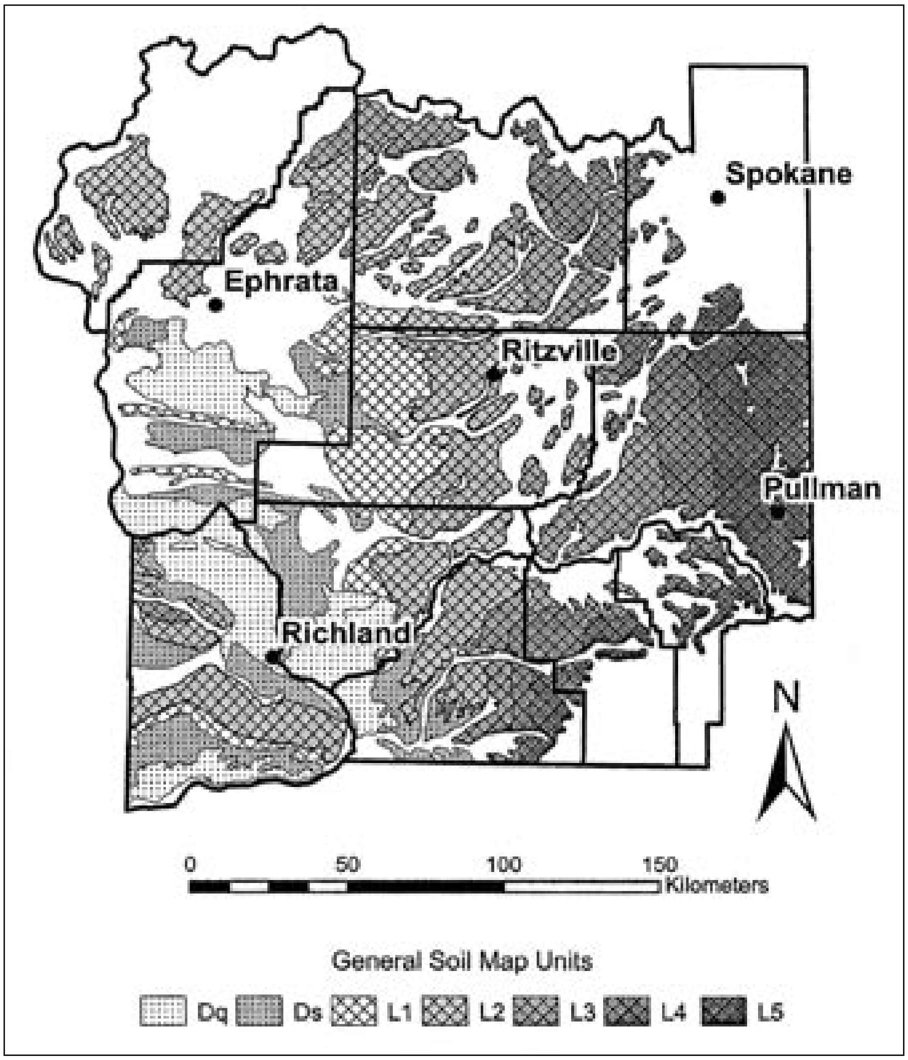

FIGURE 1.4. *General soil map units in counties withon the Columbia Plateau and Columbia Basin Major Land Resource Areas. The map unit symbol for a soil indicates information about its geographic location, character and environment given in the General Soil Map, Washington (Boling et al., 1998). The "D" group are dry soils formed in sandy or silty wind-laid materials over glaciofluvial or glaciolacustrine deposits. D_q are dry sandy soils formed under sparse dune or shrub-steppe vegetation in wind-deposited sand; D_s are dry, silty and loamy soils formed in lakebed sediments and loess. The "L" group are loessial soils primarily used for dryland farming of small grains. L1-5 are a climosequence of deep soils formed in wind-laid silts of the "loess hills" (Boling et al., 1998). The L1 and L2 soils are highly susceptible to wind erosion when tilled and in an unprotected condition. Source: Chandler et al., 2004.*

FARMING WITH THE WIND: THE FIRST FIVE YEARS (1992-97)

BEST MANAGEMENT PRACTICES

As summarized by Papendick (1998) the first five years of work by the CP_3 showed that there are considerable agronomic resources and technologies available for designing and implementing conservation or "best management practices" (BMPs) to reduce wind erosion and dust emissions on both irrigated and dry farmlands. To qualify as a BMP in the CP_3 a practice must 1) make effective use of the best resources and proven technologies available to the grower for controlling wind erosion, 2) be environmentally sound, and 3) not pose undue economic risk or hardship on the farm operation. Additional discussion on BMPs is presented in Papendick (1998, Chapter 1).

Practices developed through research and grower's experiences that have potential as BMPs are green cover from early fall planting of winter wheat, surface residue management, minimum tillage, no-till planting, increased cropping intensity, and those that leave the soil surface rough or improve soil aggregation. Some in addition that are more adaptable for irrigated than dryfarming include cover crops, importing off-farm or external sources of organic amendments (straw) for surface mulching, applying synthetic soil stabilizers, and use of vegetative barriers, strip cropping, and tree windbreaks. The Conservation Reserve Program with 10 years of perennial sod reduces wind erosion to almost zero and is highly effective in succeeding years as a conservation measure if followed by reduced- or no-till take-out.

The literature reports studies showing the high costs associated with the loss of soil productivity by wind erosion, and the potential for improving both soil and environmental quality by applying BMPs for erosion control (Dormaar, 1987; Lyles, 1977). The important inference conveyed from these and other studies is that managing eroded soil to improve soil quality is both extremely slow and expensive, and that in the long-term it is far more economical if BMPs are applied to control wind erosion and prevent soil quality decline than to reclaim soil after the damage is done.

FIGURE 1.5. *Dust plume over farmlands in the Horse Heaven Hills of south central Washington from a storm on March 5, 2003 that resulted in a 24-hr PM_{10} exceedance in Kennewick, WA, some 20 mi downwind. Blowing dust aloft is a result of inadequate surface cover and/or soil roughness during high winds across land areas with poorly aggregated, dry soils that contain significant quantities of fine particulates. Photograph by B. Rude, Department of Ecology, Olympia, WA.*

Regional atmospheric dust modeling studies

A regional modeling study involving the Windblown Dust Regional Air Quality Model in combination with a fugitive dust emissions sub-model, both developed by the CP_3 was used to predict dust transport, deposition and atmospheric concentrations of PM_{10} as affected by wind and soil characteristics, vegetative cover, management practices and soil moisture conditions. The model predicted a marked decline in the 24-hr average atmospheric PM_{10} concentrations at air quality monitoring sites in Spokane, WA during actual major dust storm events that would occur from progressive increases in the percentage of surface cover (crop residues) on fallow fields of the Columbia Plateau west and southwest of Spokane, WA. As the amount of surface cover increased, there was a marked decrease in the PM_{10} concentration.

In one scenario, simulations were conducted for major dust storms that occurred on November 23, 1990, September 3, 1993, and November 3, 1993 across the Plateau region. When the simulated surface cover was increased from a base tillage level of 5% to 25% cover on all fallow fields having two of the most erodible soil classes on the Columbia Plateau, the atmospheric PM_{10} concentrations during all three events exceeded or were at the allowable daily limit for the base level of 5% cover. However, they were well within the allowable limit with 25% cover for all three storms, reaching only 41% of the base tillage level on the two most stormy days, and only 13% on the least stormy day (November 3, 1993).

In another simulation with the November 23, 1990 storm, the predicted PM_{10} concentrations well exceeded the allowable daily limit of 150 ug m^{-3} at two locations in Spokane when all fallow land in the Plateau was at the base level of 5% cover. Exceedances of the 24-hr standard were predicted for only one of the locations when 25% residue cover was applied to all fallow land or just to the two most erodible soil classes. Atmospheric PM_{10} concentrations did not exceed allowable limits at either location when 50% cover was applied to all fallow acreage in the Plateau.

Educational initiatives and dissemination of results

An educational program conducted within the CP_3 disseminated the Project results in a timely manner to growers, and ag-industry, regulatory and action agency staff. The primary focus was to provide information on the dynamics of wind erosion, and on options for BMPs to control wind erosion and dust emissions and thereby, improve the region's air and soil quality.

The ultimate goal of the educational effort is to promote voluntary adoption and application of BMPs by area growers and to encourage and enhance the development of conservation techniques through grower participation and innovation. The program is conducted by extension specialists, and collaborating scientists through media such as grower meetings, news interviews, dissemination of information pamphlets, brochures and circulars, radio and TV talks, field days and public field tours.

Background and Current Status of Regional Particulate Matter Standards

In 1997 the EPA promulgated revised National Ambient Air Quality Standards (NAAQS) for particulate matter based on scientific studies that indicated additional changes were necessary to protect public health and the environment

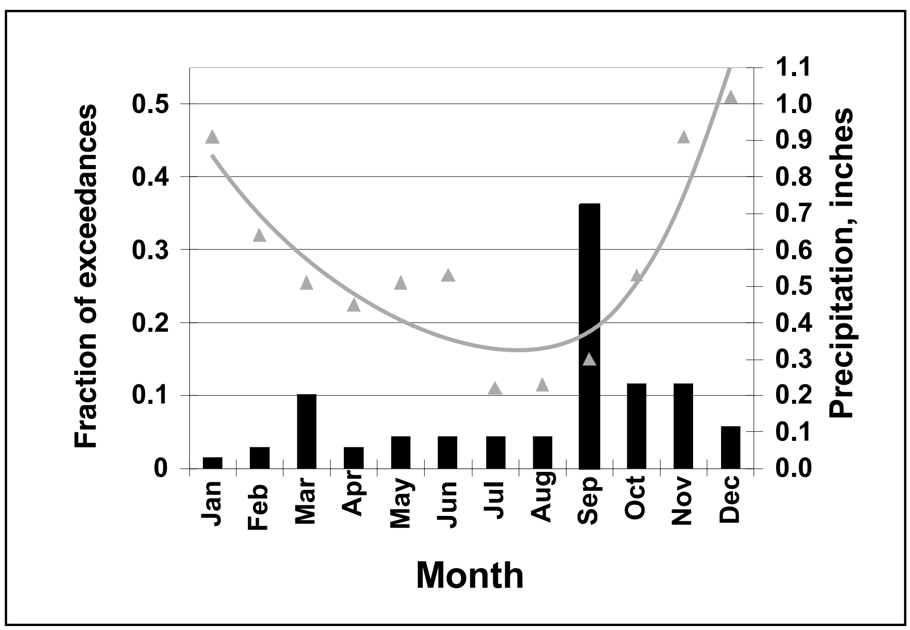

FIGURE 1.6. *Fraction of 69 exceedances of the NAAQS PM_{10} standard by month at the Columbia Plateau monitoring sites of Kennewick, Spokane, Walla Walla, and Wallula, Washington during 1989-2003. The bars represent the combined exceedances from the four monitoring sites and the triangles with the line through them the average precipitation by month at the Hanford meteorological Station that is considered near representative of the source areas. Source: Lauer et al. (2003). The high exceedance months are March and September-November.*

(EPA, 1997). These included 1) adding a new primary (health-based) annual average $PM_{2.5}$ (particulates 2.5 microns or less in aerodynamic diameter) standard of 15 micrograms per cubic meter (µg m^{-3}), and a 24-hr $PM_{2.5}$ standard of 65 µg m^{-3}; and 2) retaining the original annual PM_{10} standard of 50 µg m^{-3} but adjusting the original PM_{10} 24-hr standard of 150 µg m^{-3} by changing its form. The change involves replacing the 1-expected-exceedance form with a 99th percentile form, averaged over three years, to protect against short-term exposure to coarse fraction particles (EPA, 1997).

The revised standards were challenged and a decision in 1999 by the US Court of Appeals allowed the $PM_{2.5}$ standard to remain in effect but strongly limited EPA's ability to implement it. Following an appeal by the EPA the US Court of Appeals, District of Columbia on March 26, 2002 upheld the fine particulate matter standards issued by EPA in 1997 finding that the challenged standards were neither arbitrary nor capricious.

The 1997 fine PM standard is the first-ever requirement to keep levels of microscopic substances such as chemicals, metals, carbon soot, and soil particulates in the atmosphere below 65 µg m^{-3} over a 24-hr period and 15 µg m^{-3} on an average annual basis. EPA is currently implementing the $PM_{2.5}$ standard with designations of nonattainment areas and final rules are expected by September 2004.

Classification of areas with regard to meeting the PM_{10} standard

The Clean Air Act Amendments of 1990 mandated that EPA initially designate all areas of the US as "nonattainment," or "unclassifiable" for particulate matter. Areas in nonattainment are those determined by air monitoring that do not meet, or that impact, ambient air quality in a nearby area that does not meet the standard for this pollutant. The unclassifiable designation applies to areas that cannot be classified on the basis of available information as meeting or not meeting the PM_{10} standard. The only way an area can be designated in "attainment" (i.e., meeting the NAAQS for PM_{10}) is that it must first be designated as nonattainment, then achieve the standard after which it can be reclassified by EPA according to a protocol that would bestow attainment status.

The Columbia Plateau is commonly affected by natural events such as high winds combined with low precipitation and drought cycles that can cause extensive soil erosion on farmlands, even where BMPs have been implemented with best use of available resources. For example, CP_3 researchers observed extensive erosion from winds peaking at 50 mi hr^{-1} during a dust storm on September 23 and 25, 1999 near Ritzville, WA from a newly planted wheat field despite an estimated 40% cover of flat wheat residue (Saxton et al., 1999). This level of cover exceeds what is normally possible with best management practices for tilled fallow.

The Natural Events Policy (NEP) adopted by EPA (Nichols, 1996) allows for excluding exceedances of NAAQS violations due to natural events provided that, by their policy, "best available control measures" (BACM, equivalent to BMPs in CP_3 terminology) are implemented in the contributing source area. In order to exclude a PM_{10} exceedance as a NAAQS violation a designated State regulatory body is required in each case to establish a clear causal relationship between the exceedance and the natural event (Nichols, 1996). Moreover, EPA will not designate an area as nonattainment or fail to redesignate a nonattainment area to attainment if the state has a natural events action plan (NEAP) in effect for applying control measures that respond to public health concerns.

Prior to the NEP the EPA had proposed that the monitored locations of Spokane, the Tri-cities, and the Wallula area in Washington State be classified nonattainment due partly to PM_{10} exceedances caused by windblown dust originating from farm fields upwind. Figure 1.8 shows the number of times each year during the period of measurement that the 24-hr average limit of 150 µg m^{-3} of PM_{10} was exceeded at the three locations. A location is designated "nonattainment" for the 24-hr standard when the number of days with levels above 150 µg m^{-3} (averaged over a 3-yr period) is greater than one, or for the annual standard if the arithmetic mean of the PM_{10} concentration over a three year period is greater than 50 µg m^{-3} (data not shown in Fig. 1.8). Note that the violations at all monitoring sites were most numerous during the earlier years of measurement (i.e., prior to 1993) and tended to decline considerably after that. The reason for this trend is not entirely clear.

Presently, Spokane, WA is designated as a "moderate" nonattainment area for PM_{10} because of past exceedances from sources (unpaved road dust, wood smoke) other than high winds. Without the NEP it would have been reclassified to "serious" nonattainment with requirements for stricter control measures on all sources of PM_{10}.

The Tri-cities is currently designated as an unclassifiable area for PM_{10}. Though its standard was exceeded a number of times in the 1990s,

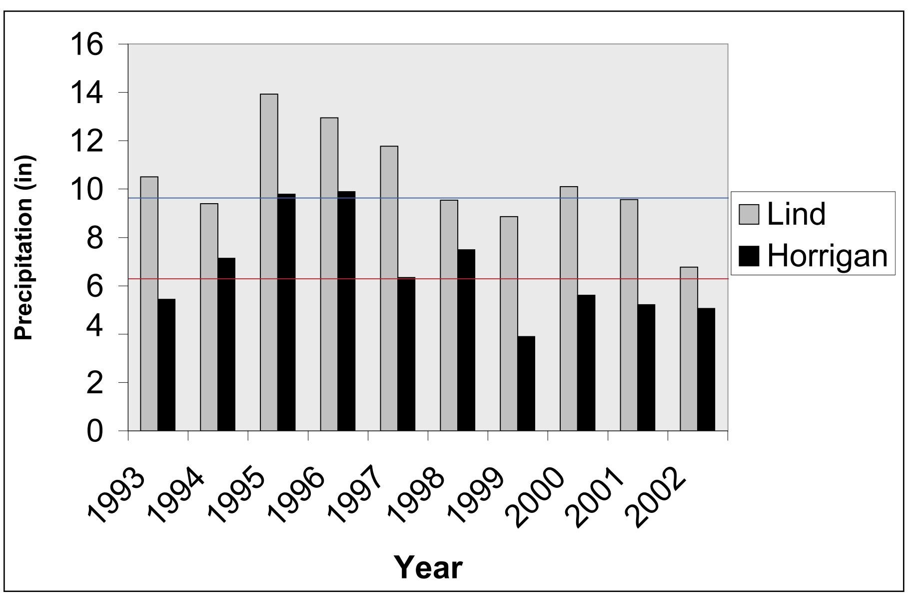

Figure 1.7. *Annual precipitation at the WSU Dryland Research Station at Lind, WA and the Horrigan weather station in the Horse Heaven Hills in south-central WA during 1993-2002 compared with long-term averages (indicated by the horizontal lines) of 9.56 inches (1921-2002) at Lind, and 6.31 inches (1989-2002) at Horrigan.*

the violations were excluded by the NEP except for one in 1999 that was explained by construction activity upwind from a monitoring site. Since the Tri-cities was not a source area for PM_{10} it was never designated as nonattainment, and therefore by law could not be reclassified as an attainment area.

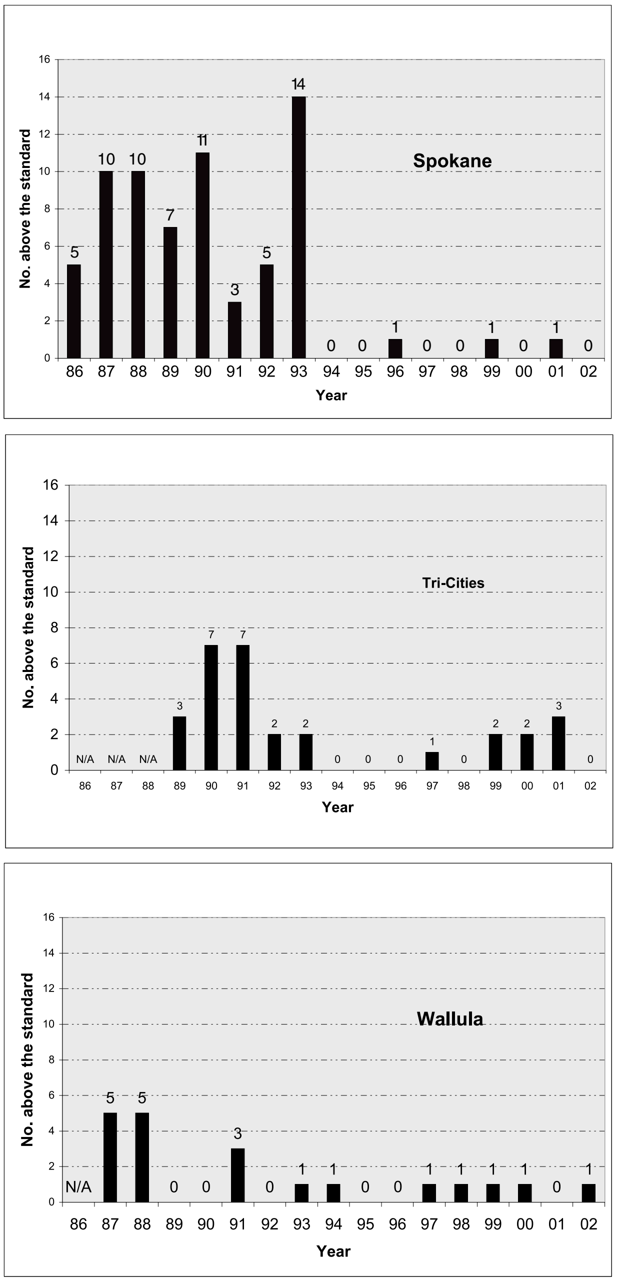

Figure 1.8. *Number of times in a year the atmospheric PM_{10} concentration exceeded the 24-hr average standard of 150 µg m^{-3} during the years indicated at monitoring sites in Spokane, Tri-Cities, and Wallula, WA. N/A indicates data not available. Source: Spokane—E. Skelton, Spokane County Air Pollution Control Authority, Spokane, WA; Tri-Cities—D. Lauer, Benton Clean Air Authority, Kennewick, WA; Wallula—B. Rude, Washington State Department of Ecology, Olympia, WA.*

On March 12, 2001, the EPA classified the Wallula area in south central Washington as "serious" nonattainment for particulate matter emissions (EPA, 2002). The action resulted from several exceedances of the 24-hr average PM_{10} standard that occurred after the area had been designated to "moderate" nonattainment status, and which prevented reclassification to attainment by the required date. The issue concerned four dates during 1997-2000 when the exceedances occurred. In its review, Ecology provided credible documentation showing that for all four days, high winds combined with low soil moisture conditions in nearby areas were responsible for the exceedances. Moreover, Ecology provided information documenting the increased and widespread use of BMPs from 1994-2000 in areas of Benton and Walla Walla counties that are upwind from the Wallula site. As a result of the review the EPA ruled that the Wallula area attained the NAAQS for PM_{10} on the designated attainment date of December 31, 2001 (EPA, 2002; Deneen, 2002). Under this ruling Wallula remains temporarily a "serious" PM_{10} nonattainment area but avoids the additional planning requirements that apply to areas failing to meet the specified attainment date.

The $PM_{2.5}$ standard

A fine particulate standard, $PM_{2.5}$ is now in effect and like PM_{10} will be implemented and regulated by EPA. Monitoring atmospheric concentrations of these particulates was initiated in late 1999 and early 2000 by Ecology at several locations impacted by Columbia Plateau agricultural areas. The EPA requires three years of data for determining attainment/nonattainment classification and it is expected that states will prepare designations by February 2004. EPA is beginning to draft implementation rules for states to use in developing both nonattainment and infrastructure state implementation plans (SIPs) for $PM_{2.5}$. These will follow the guidelines of the "General Preamble" published by EPA after enactment of the CAAA (EPA, 1992; Federal Register, 1992). Based on 2000-2002 data, no areas in Washington have violated the current $PM_{2.5}$ standard.

The EPA is required by law to review and revise the NAAQS as appropriate, every five years. The PM review was due in July 2002 but is running about a year behind schedule. The standard could be changed by this review, but every indication is that the $PM_{2.5}$ standard will remain as established in 1997. However, there is some indication that in addition to the $PM_{2.5}$ "fine" standard a "coarse standard" may be proposed for particulate matter between 2.5 and 10 micrometers in aerodynamic diameter.

Summary Observations

This publication reports on the past six years (1998-2003) of progress by the CP_3 following the Handbook "*Farming with the Wind*" that was published in 1998 covering the first five years of the project, 1992–97. The initial years developed the groundwork and set the stage for much of what is reported in the following chapters on the prediction and control of wind erosion and dust emissions from Columbia Plateau farmlands. Most importantly the earlier work showed the need for new and improved wind erosion/PM emissions prediction capability for merging with regional atmospheric dust transport and dispersion models to forecast how different farm conservation management scenarios employed in upwind areas affect PM_{10} concentrations downwind during major wind events. Simultaneously there was a need to develop practical and economically feasible conservation management options or best management practices (BMPs) that dryland and irrigated growers could implement for containing soil erosion and dust emissions to acceptable levels.

Unlike the first five years when precipitation was mostly above normal, the drylands experienced drought in the 2000-01 and 2001-02 growing seasons that reduced grain and straw yields of most crops whether grown in conventional or conservation farming systems. Most severely affected were annual cropping systems compared with after fallow where yields were considerably higher.

To qualify as a BMP, a conservation practice must not create undue economic risk or hardship on the farm operation including when precipitation is below normal, or when there are other weather hazards. EPA continues to regulate PM_{10} with an average 24-hr and annual standard and is in the process of implementing a $PM_{2.5}$ standard that, like PM_{10}, may be affected by farmland dust.

Currently, EPA's Natural Events Policy excludes PM violations due to natural events (high winds, dry conditions) provided that the appropriate state regulatory body (Department of Ecology in Washington state) rules that BMPs are implemented in the contributing source area. If it is determined that BMPs are not implemented in the contributing area the violation may not be discounted by the EPA and the area could be designated according to their protocol as "nonattainment". The state regulatory body (Ecology) would then be responsible for developing and implementing a plan for applying control measures at the field level that responds to public health concerns.

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