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RANGELAND EXPERIMENTS FOR WATER EROSION PREDICTION PROJECT

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SUMMARY:

Rangeland experiments to quantify WEPP model parameters will be conducted using one experimental design on 23 soil/vegetation sites throughout the western half of the United States. Details, descriptions, and discussion of the design, soils, vegetation, and user benefits are presented.

KEYWORDS:

Rangeland, erosion, runoff

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RANGELAND EXPERIMENTS FOR WATER EROSION PREDICTION PROJECT[1]

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A new technology is needed to predict and assess erosion and sedimentation rates on rangelands. Current erosion predicting procedures have been criticized as inadequately representing rangeland erosion processes. A realistic assessment of the impacts of rangeland management actions on erosion is needed. The Agricultural Research Service (ARS) of the United States Department of Agriculture (USDA) has set the development of new erosion prediction technology as one of its top priority goals. The Water Erosion Prediction Project (WEPP) was initiated in 1985 to meet this goal and was designed to collect experimental field data from both crop and rangeland soil and vegetation complexes.

The following experimental design and field procedures are being used by the Aridland Watershed Management Research Unit in Tucson, Arizona for development of rangeland erosion parameters in WEPP. These procedures were developed and have been used at Walnut Gulch, in southeastern Arizona for 7 years and the Nevada Test Site, Nevada rangeland location for 5 years (Simanton et al., 1985). Similar procedures are being used by Dept. of Energy laboratories, other U.S. Government agencies and state universities in Nevada, Idaho, New Mexico, Washington, and Utah.

Rotating-boom Rainfall Simulator

The rainfall simulator used in the WEPP rangeland field experiments was developed by Swanson (1965). The rotating boom rainfall simulator is trailer-mounted and has 10- 7.6 m booms radiating from a central stem. The booms support 30 V-Jet 80100 nozzles positioned at various distances from the stem. These flow-regulated nozzles spray continuously downward from an average height of about 3 m, move in a circular path over the plots, apply rainfall intensities of about 65 or 130 mm/hr and produce drop-size distributions similar to natural rainfall. Simulator rainfall energies are 77% of those of natural rainfall and intermittent rainfall impulses are produced at the plot surface as the booms pass over the plot. Rainfall spatial distribution over each plot has a coefficient of variation of less than 10%. Changes in rainfall intensities are produced by increasing or decreasing the number of open nozzles; 15 nozzles for 65 mm/hr and 30 nozzles for 130 mm/hr. Electric solenoid valves are attached to the 130 mm/hr nozzles so that rainfall intensity can be changed instantaneously between 65 and 130 mm/hr. Because of the simple design and portability of the simulator and because two plots are covered during one run, six plots can be evaluated in two days.

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Plot Treatments

Plot treatments consist of natural, clipped (all vegetation canopy clipped to about 2 cm height and clippings removed), and bare (all vegetation canopy clipped to about 2 cm height with clippings and all soil surface cover removed).

Rainfall Simulation Runs Sequence

Three rainfall simulations are made on each plot. They are the dry, wet, and very wet run which are made in the following sequence. Dry soil surface run (60 min at 65 mm/hr rainfall rate) followed 24 hours later by the wet run (30 min at 65 mm/hr rainfall rate), followed 30 min later by the very wet run which has varying rainfall intensity (65 and 130 mm/hr) and addition of overland flow for variable time periods. An example of the rainfall and overland flow application sequences for the very wet run is presented in Figure 1. This sequence provides soil infiltration data for unsaturated (dry run), field capacity (wet run) and saturated (very wet run) soil moisture conditions; provides comparable data to the existing rangeland rainfall simulator plot data and produces varying rainfall intensities and overland flow data needed for WEPP parameter identification.

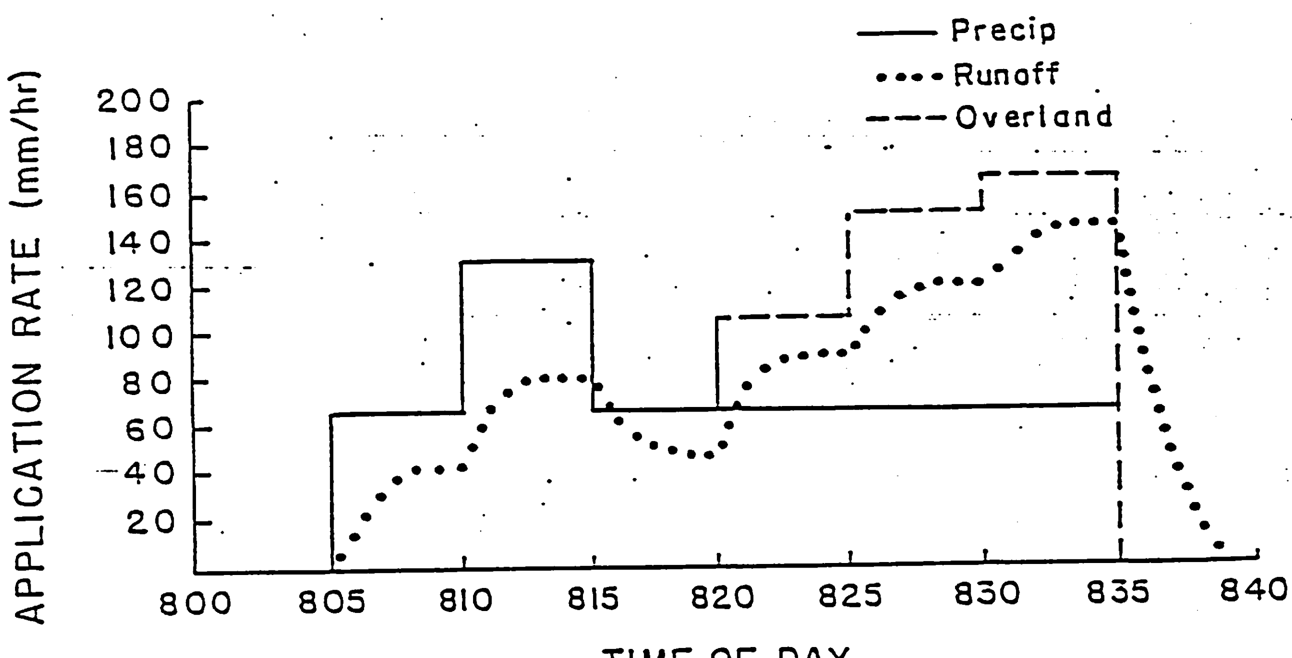

Figure 1. Very wet run sequence showing hyeteograph, hydrograph and overland flow application rates.

Overland Flow Application

Depending on soil erodibility, three or four overland water flow rates are applied at the upper end of the bare plots during the final 65 mm/hr rainfall application of the very wet run (Fig. 1). Flow rates range from 45 to 200 mm/hr with the duration of application dependent on time needed to reach runoff equilibrium at each overland flow rate.

Large Plots (3.05 x 10.7 m)

There are 2 plots of each treatment for a total of 6 large plots installed at each rangeland site. All plots at a site were grouped within a 50 by 50 m area that was determined by the Soil Conservation Service (SCS) to be in the same soil and vegetation type. Metal sheets (2 mm thick x 15 cm wide x 3 m long) are used to form the sides and upper end of each plot. These sheets are inserted 3 cm into the soil so that a 12 cm high border delineates each plot. The downslope end of the plot has a 20 cm wide metal sheet, with a sill plate formed on the upper edge, inserted into the soil so that the sill plate is flush with the soil surface. Runoff and sediment from the plot is diverted into a runoff measuring flume by troughs mounted below the sill plate.

Rainfall

Six non-recording raingages on each plot are used to measure rainfall amounts and distribution. One recording raingage is placed between paired plots to measure simulated rainfall intensity. Water temperature of applied rainfall is recorded and a rainfall water quality sample is taken for later lab analysis.

Runoff

A precalibrated runoff measuring flume is set at the trough exit and flow depths are measured using pressure transducer bubble gages. Continuous hydrographs are produced using the flume's depth/discharge rating table.

Sediment

Periodic water/sediment aliquots are manually collected from the exit of the flumes. Sampling intervals depend on hydrograph shape, with 1-2 min intervals between samples on the rising and falling portions of the hydrograph and longer intervals where concentrations appear to be nearly time invariant.

Interrill Plots (0.6 x 1.2 m)

Interrill plots are used to determine raindrop erosion rates as compared to the combination of raindrop and overland flow detachment erosion rates as produced on the longer large plots. Also, effects of raindrop impact on soil crusting and infiltration are determined from comparisons between the two treatments on the interrill plots. Two 0.6 x 1.2 m interrill plots are installed next to each of the bare treatment large plots. The interrill plots have the same treatment as the large bare plot with one of the interrill plots covered with window screen to dissipate raindrop impact and prevent soil surface crusting. Interrill runoff hydrographs and sediment yields are determined from periodic (every 2 min. during rising part of hydrograph and 5 min. intervals at or near equilibrium) volumetric samples manually collected during the rainfall simulations.

Vegetation and Plot Characteristics

A 49 pin-point meter is used to measure vegetation composition, foliar canopy cover and ground surface characteristics of each of the large plots. Surface cover characteristics include: soil, gravel (5-20 mm), rock (> 20 mm), litter, cryptogams, and basal plant cover. Ten permanent transects across each plot produce 490 point readings to describe each plot's surface and vegetation canopy cover. Total aboveground herbaceous biomass is determined by clipping 3- 0.5 by 1.0 m quadrates from the clipped and bare plots before they are treated.
Aboveground woody biomass is determined by dimensional analysis using relationships between plant volume and weight. Leaf area to leaf weight relationships are established from measurements taken at the time of simulation for the dominate plant species at each rangeland site. Belowground biomass (excluding fauna) at each site is determined from soil cores taken after the wet runs. Microtopography (random roughness) of each plot is determined with a roughness meter and by photogrammetric methods. Range site and condition classification was evaluated by the SCS.

Soil Sampling

A complete soil pedon description, sampling, and analysis are made by SCS at each of the rangeland sites. Pedon analysis includes particle-size distribution, soil moisture release curves, organic carbon, cation exchange capacity, clay mineralogy, and other physical and chemical properties. The WEPP rangeland field crew determines, using the compliant cavity method, surface horizon soil bulk density before the dry and after the very wet runs. They also determine soil moisture contents before the dry and wet runs and after the dry and very wet runs. Indices of soil strength are measured with the Torr Vane and pocket penetrometer after the dry and very wet runs. Bulk surface soil samples collected prior to the dry run are sent to various laboratories for storage and testing. Undisturbed soil core samples taken after the very wet run are used for detailed morphological descriptions of the soil surface horizon and surface crust characteristics.

RANGELAND EROSION RELATIONSHIPS

Most of the intended rangeland WEPP applications are by ranchers and Federal and state agencies field office personnel needing erosion estimates to develop range management plans. To prevent excessive off-site sedimentation and loss of the productive capacity of rangeland soils, reduction in sheet-rill erosion, concentrated flow erosion and sediment yield to acceptable levels is necessary. This requires evaluating the effects of livestock grazing systems and rangeland improvements on erosion. The rangeland manager requires technology that is easy to use in areas where little supporting climatic, soil, land use, and intensity of land use data may be available.

Rainfall simulator plot data will be used to parameterize WEPP models through development of relationships among soil properties, vegetation, cover, erosion, runoff and infiltration. Because of the many ecosystems and land uses included in the data base, management impacts on rangeland productivity and conservation can be better defined using physically-based models to describe the processes involved.

Soil Property-Erodibility Relationships

One objective of the WEPP rainfall simulation experiments is to determine soil erodibility values for a wide range of soil types and conditions. However, such values will be available for only a limited number of soils. Thus, for the WEPP model to be widely applicable, relationships must be developed that will enable soil erodibility to be predicted from easily measured soil properties. Development of the soil erodibility nomograph for the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) illustrated that such relationships could be developed and applied to a wide range of soils. Soil erodibilities used to develop the USLE erodibility nomograph were measured on bare soils that had been tilled up and down slope. Such uniform treatment of plots for erodibility measurements is imperative for valid soil property/erosion relationships to be developed. Soil tillage is not a standard rangeland practice and in most range conditions is impractical or impossible because of shallow soils, rough terrain and harsh climates. Many soils in arid and semiarid regions have thin horizons (2-5 cm) that would be mixed during tillage and the resulting mixture may not be representative of the soil surface subject to erosion. Additionally, large stones in the soil may cause tillage to be impractical, or unduly alter surface roughness and depression storage. Because of these and other potential problems with tillage, soil erodibility will be determined from the bare plot treatment previously described.

Recent studies have indicated the in situ measurements of soil strength and bulk densities may relate to interrill and rill erodibility (Watson and Laflen, 1986; Al-Durrah and Bradford, 1981). Additionally, laboratory measurements such as a modification of the pinhole test (Lefebvre et al.,1985) made on undisturbed cores from the rangeland study sites may relate to measured erodibility. Measurements such as these incorporate the effects of many of the more basic chemical, physical, biological, and mineralogical soil properties as well as the effects of more transitory properties such as surface sealing and aggregation. Thus, if such measurements can be successfully related to soil erodibility regardless of the land use, they will provide a mechanism to predict interrill and rill erodibility for a range of soils and conditions necessary for the WEPP model to be universally applied.

Vegetation and soil surface characteristics may be more important in determining erosion and runoff rates from rangelands than are basic soil properties (bulk density, soil texture, soil strength, etc.). Changes in type and quantity of vegetation can alter infiltration and runoff rates 2-3 fold. Algorithims to express infiltration rates as functions of total foliar and ground cover (%) are currently being evaluated and will be incorporated into a more complex infiltration routine in the WEPP model. Time to peak discharge, concentrated flow paths, overland flow velocities, and associated sheer stresses on the soil surface are all affected by the type, quantity and distribution of vegetation and surface cover. Rootmass, standing biomass, litter, random roughness, ground surface cover and shrub density will be analyzed to determine plant community architecture effects on overland flow routing and sediment yields. Relationships among vegetation temporal and spacial variabilities on the hydrologic/erosional processes are being developed. These relationships will help the model user determine the effect of different management practices on soil loss before management changes are made.

RANGELAND SITES

As part of the WEPP effort, a 2-year program is underway to continue simulator studies on many rangeland soil/vegetation complexes in the western United States. During the summer of 1986, 23 sites were selected at 15 locations in the West and Great Plains (Fig. 2). Soils at the sites are in the orders of Mollisols, Altisols, Entisols, and Inceptisols. Moisture regimes are ustic, xeric, and aridic. Surface textures range from loamy sand to clay and many of the soils have appreciable contents of coarse fragments. Two of the sites have paired plots with rainfall simulation experiments run on the same soil type on both rangeland (not tilled) and cropland conditions (tilled). Many of these locations are ARS research stations where response to cooperative efforts has been excellent. Cooperative work at other locations involves U.S Bureau of Land Mgt., U.S. Dept. of Energy, U.S. Forest Service, Univ. of Calif., South Dakota State Univ., and Texas A & M Univ. The Soil Conservation Service has been totally involved in site selection and has been responsible for soil and range condition identification.

During the spring and summer of 1987, rainfall simulator studies were made on plots at the following rangeland sites:

RANGELAND SITES

LOCATION	SITE	# PLOTS
Walnut Gulch, AZ	Chihuahuan Desert Shrub, Gravelly loam	8
Walnut Gulch, AZ	Chihuahuan Desert Grass, Silt-clay	6
Nevada Test Site, NV	Mohave Desert Shrub, Clay loam	6
Nevada Test Site, NV	Great Basin Shrub, Coarse loam	6
Sonora, TX	Savanna Grass, Cobbly clay	4
Chickasha, OK	Tallgrass Praire (native), Silt loam	6
Chickasha, OK	Tallgrass Praire (reverted), Silt loam	4
Woodward, OK	Mixedgrass Praire, Loamy fine sand	6
Woodward, OK	Mixedgrass Praire,(cont. graze), Loam	4
Sidney, MT	Mixedgrass Praire, (club moss), Clay loam	6
Meeker, CO	Salt Desert Brush, Silty clay loam	6
Cottonwood, SD	Shortgrass Praire, (heavy graze), silty clay	4
Cottonwood, SD	Mixedgrass Praire, (light graze), silty clay	6
Los Alamos, NM	Pinyon-Juniper Interspace, Sandy loam	4

LOCATION	SITE	# PLOTS
Cuba, NM	Shortgrass Desert Grassland, Loam	4
Susanville, CA	SW Shrubsteppe, Gravelly loam	4
Susanville, CA	SW Shrubsteppe (burned), Gravelly loam	4
Fresno, CA	Annual Grassland, Clay loam	6
	TOTAL	94

In addition to the Tucson based field experiments, 3 rangeland sites (6 plots each) near Boise ID were evaluated by ARS (Cliff Johnson of the Northwest Watershed Research Center) during the summer.

TOTAL 18

Rangeland plots ARS evaluated this spring and summer: TOTAL 112

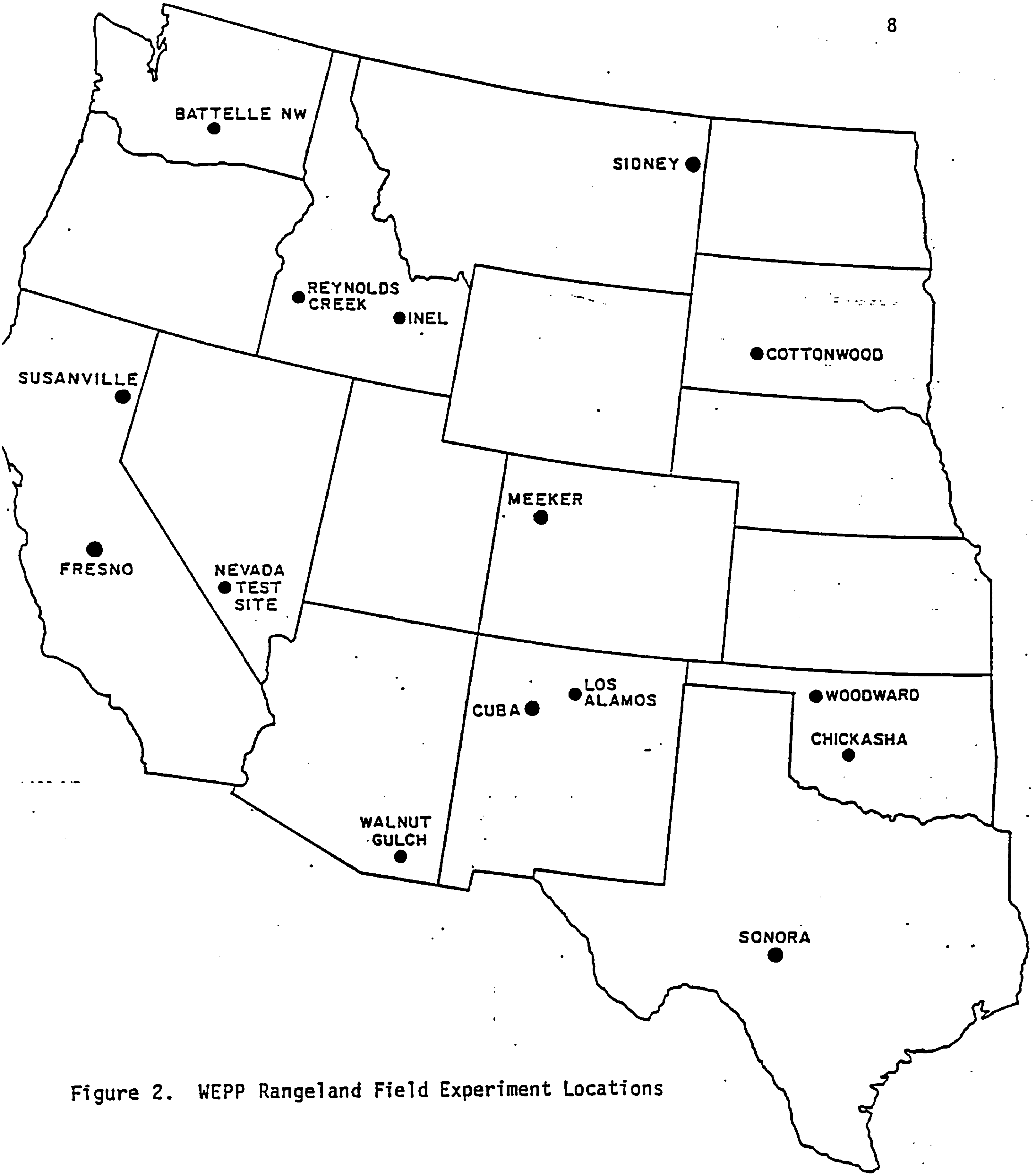

Figure 2. WEPP Rangeland Field Experiment Locations

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