C. L. Douglas, Jr., R. W. Rickman, B. L. Klepper and J. F. Zuzel, USDA Agricultural Research Service, Columbia Plateau Conservation Research Center, Pendleton, Oregon 97801

and

D. J. Wysocki, Oregon State University, Columbia Basin Agricultural Research Center, Pendleton, Oregon 97801

Agroclimatic Zones for Dryland Winter Wheat Producing Areas of Idaho, Washington, and Oregon[1]

Abstract

There is a need to develop a series of "zones" to facilitate technology transfer within the Intermountain Northwest. Six agroclimatic zones have been delineated based on three climatic and soil parameters important in growing winter wheat: soil depth, mean annual precipitation, and cumulative growing degree days from 1 January through 31 May. Thus each zone, regardless of the state in which it is located, has similar soil and climatic conditions. There are uncultivated areas within each zone that are not identified but if farmed would be farmed like other parts of the same zone. The zones provide a common basis for identifying areas where successful exchange of practices, experience, and knowledge between and among producers, researchers, extension, and Soil Conservation Service personnel will most likely occur. Management decisions that produce desired results in one zone in one state will probably succeed in that same zone in any other state. Conservation practices and erosion control techniques should be similar within but not between zones.

Introduction

New farming technologies have been developed over the last 10 years in the Pacific Northwest (PNW) as a result of a three-state (Oregon, Idaho, and Washington) research effort called Solutions to Erosion and Economic Problems (STEEP) established to develop new erosion control strategies (Oldenstadt *et al.* 1982). However, evaluation and adoption of these technologies have lagged behind the research phase of development partially because of insufficient technology transfer. Producers are hesitant to adopt practices developed in another state or area even if their local soil and climatic conditions are similar. There are few published aids establishing locations of similar soil and climate in this diverse region. Successful management of conservation tillage systems, for example, may benefit from application of available technologies from research done in geographically different locations that have similar agronomic parameters.

This paper describes a series of agroclimatic zones (AZ) delineated on the basis of similar soil and climatic factors in the Intermountain Northwest (Idaho and those parts of Oregon and Washington east of the Cascade Mountains). Objectives were to develop a series of zones for the PNW that would allow scientists, field personnel, and producers to compare new technologies more effectively, to design farm management systems by adapting methods tested in plots located in other areas with similar soil and climatic conditions, and to present their research findings for use in a variety of farming situations.

Criteria Used to Define Agronomic Zones

Criteria used to define and delineate AZ are based on soft white winter wheat, the major crop grown in the Intermountain Northwest. Initial evaluation of criteria needed to effectively delineate zones was done in a five county area in northcentral Oregon (Douglas *et al.* 1988). Only three criteria [soil depth (SD), mean annual precipitation (MAP), and cumulative growing degree days (CGDD) from 1 January to 31 May] were needed to identify six zones that delineated management systems for winter wheat production with regard to erosion control and sustained productivity. The same three criteria were used to delineate these same six zones for the Intermountain Northwest (Douglas *et al.* 1990).

The first criterion used to define AZ was SD. Soil depth is important because it affects soil water storage capacity. Soil depths were determined from published SCS County soil surveys. Most agricultural soils in the Intermountain Northwest have medium textures and thus have the potential to store similar amounts of available water per unit

[1]Joint contribution of the USDA-ARS and Oregon State University Agricultural Experiment Station. Technical Paper No. 8796.

depth of soil [approximately 50 mm (2 in) per 0.3 m (12 in) soil]. Much of the precipitation falls during winter when evaporation is low and storage potential is high. Observing appropriate water conservation practices can result in storage of approximately 70 percent of the winter precipitation (Ramig and Ekin 1991). For example, if annual precipitation is 300 mm (12 in), approximately 70 percent or 210 mm (8.4 in) will fall during the winter months, of which 70 percent or 147 mm (5.9 in) could be stored. This amount of water will recharge a medium textured soil to a depth of approximately 1 m (40 in). Soils deeper than 1 m (40 in) will require more than one winter's precipitation to recharge the profile unless annual precipitation is greater than 400 mm (16 in). Thus, two SD categories (Figure 1) were used to define AZ: less than 1 m (shallow) and greater than 1 m (deep).

Water is the single most limiting factor for dryland crop production in the Intermountain Northwest. Thus, the second criterion for segregating land areas into zones was MAP (Figure 2). Mean annual precipitation was determined from National Weather Service 30 year precipitation records, and was used to subdivide cropping areas into three classes: wet, dry, and very dry. The wet class consisted of areas receiving over 400 mm (16 in) of annual precipitation. These areas normally receive sufficient rainfall to support annual cropping of cereals irrespective of SD. The dry class [250 to 400 mm (10-16 in) annually] was chosen to identify areas where SD is important in managing stored soil water. This "dry" area was subdivided into two subclasses: 250-350 mm (10-14 in) and 350-400 mm (14-16 in). Shallow soils (<1 m) are fully recharged almost every winter in both subclasses and can produce a crop annually. Deep soils (>1 m) in the drier subclass do not fully recharge each season and are usually summer fallowed to maximize crop production and water use efficiency. Deep soils in the wetter subclass recharge in most years and can produce a crop annually approximately 70 percent of the time, i.e., seven years out of 10 (personal communication Dr. R. E. Ramig, USDA-ARS, Pendleton, Oregon). These soils can be annually cropped when wetter conditions prevail and summer fallowed when conditions are drier. The very dry class [<250 mm (10 in)] was selected to identify the approximate lower limit of dryland winter wheat production.

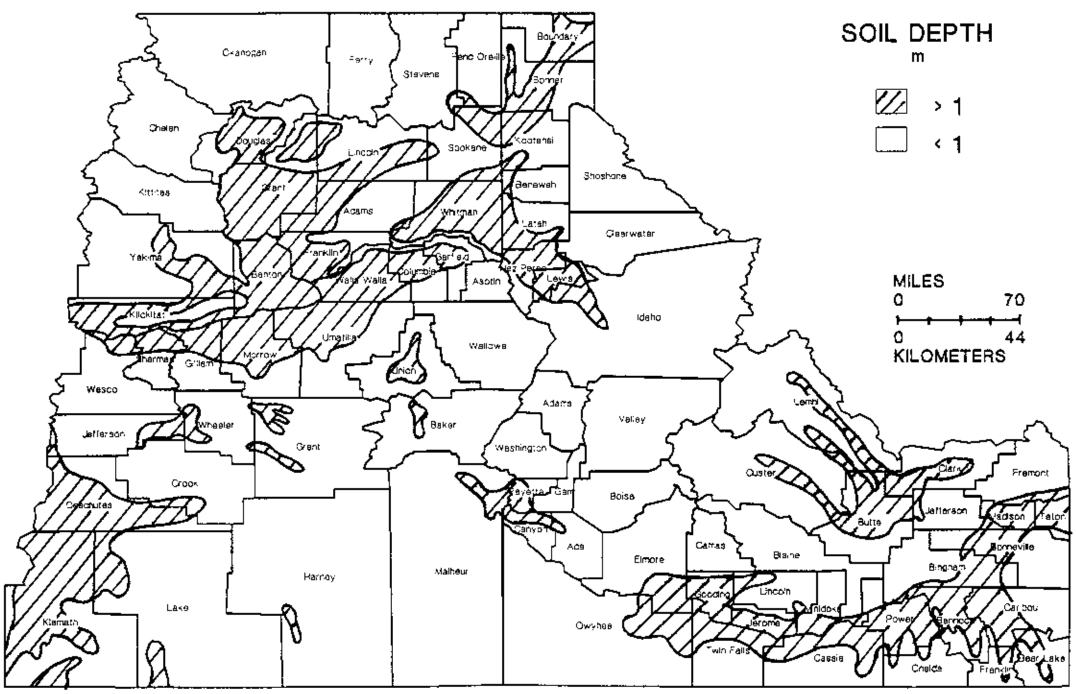

Figure 1. Soil depths for the Intermountain Northwest (m).

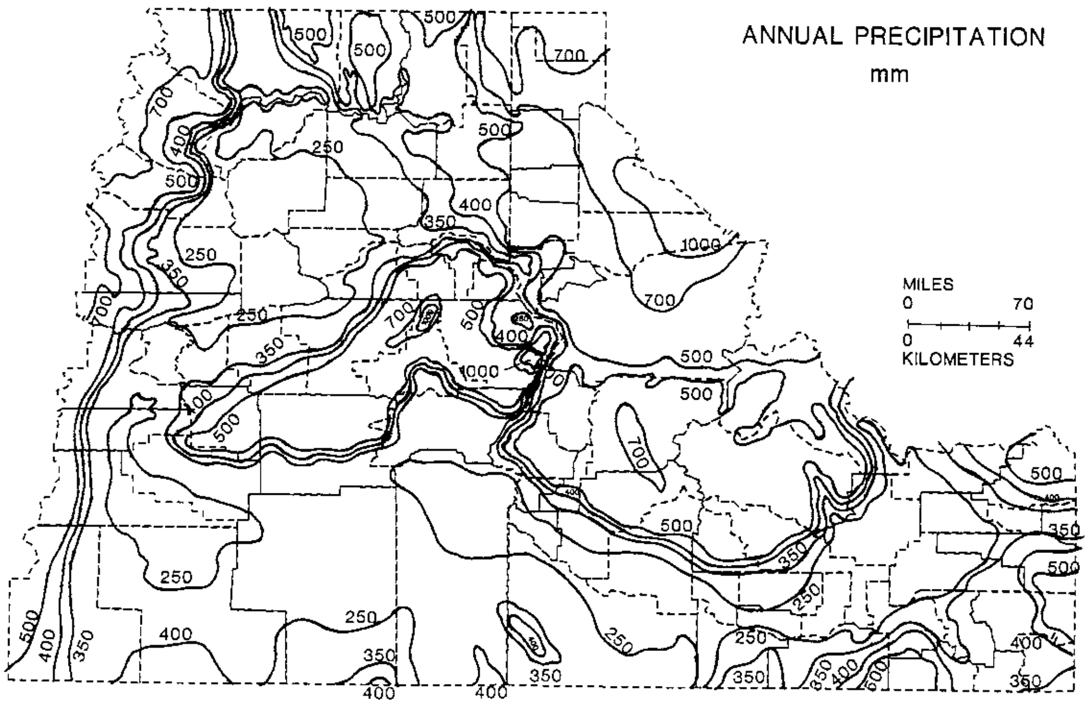

Figure 2. Annual precipitation isohyets for the Intermountain Northwest (mm).

Areas in this class not only receive very little precipitation, they have very high evapotranspiration rates.

The third criterion used to define AZ was CGDD from 1 January through 31 May. Winter wheat growth and management practices in a five-county area in northcentral Oregon were observed and CGDD were determined that fit these observed management patterns (Douglas *et al.* 1988). CGDD were calculated for each weather station by averaging daily maximum and minimum Celsius temperatures, setting negative values (below the freezing point) to zero, and summing for each day from 1 January through 31 May. National Weather Service 30 year temperature records were used to make the calculations.

Three classes were recognized <700 (cold), 700-1000 (cool), and >1000 (warm). CGDD from 1 January-31 May are shown in Figure 3. Figure 3 was constructed from CGDD values for 102 weather stations in the three state area. Values range from a low of 122 in western Klamath Co., Oregon, elevation 1974 m (6475 ft), to 1297 in northern Wasco Co., Oregon, in the Columbia River Canyon, at an elevation of 85 m (280 ft). Values in Idaho, southern Oregon and northern Washington are generally lower than in the rest of the region because of the larger percentage of high elevation land in these areas. The higher values occur in river valleys of the Snake and Columbia Rivers.

In areas receiving <700 CGDD, there is danger of frost in any month, the growing season is short, and evapotranspiration is relatively low. Soil frost damage is generally minimized due to the insulating qualities of a deep, continuous wintertime snowpack, and the thawing of soils frozen prior to the first snowfall by residual soil heat. However, growers must use cereal varieties that are frost tolerant and resistant to snow mold and other pathogens that thrive in cold, moist conditions. The geographic area covered includes most of Idaho, except for the warmer, lower elevation Snake River valley system, southwestern and northeastern Oregon, and northern Washington.

In areas receiving between 700 and 1000 CGDD, winters are sufficiently cold that grains must have some frost hardiness, but the principal frost damage comes from brief, severe, cold periods when there is no snow cover. These areas are prime wheat growing areas with cool temperatures, adequate moisture, and moderate evapotranspiration.

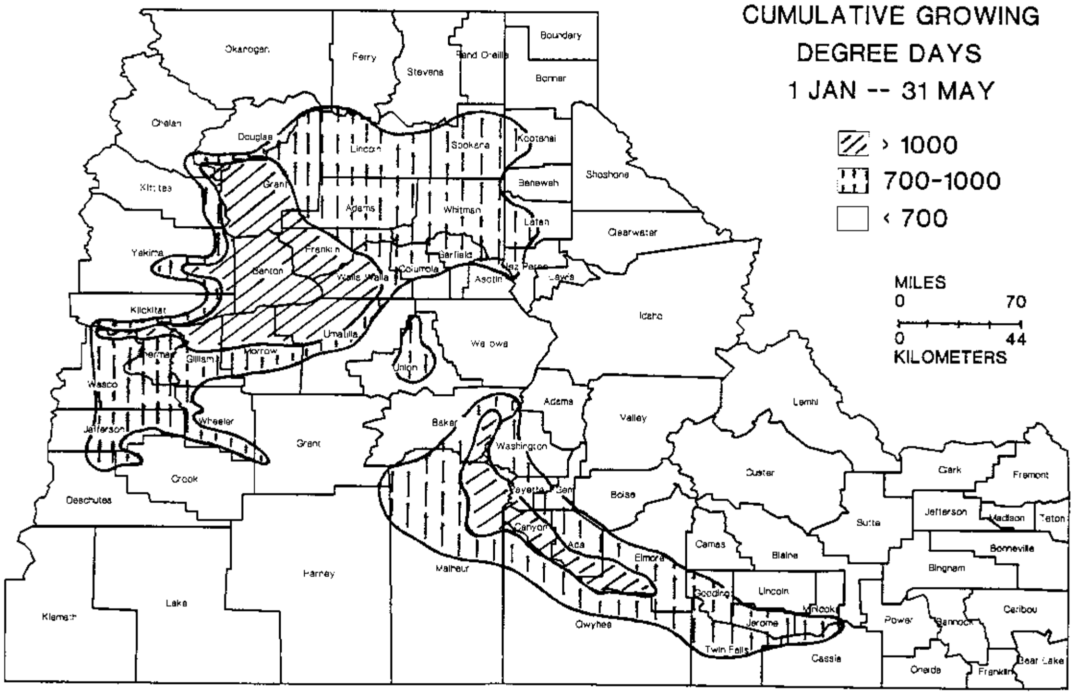

Figure 3. Cumulative growing degree days from 1 January through 31 May for the Intermountain Northwest.

These conditions prevail over a large acreage in central Washington and in narrow bands crossing north-central Oregon, southeastern Idaho, and west central Idaho.

Areas receiving over 1000 CGDD have very warm growing conditions, high evaporative demand, rare frost damage, and a high probability of heat stress after boot stage. Generally early-maturing varieties of wheat are most successful in this area because grain filling occurs before the high summer heat stress begins. This area covers a banana-shaped band running through parts of Grant, Adams, Franklin, Benton, Yakima, and Walla Walla counties in southcentral Washington, and Umatilla, Morrow, and Gilliam counties in northcentral Oregon (Figure 3). There are small elongated bands in southwestern Idaho and in eastern Oregon paralleling the Snake River.

Agroclimatic Zones

Six agroclimatic zones (Figure 4, Table 1) have been delineated based on differences in SD, MAP, and CGDD. These zones have been defined to facilitate technology transfer and application of conservation farming technologies in the Intermountain Northwest. For this reason the discussion of soils in each zone is concerned primarily with those used for cultivation. Vast areas of the Intermountain Northwest are not suited to cultivation and soils of these non-cultivated areas may be very different from the cultivated soils. Sources of soils information for each zone include Boling (1988); USDA Soil Conservation Service (1984 and 1986); and numerous SCS county soil surveys. Many of the areas are still covered with forests and rangelands but if cultivated would be farmed like other parts of the same zone. These uncultivated areas are not identified within each AZ.

Zone 1: ANNUAL CROP-WET-COLD
SD: depth not a factor
MAP: >400 mm (16 in)
CGDD: <700

Zone 1 (Figure 4, Table 1) comprises areas of high elevation and mountainous terrain. Most soils are not suited for cultivation and are marginal for crop production because they are too shallow, too steep, or too cold. Cultivated soils occupy intermountain valleys or mountain foothills and occupy less than 20 percent of the area. In northern Washington and Idaho, soils of this zone are mostly

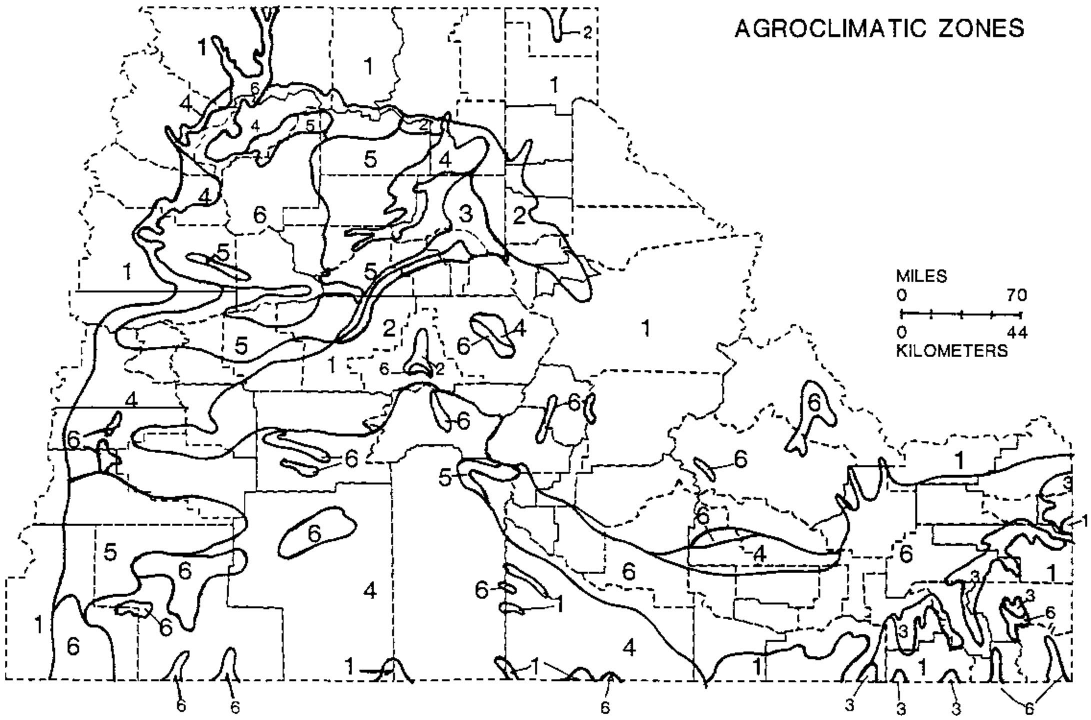

Figure 4. Agronomic zones for the Intermountain Northwest (See Table 1 for legend).

TABLE 1. Agroclimatic zone legend for Figure 4.

Zone	Name	Mean Annual Precipitation (mm)	Soil Depth (m)	Cumulative Growing Degree Days (1 Jan-31 May)
1	ANNUAL CROP-WET-COLD	Over 400 (16 in)	–	Under 700
2	ANNUAL CROP-WET-COOL	Over 400 (16 in)	–	700-1000
3	ANNUAL CROP-FALLOW-TRANSITION	350-400 (14-16 in)	Over 1	700-1000
4	ANNUAL CROP-DRY	250-400 (10-16 in)	Under 1	Under 1000
5	GRAIN-FALLOW	Under 350 (14 in)	Over 1	–
6	IRRIGATED	–	–	–

glacial, glaciofluvial, lacustrine or alluvial in origin. Frequently, the upper profile is formed in a thin, less than 0.5 m (20 in), layer of loess and volcanic ash. These soils are predominantly Xerochrepts with frigid or mesic temperature regimes, with some Andepts and Mollisols. They are coarse to medium textured and level to steeply sloping. Representative series are Waits, Nevine, and Spokane.

Soils of the hills and foothills of the Blue Mountains of Oregon and Washington have formed in loess, residium, and colluvium, have moderate to high amounts of organic matter in the surface, are medium to fine textured, and are gently to very strongly sloping. Most of the soils are Argialbolls or Argixerolls with mesic or frigid temperature regimes. Representative series are Waha and Cowsly.

Soils along the eastern side of the Cascade Mountains are composed of a mixture of parent materials including volcanic ash, loess, and alluvium. They are level to strongly sloping, medium to moderately fine textured, and contain moderate to high amounts of organic matter. Most are Xerochrepts, Xeralfs, and Argixerolls with mesic temperature regimes. Representative series are Goldendale, Gunn, and Wamic.

Native vegetation is primarily dry to moderately dry coniferous forest or PNW bunchgrass types, except in the southeastern part of Idaho where it is shrub-steppe. The primary species in these forests are ponderosa pine (*Pinus ponderosa* Lawson & Lawson), Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), and grand fir (*Abies grandis* (Don) Lindley) at higher elevations. Lower elevations, which comprise most of the cropped areas in this zone, consist of open forests of ponderosa pine in a woodland savannah-type vegetation (Franklin and Dyrness 1973). In southeastern Idaho, precipitation patterns include more summer rainfall and water storage is less efficient. Thus the cold high elevation land receives more than 400 mm (16 in) of precipitation, but the vegetation is a shrub-steppe dominated by big sagebrush (*Artemisia tridentata* Nutt.) with bunchgrasses such as *Festuca idahoensis* Elmer and other grasses and forbs in the understory (Franklin and Dyrness 1973).

Snow cover in this zone helps decrease winter injury to plants. However, cereal varieties that exhibit the most resistance to snow mold must be planted. There are a few areas in zone 1, especially in eastern Idaho and at very high elevations, where winter cereals cannot be grown because the weather is too cold.

ZONE 2: ANNUAL CROP-WET-COOL

SD: depth not a factor
MAP: >400 mm (16 in)
CGDD: <700-1000

Soils in zone 2 (Figure 4, Table 1) are deep (>1 m [40 in]) and are ideally suited to crop production. Approximately 95 percent of the area is cultivated. Soils are almost entirely formed in deep loess, with minor amounts of alluvium and eolian sand. This zone includes the most productive soils of the region. However, they are very susceptible to water erosion. In Washington and Idaho this zone contains the area commonly known as the "Palouse." Loess can exceed thicknesses of 60 m (approximately 200 ft), especially in Whitman County, Washington (Gentry 1974). In Washington, Oregon (Umatilla County), and Idaho (Benewah and Latah Counties), soils are medium to moderately fine textured, moderate to high in organic matter, and nearly level to steeply sloping. Most soils in this part of the zone are Haploxerolls, Argixerolls, and Argialbolls with mesic temperature regimes. Representative series are Palouse, Athena and Thatuna. In Nez Perce and Lewis counties in Idaho soils are slightly higher in organic matter and have B horizons that are finer textured than the other areas of this zone. These soils are Argialbolls, Palexerolls, and Argixerolls. Nez Perce is a representative series. In the Grand Rhonde valley (Union County), Oregon, the soils are developed from loess, eolian sands and alluvium. The loess soils are similar to those found in the other areas of this zone. The alluvial soils in this valley are high in organic matter and commonly have poor drainage. They are classified as Haploxerolls and Haplaquolls. Alicel and Catherine are representative series.

Zone 2 includes wetter parts of the steppe land originally in the Palouse and Nez Perce prairies. Dominant perennial grass species include bluebunch wheat grass (*Agropyron spicatum* (Pursh) Scribner & J. G. Smith), Idaho fescue (*Festuca idahoensis* Elmer), and a variety of forbs (Daubenmire 1969). This zone receives slightly less precipitation than zone 1, but still greater than 400 mm (16 in) annually. Elevations are generally lower than in zone 1 and temperatures are slightly warmer; thus CGDD are higher (700-1000). However, with the intermittent snow cover, potential for winter injury still exists.

ZONE 3:ANNUAL CROP-FALLOW TRANSITION

SD: >1 m (40 in)
MAP: 350-400 mm (14-16 in)
CGDD: 700-1000

Zone 3 (Figure 4, Table 1), of which 90-95 percent is cropland, identifies areas of deep soils that occasionally have less than adequate precipitation for optimum crop production. Major soils have formed in loess and are medium to moderately fine textured with moderate amounts of organic matter. Landscapes are gently to strongly sloping. In Washington and Oregon these soils are classified as Haploxerolls and Argixerolls with mesic temperature regimes. Representative series are Walla Walla, Athena, and Broadax. Soils in southeast Idaho are Haploxerolls and Argixerolls with mesic and frigid temperature regimes. A representative series is Rexburg.

Zone 3 comprises land in the Palouse and Nez Perce prairies at slightly lower elevations than zone 2. In southeastern Idaho, it includes shrub-steppe vegetation characterized by an overstory of *Artemisia tridentata* Nutt. and bitterbrush (*Purshia tridentata* (Pursh) DC) interspersed with an understory of forbs.

ZONE 4: ANNUAL CROP-DRY
SD: <1 m (40 in)
MAP: 250-400 mm (10-16 in)
CGDD: <1000

Zone 4 (Figure 4, Table 1) identifies areas with soils that are generally less than 1 m (40 in) thick over bedrock or a restricting layer. Approximately 50 percent of the area is cultivated. Soils in this zone are developed in loess, glacial till and alluvium. They vary widely in texture, and some contain moderate amounts of coarse fragments. Soils of cental and southeastern Washington are developed in loess, glacial till or alluvium with basalt or a restricting layer at a shallow (<1 m) depth. These soils are Haploxerolls and Durixerolls with frigid and mesic temperature regimes. Representative series are Ritzville and Willis. In Oregon (Wasco, Sherman, Gilliam, and Morrow counties), and Washington (Klickitat county), soils are developed in loess over basalt or indurated hardpan. These soils classify as Haploxerolls, Durixerolls, and Argixerolls with mesic temperature regimes. Representative series are Morrow, Willis, and Condon. Soils in central and southern Oregon have developed in loess and alluvium over indurated hardpan, basalt, or other rock. These soils are classified as Durixerolls, Durargids, and Camborthids. Madras is a representative series.

Zone 4 receives 250-400 mm (10-16 in) precipitation yearly and is warm (generally 700-1000 CGDD but can be <700) with shallow soils, therefore, many vegetation types are included. Much of central Oregon, near the Cascade Mountains, is covered with dry, open, ponderosa pine or juniper forests. These areas grade into shrub-steppe and steppe vegetation often dominated by sagebrush (*Artemisia tritendata* Nutt.) and blue bunch wheatgrass (*Agropyron spicatum* (Pursh) Scribner & J. G. Smith). Sandier areas have indian ricegrass (*Oryzopsis hymenoides* (Roemer & Schultes) Ricker) and needle and thread grass (*Stipa comata* Trin. & Rupr.). Sandberg bluegrass (*Poa secunda* J. S. Presl) is common on rockier outcrops (Daubenmire 1970).

ZONE 5: GRAIN-FALLOW
SD: >1 m (40 in)
MAP: <350 mm (14 in)
CGDD: not a factor

Zone 5 (Figure 4, Table 1) identifies areas of deep (>1 m [40 in]) soils that receive limited rainfall (350 mm [14 in] or less). In Washington, and adjacent areas of Oregon, approximately 90 percent of this zone is cultivated. Soils are formed in deep loess, are low in organic matter, and are medium textured. These soils are very susceptible to wind and water erosion. Landscapes are gently sloping to moderately steep. Soils are Camborthids and Haploxerolls with mesic temperature regimes. Representative series are Shano, and Walla Walla. In Klamath, Lake, and Deschutes counties in Oregon, less than 20 percent of the zone is cultivated. Soils are formed in volcanic, alluvial, and lacustrine material. These soils are classified as Haploxerolls and Argixerolls. Representative series are Deschutes and Fordney.

Vegetation in this zone is primarily shrub-steppe in Washington and northcentral Oregon but ponderosa pine and juniper occur on the pumice soils in south-central Oregon near the high Cascades.

ZONE 6: IRRIGATED
SD: depth not a factor
MAP: not a factor
CGDD: not a factor

Zone 6 (Figure 4, Table 1) identifies areas that usually cannot be cultivated without irrigation There are also relatively small irrigated areas in all other zones from 1 through 5.

Native vegetation in zone 6 is generally steppe or shrub-steppe dominated by perennial shrubs and grasses. Soils are coarse to moderately fine textured, low in organic matter, and level to gently sloping. Many are gravelly to very gravelly. In Washington and Oregon, these soils are formed in eolian sands or silty alluvium. They are classified as Torripsamments or Camborthids with mesic temperature regimes. Representative series are

Quincy, Winchester, Sagehill, and Warden. Soils in southern Idaho are formed in loess or alluvium and are classified as Camborthids, Paleargids, Durorthids, Calciorthids, or Haplargids with mesic temperature regimes. Representative series are Gooding, Power, Minidoka, Trevino, and Portneuf. South-central and south-eastern Oregon soils are formed in thin loess and alluvium. They are Haploxerolls, and Durorthids with mesic temperature regimes. Representative series are Fordney, and Nyssa.

Discussion

The dryland Intermountain Northwest, which has a wintertime precipitation regime, is dependent primarily on soil water storage for crop growth. There must be enough water stored over winter, or over two winters, to supply the growing crop during the essentially rainless summer months. Since the major crop grown in the dryland areas of the Intermountain Northwest is winter wheat, we based the delineation of AZ on climatic and soil parameters important in winter wheat growth.

Cumulative growing degree days provide a reliable index to plant development (Rickman *et al.* 1985). The appearance of each successive leaf on the main stem of wheat is linearly related to CGDD with approximately 100 CGDD required for the development of each leaf. Tillers also appear in the same regular pattern at predictable intervals relative to main stem leaf number (Klepper *et al.* 1982). Dates of 1 January to 31 May were chosen for the accumulation of degree days because all winter cereals, regardless of planting date, pass through this time interval. Many of the important temperature-sensitive, yield-determining growth events, such as number of heads per unit of land surface, number of spikelets per head, number of kernels per spikelet, and size and vigor of the last three leaves on each culm, occur during this period.

Since water is the basic resource and is limiting for crop production, AZ can be used to assess the potential for other winter crops such as barley or rapeseed. Most of zone 1 is actually forest and much of zones 4 and 5 is presently rangeland. Forest and rangeland is not delineated, but is included in the zone in which it would fit if it were cropped. These six AZ for the intermountain Northwest may not be useful where wintertime rainfall is not predominant and crops do not depend on soil moisture stored overwinter. However, criteria and concepts should be expandable to develop similar zones in other dryland agricultural areas.

Zones 1 and 2 differ only in CGDD; <700 and 700-1000, respectively. Erosion by water is severe in both zones and annual cropping should be practiced to decrease the erosion potential. Annual cropping helps deter soil erosion by water by keeping the soil surface covered for longer periods of time than if summer fallow was used. Some form of chisel tillage may help increase water infiltration, and subsequently decrease surface water movement down slopes, during winter and early spring in heavy frost areas of eastern Idaho (Massee and Siddoway 1969).

Zone 3 differs from zone 2 in that it is drier (350-400 mm [14-16 in] MAP), therefore, is marginal for annual cropping. Annual cropping can be done approximately 70 percent of the time (personal communication, Dr. Robert Ramig, USDA-ARS, Pendleton, Oregon). In some years annual precipitation will recharge the deep profiles but in drier years it will not. Even though zone 3 falls within the 700-1000 CGDD zone as does zone 2, it requires more careful attention to water management than do either zones 1 or 2.

Zone 4 has very little annual cropping being practiced at this time. However, because soils are <1 m (40 in) to bedrock or an impermeable layer, they are normally recharged completely with one winter's precipitation. Annual cropping would result in more efficient soil water use and reduced soil loss to water erosion. Consequences of erosion are very serious because soils are already shallow. Fallowing almost always guarantees soil loss by water erosion every crop year. Some years, timing of precipitation is such that rains do not begin until it is too late in the fall for germination and emergence of winter cereals before winter. Rotations including early seeded spring cereals would be ideal for this zone.

There is a slight MAP difference between zones 4 and 5 (Table 1) but the major difference is in SD. Zone 5 has deep soils (>1 m), precipitation is low (<350 mm), and the soil profile is not recharged with water in the first winter following harvest, as are soils in zone 4. Temperature is not a factor in this zone as precipitation is dominant. Therefore, the recommended rotation is crop-summerfallow which allows for improved recharge of soil water and maximum water use by the crop.

Soil erosion by water during the summer-fallow season, although severe, is not as severe as summerfallow in zone 4.

Large areas of zone 6 in southcentral Washington and southern Idaho have within their boundaries areas receiving <250 mm (10 in) precipitation that utilize a grain-summerfallow rotation. These are usually areas of silt loam soils that because of the low MAP produce very low grain yields (1.3-1.7 Mg ha^{-1} [20-25 bushel $acre^{-1}$] every other year). Less than 20% of this zone is cropland. Much of zone 6 receives less than 250 mm (10 in) of precipitation annually and has a very high evaporation rate.

Major Land Resource Regions (MLRR's) and Major Land Resource Areas (MLRA's), in another land use classification system (USDA 1981), have been in widespread use for resource planning for farming, ranching, forestry, engineering, recreation, and other uses. MLRA's are geographically associated land resource units "characterized by a particular pattern of soils, climate, water resources, and land uses" (USDA 1981). MLRA's were designed to help "make decisions about national and regional agricultural concerns, identify needs for research and resource inventories, provide a broad base for extrapolating the results of research within national boundaries, and serve as a frame-work for organizing and operating resource conservation programs. Identification of these large areas is important in statewide agricultural planning and has value in interstate, regional, and national planning" (USDA 1981). Agroclimatic zones (Figure 4, Table 1) are different from MLRA's in that they are associated land areas characterized by particular patterns of SD, MAP, and temperature, that require similar management practices for production of winter cereals in Idaho, Oregon, and Washington. They are important in local, intrastate, and inter-state technology transfer and planning, and provide a base for extrapolating the results of research and farming practices across state boundaries. They provide a common basis for identifying areas where successful exchange of practices, experience, and knowledge will be most likely between and among producers, researchers, extension, and Soil Conservation personnel. Each zone has approximately the same climatic and soil depth conditions regardless of the state in which it is located, and decisions that produce the desired results in one zone in one state should work in the same zone in any other state. Conservation tillage practices and erosion control techniques should be similar within but not between zones.

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Received 8 February 1991
Accepted for publication 31 July 1991

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