Photo: Lynn Ketchum, © Oregon State University

Chris Williams plants winter wheat near Pendleton, Ore. Extensive areas of the inland Northwest are used for growing grains.

Agronomic Zones of the Dryland Pacific Northwest

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The production of wheat and other small grains is important to the economies of Idaho, Oregon, and Washington. Producers harvest 4.2 million acres of wheat, valued at $2.1 billion, each year. But climate, soils, and topography can vary greatly across this landscape, and it's important for producers to leverage the conditions specific to their fields so they can adapt farming practices and better respond to changes in precipitation and threats posed by pests and disease.

Extensive areas of the inland Northwest are well suited to dryland production of small grains, mustards, and legumes. The majority of wheat acreage is cultivated in rotation with summer fallow. Producers rotate a much smaller portion of wheat acreage with legumes, alternative crops, and other small grains such as barley or triticale.

What is an agronomic zone?

Landscapes vary from small spatial scales, such as within one farm, to large spatial scales, such as across a state. Agronomic zones take those variabilities and make relevant generalizations to categorize the landscape into zones with similar characteristics. In the dryland Pacific Northwest, agronomic zones are defined by precipitation, soil depth, and growing degree days. Growers and stakeholders can use generalizations to identify the agronomic zone or zones that best fit their individual farms or fields. Once identified, agronomic zones provide producers a basis for applying research and management strategies.

Based on published studies and climate data, agronomic zones were defined to allow delineation of areas that are agronomically similar for dryland production. Agronomic zones can be used as a reference for comparing, interpreting, and extrapolating research results; they serve as a basis for implementing new technologies and improving management practices.

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Although farmland in this region is highly productive, every year growers face production uncertainties and economic difficulties because of seasonal variability. Unpredictable fluctuations in seasonal weather conditions can impact the production system and influence infestations of weeds, diseases, and insects. Over time, farming systems in this region have evolved to minimize the uncertainties of production. Management strategies have focused on specific zones as research, technology, and varieties have improved to address the challenges presented in those zones.

Climate change

Climate change is causing land and ocean temperatures to increase all over the world, giving rise to more extreme weather events. Producers in the Pacific Northwest are likely to see more variability in precipitation rates and temperatures.

The regions most vulnerable to these changes contain both small- and large-scale agricultural production. These regions face increasing challenges under changing global, regional, and local climate dynamics.

Climate change exacerbates seasonal uncertainties. Predicted temperature extremes and extreme precipitation events will impact the way agronomic zones are classified and the extent to which their boundaries shift over time. In addition, increasing temperatures in the Pacific Northwest are linked to longer frost-free seasons, which will influence winter wheat dormancy and the overwintering of pests and diseases. Seasonal temperature and precipitation changes at smaller regional scales may provide a better picture of climate impacts that could otherwise be overlooked with mean annual temperature data. Since 1980, few years have had below average annual mean temperatures. In fact, 1998–2007 was the warmest 10-year period in the PNW since 1900. (Few U.S. Historical Climatology Network stations existed before 1900.) Temperature increases of 3 to 4 °F are expected in the Pacific Northwest by the 2050s, with annual average warming of 4 to 6.5°F projected by 2100. Agronomic zones will need to be updated to reflect regional responses to climate. Growers should re-evaluate variety selection, pest management, and cultural agronomic practices on an annual basis.

Why use an agronomic zone?

Agronomic zones are an important tool for producers, crop consultants, and stakeholders, especially when considering the adoption of new technologies. Some management decisions directly related to agronomic zones include planting dates, variety selection, residue management, tillage practices, disease management, weed management, and crop rotations.

Research efforts continually generate new infor-
mation and increase the type and number of cultural practices available to growers. However, several factors can sometimes hinder adoption:

- Complexity of soils
- Weather conditions
- Relief and topography of the region
- The relative costs and benefits of adopting new technology

Dryland farming practices that are successful in one region are often not suitable in another because of one or more of these factors.

Producers will need to evaluate and test new technologies and practices under their own conditions. Agronomic zones allow scientists, agricultural professionals, and producers to more effectively communicate results of scientific investigations and to promote the transfer and adoption of new farming technologies.

Three criteria define each agronomic zone: annual precipitation, soil depth, and growing degree days.

Precipitation

CRITERION DESCRIPTION

Precipitation is the single-most limiting factor to dryland crop production in the Pacific Northwest. Agronomic zones are defined by four classes of annual precipitation (Table 1).

Table 1. Classes of annual precipitation

Moist More than 16 in. (400 mm)	This amount of annual precipitation is generally sufficient to recharge a 5-foot soil profile and support annual cropping.
Moderately dry 14–16 in. (350–400 mm)	Annual crop production in areas receiving precipitation in this range is marginal. In wetter years, annual cropping can be practiced; in drier years, summer-fallowing is preferable.
Dry 10–14 in. (250–350mm)	Crop production in areas receiving this range is strongly influenced by soil depth. Deep soils with high water storage capacity can be summer-fallowed to maximize production and water-use efficiency. Shallow soils or those with limited water storage capacity recharge each year, and water-use efficiency will not be improved by summer-fallowing.
Very dry Under 10 in. (250 mm)	This is the approximate limit of crop production without irrigation.

PRECIPITATION DATA

Gridded precipitation and growing degree day data were acquired using Oregon State University's Parameter-elevation Relationships on Independent

Slopes Model, or PRISM, spatial climate datasets within Google Earth Engine. The map used the long-term average (1981–2010) as the precipitation feature variable.

Soil depth

CRITERION DESCRIPTION

Dryland agricultural soils in the inland Pacific Northwest usually range in texture from silty clay loam to silt loam to fine sandy loam. These textures store approximately 1.6 to 2 inches of water per foot of soil.

Because of this narrow range, the potential water storage capacity of most soils is a function of depth to bedrock or root-restricting layer. Soil depth, along with crop season precipitation, is a reasonable indicator of plant-available water.

Two depth classes are used to define agronomic zones (Table 2).

Table 2. Depth classes

Deep 40+ in. (100 cm) to bedrock or root-restricting layer	In general, annual precipitation must exceed 16 in. for soil profiles of this depth to fully recharge each year.
Shallow Under 40 in. (100 cm) to bedrock or root-restricting layer	Soils profiles of this depth generally recharge each year, even when annual precipitation is as low as 10–14 in.

SOIL DEPTH DATA

Soil depth data was acquired for each state from the Soil Survey Geographic database provided by the USDA Natural Resources Conservation Service (http://soildatamart.nrcs.usda.gov). SSURGO is a compilation of county and state soil surveys at a 1:24,000 map scale.

The SSURGO feature "depth to bedrock" was used to estimate soil depth for the agronomic zone map. That variable did not exist for the entire study area; SSURGO data often display spatial discontinuities at the county and state levels, and some surveys do not include the entire breadth of soil features. To overcome this, a nearest neighbor interpolation model was run to fill in gaps.

Growing degree days

CRITERION DESCRIPTION

Growing degree days are a measure of heat available for plant growth. They can be used to predict rate of crop development.

Cumulative GDD for winter wheat are calculated by adding daily maximum and minimum air temperatures (degrees Celsius), dividing by two, discarding values less than zero, and summing the GDD values.

Values less than zero are discarded because cereal plants are dormant below freezing. Agronomic zones are based on total GDD acquired Jan. 1–May 31 because winter crops will all experience this part of the growing season, regardless of planting date.

GDDs are broken into three classes (Table 3).

Table 3. Growing degree days

Cold Under 700 GDD	Winter temperatures are cold, and snow typically covers the ground for extended periods. Cold injury to plants is a common threat, and the growing season is shorter than optimum.
Cool to warm 700–1,000 GDD	Winter temperatures are not excessively cold, and snow cover does not exist for extended periods. Cold injury usually is not a problem. Temperatures during final grain ripening are warm to hot, but evaporation is not excessive. This range is considered optimum for winter cereal production.
Hot Over 1,000 GDD	Temperatures during final grain ripening are hot, and evaporation is very high. Water stress is a frequent problem, and crop production is usually not feasible without irrigation.

GDD DATA

In addition to long-term averages, daily PRISM datasets also exist from 1981 to present. Within Google Earth Engine, per-pixel (800m) GDD values were calculated for each year from 1981 to 2010 to match precipitation data and then averaged to create a single GDD value as input for the map.

Agronomic zones

Annual precipitation, soil depth, and GDD were combined to define six agronomic zones for the Pacific Northwest east of the Cascade Mountains (Table 4, page 6).

Using agronomic zones

The map on pages 4–5 shows the distribution of agronomic zones. Each zone represents an area relatively uniform in agronomic characteristics for dryland production, and each provides a geographical base for

Six agronomic zones for the dryland Northwest
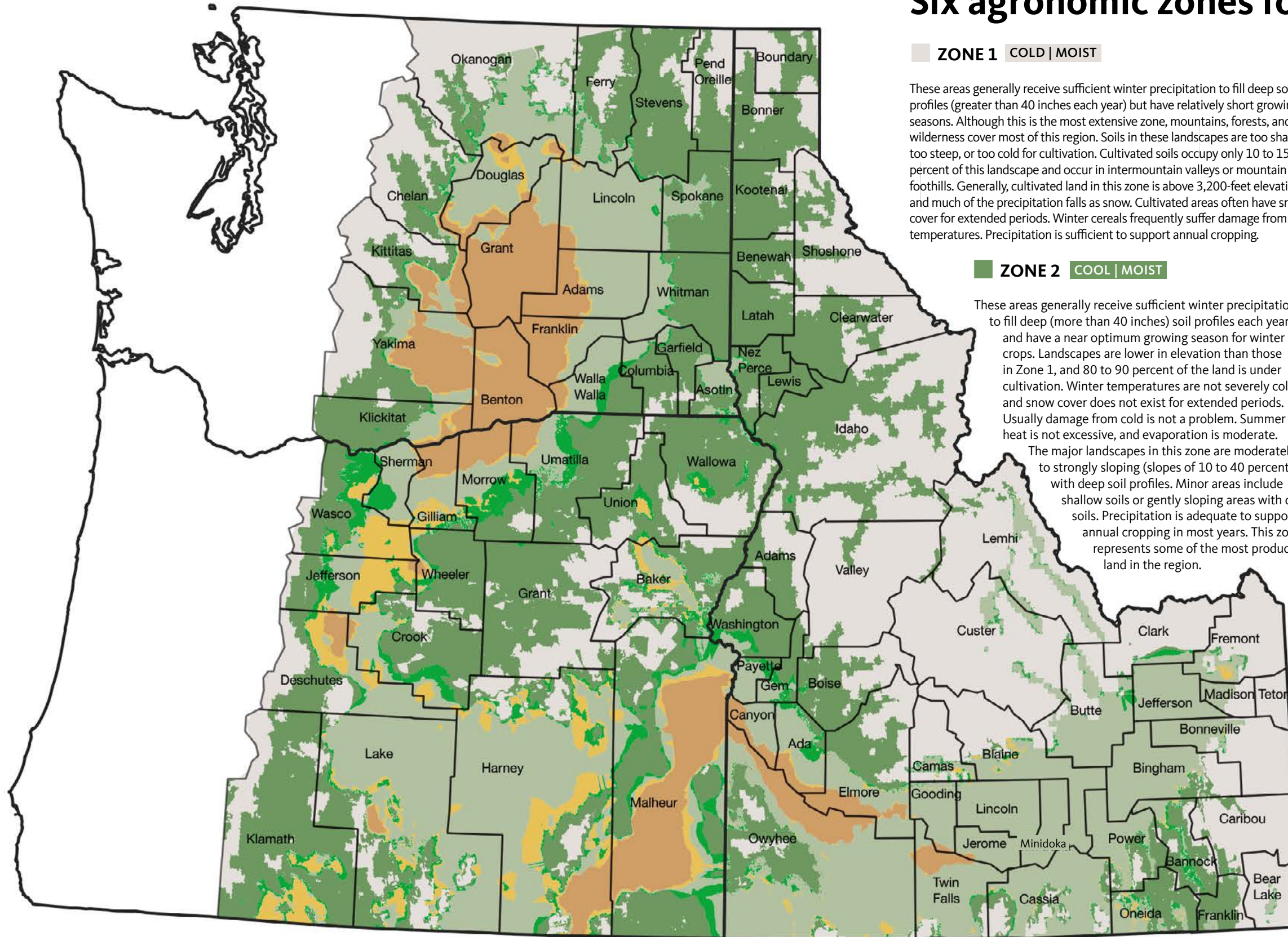
ZONE 1 COLD | MOIST

These areas generally receive sufficient winter precipitation to fill deep soil profiles (greater than 40 inches each year) but have relatively short growing seasons. Although this is the most extensive zone, mountains, forests, and wilderness cover most of this region. Soils in these landscapes are too shallow, too steep, or too cold for cultivation. Cultivated soils occupy only 10 to 15 percent of this landscape and occur in intermountain valleys or mountain foothills. Generally, cultivated land in this zone is above 3,200-feet elevation, and much of the precipitation falls as snow. Cultivated areas often have snow cover for extended periods. Winter cereals frequently suffer damage from cold temperatures. Precipitation is sufficient to support annual cropping.

ZONE 2 COOL | MOIST

These areas generally receive sufficient winter precipitation to fill deep (more than 40 inches) soil profiles each year and have a near optimum growing season for winter crops. Landscapes are lower in elevation than those in Zone 1, and 80 to 90 percent of the land is under cultivation. Winter temperatures are not severely cold, and snow cover does not exist for extended periods. Usually damage from cold is not a problem. Summer heat is not excessive, and evaporation is moderate. The major landscapes in this zone are moderately to strongly sloping (slopes of 10 to 40 percent) with deep soil profiles. Minor areas include shallow soils or gently sloping areas with deep soils. Precipitation is adequate to support annual cropping in most years. This zone represents some of the most productive land in the region.

ZONE 3 COLD | DEEP | MODERATELY DRY

These areas have deep soils (more than 40 inches) and a near optimum growing season, where there is enough winter precipitation to recharge the soil profile in most years. With proper rotations and management techniques, growers can practice annual cropping in most years. Summer fallowing in drier years may be necessary to maximize production and make efficient use of water. About 90 percent of this zone is cropland. Most landscapes in this zone are gently to strongly sloping (slopes of 10 to 40 percent) with deep loess soils over basalt bedrock or hardpan.

ZONE 4 COOL | SHALLOW | DRY

These areas have shallow soils (less than 40 inches) and near optimum growing seasons. Although the annual precipitation is low, the shallow soils fill with water most winters. Summer-fallowing has little advantage from the standpoint of water conservation or water use. Annual cropping provides the most efficient use of these soils. A typical landscape in this zone consists of gently to steeply sloping (slopes of 4 to 30 percent) loess soils over basalt of root-restricting layer at shallow depths. About 50 percent of this zone is cultivated.

ZONE 5 COOL | DEEP | DRY

Zone 5's areas have deep soils (more than 40 inches) and near optimum growing seasons but receive insufficient winter precipitation to fill the soil profile. Because of these conditions, it is practical to increase production and water-use efficiency by summer fallowing. Typically, landscapes in this zone consist of gently to moderately sloping, deep, loess soils over basalt bedrock or Pleistocene flood deposits. About 90 percent of this zone is cultivated. Soils in this zone are low in organic matter, medium textured, and susceptible to wind erosion. Landscapes are gently sloping to moderately steep.

ZONE 6 HOT | VERY DRY

This zone identifies areas that typically receive very low annual precipitation and have hot summers with high evaporative demands. These areas are unsuited for crop production unless irrigated. Included in this zone are small areas that, without irrigation, would fall in zones 1 through 5. About 50 percent of this zone is cropland. Soils in this zone are quite variable; many are sandy loam (coarse in texture). Some are gravelly at shallow depths, which accentuates drought conditions.

HOW THIS MAP WAS MADE: Soils data were converted from vector format to raster at an 800m spatial resolution and grid, matching both precipitation and GDD inputs. Then, a per-pixel decision tree classification model was run with criteria for each individual zone. Pixels missing soil features were stored as no-data. After running the zone classification, an interpolation model to fill gaps in data was run; the model was run using inverse distance weighting and a maximum search neighborhood of 10 pixels. The result is a continuous raster of all six agronomic zones.
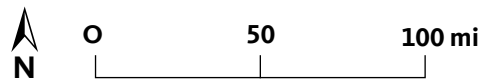
Table 4. Agronomic zone criteria for the Pacific Northwest east of the Cascade Mountains

Zone	Description	Growing degree days	Soil depth (in)	Annual precipitation (in)
1	Cold-moist	Under 700	All	Over 16
2	Cool-moist	700–1,000	All	Over 16
3	Cool-deep-moderately dry	700–1,000	Over 40	14–16
4	Cool-shallow-dry	Under 1,000	Under 40	10–16
5	Cool-deep-dry	Under 1000	Over 40	10–14
6	Hot-very dry	Over 1000	All	Under 10

applying or extrapolating research results or management recommendations.

Research conducted at a certain point within a zone may be applied throughout that zone. Likewise, management practices valid for a single location may be applied throughout that zone.

Exercise caution in applying this map. It was designed as a general tool for assisting with agronomic zone classification. Individual farming and cropping practices may alter zone applications. Complex soil patterns cannot be shown effectively at this scale. For instance, a farm may include more than one agronomic zone, but only a large-scale map (too cumbersome for this publication) could accurately show this detail. Producers, consultants, and agency employees can use agronomic zones to describe field and farm characteristics.

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