

Introduction

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The Pacific Northwest is an important wheat production region. In 2015, the National Agricultural Statistics Service indicated that Washington, Idaho, and Oregon harvested more than 240 million bushels of wheat, worth an estimated \$1.3 billion. The major areas of production in the inland Pacific Northwest are shown below, and incorporate both irrigated and dryland acreage.



The Columbia Plateau ecoregion, commonly referred to by growers as the inland Pacific Northwest.

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The area includes three major land resource areas with distinctive geologic features and soils as defined by the US Department of Agriculture: the Columbia Basin, the Columbia Plateau, and the Palouse and Nez Perce Prairies, all of which are within the Northwestern Wheat and Range Region. It also includes a small portion of dryland cropping in the North Rocky Mountains major land resource area, adjacent to the eastern edge of the Palouse and Nez Perce Prairies. In the dryland areas, which are the focus of this book, wheat is grown in rotation with crop fallow and much smaller acreages of other small grains, legumes, and alternative crops.

This area, identified from here forward by the more familiar term “inland Pacific Northwest,” encompasses great diversity, characterized by some common overarching patterns of climate, geography, and agriculture. The inland Pacific Northwest extends eastward from the Cascade Mountain Range in Washington and Oregon into parts of northern Idaho. The landscape includes glacial deposits, coulees, channeled scablands, and rolling terrain with deep, fertile soil. The climate is semi-arid, with cool, wet winters and hot, dry summers.

Across the dryland wheat production areas, there are three major agroecological classes (AECs), with different patterns of cropping:

- Grain-Fallow AEC (defined as areas with greater than 40% fallow)
- Annual Crop-Fallow Transition AEC (with 10–40% fallow)
- Annual Crop AEC (with less than 10% fallow)

There is a considerable precipitation gradient across the region, with drier conditions in the rain shadow immediately east of the Cascades and wetter conditions further inland. The Grain-Fallow AEC is associated with lower precipitation areas, while the Annual Crop AEC is generally, but not always, associated with areas that receive higher levels of precipitation. These AECs, further described in Chapter 1, are dynamic and change as land use and land cover shift over time—with the potential to be influenced by climate, soils, terrain, land and commodity prices, and other factors. Because many recommendations in this book are specific to a farm’s AEC characteristics, research results have been coded accordingly: Grain-Fallow ■; Annual Crop-Fallow Transition ▲; and Annual Crop ●. On the first page of each chapter, we have included a legend to help readers easily identify these symbols and the information most pertinent to their AEC.

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Climate has always had a dominant influence on dryland production in this region, shaping crop choices, agronomic management systems, and conservation efforts. Though farmers are already highly skilled managers in the context of variable temperature and precipitation patterns, climate change is expected to add uncertainty, stretching the limits of existing management systems. Projected climate change also brings new urgency to questions of sustainability, as changing seasonal climate patterns may exacerbate conditions that have been historically linked to major soil erosion events in the region.

The inland Pacific Northwest has long faced challenges of soil erosion, soil organic matter depletion, and consequent soil fertility loss. One strategy for overcoming these challenges is managing for improved soil health through building and maintaining the continued capacity of soil to function as a vital living ecosystem that sustains plants and animals. Management of other biological, physical, economic, and policy components are also important for achieving a system that can sustain food and fuel production over the long term.

In light of ongoing and new challenges being faced by farmers in the region—and recent significant investments in research to help address these challenges—it is an opportune time to synthesize research-based advances in knowledge to support farmer decision-making and improve the long-term productive capacity of farmland in the region. This book should be viewed as a resource that launches further inquiry rather than an end point. Accordingly, the book includes both citations and links that direct readers to additional resources for more in-depth information. Additional and updated research-based information can also be found through several channels, including:

- The Regional Approaches to Climate Change (REACCH) project website, which houses information resulting from this wide-ranging research effort.
www.reacchpna.org
- The Extension Libraries for University of Idaho, Washington State University, and Oregon State University.
- The WSU Wheat and Small Grains website.
<http://smallgrains.wsu.edu/>

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- The WSU Oilseed Cropping Systems website.
<http://css.wsu.edu/biofuels/>
- The University of Idaho AgBiz website, which houses Extension economics information.
www.idahoagbiz.com
- The Agriculture Climate Network, a site providing up-to-date information about research relevant to agriculture and climate change in the Pacific Northwest.
<https://www.agclimate.net/>
- The NW Climate Hub, an effort by the USDA to deliver science-based knowledge and practical information to farmers, ranchers, forest landowners, and Native American tribes that will help them adapt to climate change.
<https://www.climatehubs.oce.usda.gov/northwest>
- The joint USDA-WSU Long-Term Agroecosystem Research (LTAR) site provides information relating to long-term dryland cropping systems in the region.
<http://ltar.wsu.edu/>

This book represents a joint effort by a multi-disciplinary group of research and Extension scientists from across the region. The undertaking was made possible with the support of the USDA National Institute of Food and Agriculture through the REACCH project. This six-year project aimed to enhance the sustainability of Pacific Northwest cereal systems and contribute to climate change mitigation. The REACCH project, led by the University of Idaho, also convened scientists from Washington State University, Oregon State University, the USDA Agricultural Research Service, and Boise State University. In addition to supporting a number of ongoing research and Extension activities and experimental sites across the region, the project provided an opportunity for new projects and collaborations.

Advances in Dryland Farming in the Pacific Northwest is organized into topical chapters that cover major management challenges for dryland farming in the region. Topics are interrelated, and we attempt to make links between chapters clear to the reader throughout.

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Chapter 1, *Climate Considerations*, describes the temperature and precipitation patterns that have historically defined crops, yields, and cropping systems across the inland Pacific Northwest. Year-to-year variability in temperature and precipitation have also been an important feature. Human-caused climate change is forecasted to increase the frequency of temperature-induced drought conditions and late summer water deficits, with these changes likely to surpass historic year-to-year climate variability by mid-century. The frequency and severity of extreme weather events will also increase, and may increase production risk. Meanwhile, increased atmospheric carbon dioxide may benefit yields by increasing energy and water use efficiencies. The overall impact of these various factors is likely to vary across the region.

Chapter 2 introduces the concept of *Soil Health* and describes its vital role in sustainable agricultural production. It describes how measurement of the soil's physical, chemical, and biological indicators can be used to assess soil health, though the high degree of spatial variability in the region's soils poses challenges for the selection of indicators sensitive to management in soil quality assessment programs. Nonetheless, adaptive management appropriate to a specific site can benefit soil health, using practices including reduced tillage, cropping intensification, crop diversification, crop residue retention, and application of organic amendments.

Conservation Tillage Systems, Chapter 3, describes the challenges that are presented by conventional tillage-based cropping systems, including soil erosion, soil organic matter depletion, and soil fertility loss. It also describes how conservation tillage systems have been improved and increasingly adopted by growers in the inland Pacific Northwest to address these challenges. Appropriate conservation tillage systems vary across the inland Pacific Northwest, and successful implementation is influenced by crop rotations, equipment choices, residues, soil fertility, economics, and other factors.

The challenges of *Crop Residue Management*, covered in Chapter 4, vary across the region. Heavy residue produced in high-yielding areas can make planting difficult and contribute to unfavorable growing conditions in the early spring. In contrast, in areas with low or intermediate yields, additional residue is desired for enhancing soil and water conservation.

Strategic conservation of crop residue is important for preventing wind and water erosion, enhancing soil water recharge, maintaining soil health, and returning nutrients to the soil. Different residue management strategies, including conservation, harvest, and burning, involve tradeoffs between production, economics, environment, and soil and human health. Calculating immediate economic tradeoffs at the field scale and the within-field scale can support decisions about residue management practices.

Chapter 5 covers *Rotational Diversification and Intensification*. Diversity is low in the wheat-dominated cereal production systems of the inland PNW. Diversifying or intensifying cropping systems can help growers minimize lost production opportunities, improve farm productivity, increase grower income and flexibility, adapt to forecasted climate change, and achieve long-term environmental benefits. These can benefit wheat yields elsewhere in the rotation, an economic benefit that should be accounted for when evaluating potential returns for alternate crop rotations. However, adopting alternative rotations comes with tradeoffs and can also increase risk. Success depends on geographic location, production potential, rotational fit, market opportunity, crop price, and production costs. Specific diversification strategies of interest include inclusion of legumes and oilseeds. Meanwhile practices such as undercutter tillage fallow, no-till fallow, or flex cropping can build soil resiliency and increase opportunities for diversification and intensification in tilled grain-fallow systems.

Chapter 6 discusses *Soil Fertility Management*, which varies depending on precipitation gradients and landscape position that together affect crop fertilizer accessibility, nutrient use efficiencies, and growth. Practices that maximize nitrogen use efficiency include fertilizer placement, source, timing, and rates that match the nitrogen needs of the crop species and variety being grown. Appropriate management strategies and regular soil testing, along with quality recordkeeping, can reduce nutrient loss. This, in turn, can improve farm profitability and reduce the harmful effects of nutrients on air, water, and soil quality. Decreasing soil pH, due mostly to application of nitrogen fertilizers, along with plant nutrient uptake and precipitation, is a growing concern in some areas of the inland Pacific Northwest. Acidification can make nutrients less available to plants and can have a variety of other negative impacts that can decrease yields if not

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addressed. The chapter also discusses other nutrients such as sulfur and phosphorus that are necessary for wheat crops, but are less susceptible than nitrogen to being depleted annually.

Soil Amendments, the topic of Chapter 7, have historically had limited use in dryland systems of the inland Pacific Northwest, but could improve soil health by benefitting soil carbon, nutrient availability, soil structure, water infiltration and retention, bulk density, and microbial activity. Biosolids can be used by conventional producers, but not certified organic producers, and may be available at relatively low cost, though supply is limited. Manures and composts can be an important resource for building or maintaining soil quality for producers in proximity to concentrations of livestock. Manures with higher nutrient concentrations may be an important nutrient source for some certified organic dryland producers, though cost can be an issue.

Chapter 8, *Precision Agriculture*, describes how technology can be used to manage within-field variability. In cases where variability in the major factors that affect crop yield and quality can be accurately measured at scales relevant to farm management, and when this information can be used to improve the efficiency of crop input use, precision agriculture has the potential to improve yields and crop quality, increase economic returns, and decrease environmental impacts from excessive input use. Precision agriculture technologies can also be used to monitor crop and field variability and help diagnose problems that occur across fields and years.

Integrated Weed Management is discussed in Chapter 9. An integrated approach relies on knowledge and application of ecological principles, including an understanding of weed biology, plant interference, and weed-crop competition. Successful long-term approaches emphasize growing healthy, competitive crops in an effective cropping sequence supported by appropriate use of a variety of preventative, cultural, mechanical, and chemical strategies. Judicious use of herbicides alongside other strategies can ensure that weed management is effective, economical, and prevents the development or spread of herbicide-resistant weed biotypes. Management of selected problematic weeds of inland Pacific Northwest grain production is discussed: downy brome, Russian thistle, jointed goatgrass, and Italian ryegrass.

Disease Management for Wheat and Barley is discussed in Chapter 10. Successful disease management relies on integrated strategies including prevention, avoidance, monitoring, and suppression. The specific implementation of these strategies varies by pathogen and cropping system. This chapter presents information on geographic distribution, disease cycle, diagnostic features, conditions that favor disease, and management practices for selected diseases that affect inland Pacific Northwest cereal production, including stripe rust and those caused by soilborne fungal pathogens and nematodes. For many soilborne pathogens, genetic resistance or chemical controls are not available, and growers rely on cultural practices to favor plant health. System-wide monitoring of crop response is an important tool to determine if changes in cropping practices, or climate effects, reduce the effectiveness of current management strategies.

Chapter 11 discusses *Insect Management Strategies*. Similar to weeds and diseases, effective management of insect pests relies on an integrated approach. That depends on an understanding of each species' distribution, life cycle, crop damage caused, and potential control strategies. The chapter reviews the basic principles of integrated pest management and the implications of technology, a changing climate, and invasion by new pests. It offers summaries of the biology and management for 16 of the most important pests or pest complexes as well as what is known of their responses or potential responses to climate change. These responses are likely to occur through mechanisms including changes in the timing of pest activity, shifts in the geographical range of pests, reductions in the time needed for life cycle completion, and an increased number of generations per year. Finally, this information is placed within the context of the larger agroecosystem and production landscape.

Farm Policies and the Role for Decision Support Tools is the topic of Chapter 12. Policy influence occurs through avenues including the development of risk management options, management recommendations and incentives, and the adoption of agricultural technologies. These influences, in turn, affect management practices in inland Pacific Northwest grain production systems including use of conservation tillage, residue and soil water management, crop rotations, and pest management. The use of spatially explicit data and regional impact models will likely play a larger role in

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the design and implementation of future farm policies. Decision support tools can also be used to examine the impacts of a targeted conservation policy.

Considering all of the challenges facing dryland agricultural systems in the inland Pacific Northwest, the future can seem more daunting than ever. Fortunately, there is also evidence of significant overlap in the practices that may benefit farmers' bottom lines, enhance long-term productivity and resilience, and reduce dryland farming's contribution to atmospheric greenhouse gases. For example, reducing periods of fallow can potentially increase farm productivity and income, while also increasing the amount of residues that are incorporated into the soil over time. This can enhance soil organic carbon levels, providing a range of benefits in terms of improved soil structure, reduced soil compaction, improved water infiltration, and improved water holding capacity. All of these enhance productivity and resilience over the long run. Meanwhile, increased soil organic carbon allows carbon dioxide to be stored in the soil, reducing atmospheric carbon levels.

These and other practices may create win-win-win strategies: a win for producers by enhancing farm profitability, a win for sustainability and long-term productivity, and a win for climate. The table below summarizes some potential win-win-win strategies for the dryland agricultural systems of the inland Pacific Northwest. While promising, the win-win-win strategies identified here do not fully define a path toward a productive future in the context of a changing climate. There are still many gaps in our knowledge of dryland farming, key barriers that remain to be overcome before some promising strategies can be fully adopted, and uncertain futures in the region.

To be successful, growers need to be highly skilled in evaluating and applying knowledge and experience according to their site-specific context and needs. Research-based recommendations in the book may conflict with each other depending on the specific problem that is a priority for management. Growers will need to exercise caution in the application of information and recommendations contained in this volume based on an understanding of these tradeoffs. Utilizing farmer mentors, knowledgeable technical support providers, and University, USDA, and private-sector researchers will better enable growers to build

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Win-win-win strategies can enhance farm profitability, climate, and long-term farm productivity.

Management Strategies	Short-Term Benefits (1-10 years)	Long-Term Benefits (40+ years)
Reduced Tillage/ Direct Seeding	<ul style="list-style-type: none"> • Decreased soil erosion and nutrient runoff • Increased SOM and improved soil quality • Increased nutrient cycling and storage 	<ul style="list-style-type: none"> • Reduced GHG emissions by storing soil C
Crop Intensification-Reduce Fallow	<ul style="list-style-type: none"> • Increased food, fuel, and feed production • Increased farm productivity and income 	<ul style="list-style-type: none"> • Removes additional CO₂ from atmosphere by increasing photosynthesis • Increased straw biomass and soil C sequestration
Crop Diversification-Legumes	<ul style="list-style-type: none"> • Improved control of pests and grass weeds using broadleaf crop in rotation • Reduced N fertilizer costs using biological nitrogen fixation 	<ul style="list-style-type: none"> • Reduced GHG emissions and natural gas use during N fertilizer production • Reduced reactive soil N that leads to GHG emissions
Crop Diversification-Oilseeds	<ul style="list-style-type: none"> • Improved control of pests and grass weeds using broadleaf crop in rotation • Improved soil structure and water infiltration with canola's strong taproot • Glyphosate-resistant canola is the only Roundup-ready crop that can be grown in PNW rotations 	<ul style="list-style-type: none"> • Increased net productivity, photosynthesis and C fixation • Reduced atmospheric CO₂ through increased soil C sequestration • Reduced GHG emissions and improved N cycling • Avoid summer heat and drought stress with a short season crop

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Win-win-win strategies can enhance farm profitability, climate, and long-term farm productivity.

Management Strategies	Short-Term Benefits (1-10 years)	Long-Term Benefits (40+ years)
Customize Wheat Class and Variety to AEC	<ul style="list-style-type: none"> • Potential to improve protein premiums • Improved overall regional wheat quality and market reputation • Match heat and drought tolerance to AEC • Potential to adapt to pest variability 	<ul style="list-style-type: none"> • Improved resource efficiency and lower loss, as crops are better suited to environment • Tolerant varieties are more adaptable to climate change and associated concerns
Precision N Management	<ul style="list-style-type: none"> • Reduced N fertilizer costs • Reduced N over-fertilization that can reduce yields • Reduced N runoff and loss 	<ul style="list-style-type: none"> • Reduced GHG emissions and natural gas use during N fertilizer production • Reduced reactive soil N that leads to GHG emissions
Recycle Organic Byproducts as Soil Amendments	<ul style="list-style-type: none"> • Increased SOM and improved soil quality • Reduced N fertilizer costs • Recycled valuable nutrients • Reduced landfilling of biological wastes 	<ul style="list-style-type: none"> • Reduced GHG emissions and natural gas use during N fertilizer production • Tightened global nutrient cycle reduces GHG emissions

Table by Bill Pan and Kristy Borrelli.

Abbreviations: SOM = soil organic matter; C = carbon; CO₂ = carbon dioxide; N = nitrogen; AEC = agroecological class; GHG = greenhouse gas; PNW = Pacific Northwest.

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on the information contained in this volume. Ultimately, the best hedge against the impact of climate change is highly skilled and creative farmers utilizing the best available research and management information to make decisions in an uncertain context.

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