RETROSPECTIVE SIMULATION ANALYSIS OF DUAL-PURPOSE AND GRAIN-ONLY WHEAT PRODUCTION ACROSS OKLAHOMA WITH PARALLEL GRIDDED DSSAT-CSM

By

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Bachelor of Science in Plant and Soil Sciences
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2017

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July 2021

RETROSPECTIVE SIMULATION ANALYSIS OF DUAL-PURPOSE AND GRAIN-ONLY WHEAT PRODUCTION ACROSS OKLAHOMA WITH PARALLEL GRIDDED DSSAT-CSM

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ACKNOWLEDGMENTS

I would like to thank my advisor Dr. Alderman. I would like to give special thanks to Pratishtha Poudel, and Mason Blinson for their advice and feedback. I would also like to thank my committee members and my family for their patience.

Acknowledgments reflect the views of the author and are not endorsed by committee members or Oklahoma State University.

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Date of Degree: JULY 2021

Title of Study: RETROSPECTIVE SIMULATION ANALYSIS OF DUAL-PURPOSE AND GRAIN-ONLY WHEAT PRODUCTION ACROSS OKLAHOMA WITH PARALLEL GRIDDED DSSAT-CSM

Major Field: PLANT AND SOIL SCIENCES

Abstract: Wheat grain and forage production is an important aspect of many Oklahoma wheat management systems. Given the high interannual variability in rainfall and temperature conditions during the wheat season, agricultural producers and post-harvest processors would benefit from information regarding how these factors interact with soil properties to affect wheat production within different regions over time. The overall goal of this study was to assess the ability of the parallel gridded version of the CROPSIM-CERES-Wheat within the Decision Support System for Agrotechnology Transfer Cropping Systems Model to capture wheat production patterns in wheat grain yield and forage biomass within Oklahoma wheat production systems over space and time. Gridded simulations of winter wheat growth and development were run for 20 seasons (1997-2017) across Oklahoma at a 5-km resolution. Two production systems (grain-only and dual-purpose) and two genotypes (Tam 101 and Jagger) were used for simulation. The 20 year simulated average yield was typically higher than both NASS and Oklahoma Wheat Variety trial yield data. Correlation of grain yield to cumulative season rainfall shows that yield typically goes up when the cumulative rainfall is high. Dual-purpose grain estimates performed similarly to grain-only, however end of season forage biomass estimations performed poorly for all years. Maturity date was reported by the model earlier in the southern part of the wheat belt varied from 120 to 150 days after planting.

The introduction of a spatially diverse temporal data set including weather data spanning 1997 to 2018 from the Oklahoma Mesonet, paired with wheat variety trial data spanning 1999 to 2018, as well as soil data from SSURGO. The database is a robust combination of genetic information such as yield from over 100 wheat genotypes, soil, weather, and management. The resulting data structure provides detailed insight on wheat production across Oklahoma over roughly 20 years, into a single condensed dataset that has potential to be used for crop simulation modeling and exploring the effects of genotype, environment, and management interactions (G x E x M). In total there are 391 WHA files, 60 WHT files, 425 weather files, and 1 soil file as a bi-product to be used in future analysis.

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CHAPTER I

GENERAL INTRODUCTION

Insights on wheat grain and biomass production in Oklahoma can be gained through the use of survey data from the National Agricultural Statistics Service (NASS) and wheat variety trials conducted by Oklahoma State University (OSU). These sources of information provide different resolutions of wheat production information across the state. The NASS survey data provides a coarse overview of wheat production through county-level averages, while the OSU wheat variety trials provide high quality point-specific information at a collection of locations across the state. However, higher resolution information would greatly enhance our understanding of grain production volume across the state under different management practices.

Crop models, such as the Decision Support System for Agrotechnology Transfer Cropping Systems Model (DSSAT-CSM), have potential to provide important information on wheat production by integrating multiple sources of real-world forcing data (e.g. soil, weather, management practices). Crop management data, combined with high-resolution soil data from Natural Resource Conservation Service (NRCS) databases and weather data from the Oklahoma Mesonet could assist in providing needed high-resolution estimates of wheat grain and fall forage production across the state. An improved version of DSSAT-CSM that utilizes a spatially-referenced parallelized framework to simulate crop production across large areas of land makes analyses such as these possible (Alderman, 2021). The gridded approach to crop modeling could provide insight to grain market advisers, or co-ops in identifying areas of high grain production, or biomass potential that could be utilized for fall forage in cattle production systems. Chapter two seeks to explore these concepts in more detail, and to provide a method for quantifying aspects of wheat grain and forage production in the Oklahoma Wheat-Belt, a region that is typically known for the large volume of wheat production in Oklahoma.

The effective use of a crop model, such as DSSAT-CSM, for the analyses described above requires that the model can be properly calibrated and validated within the intended region of model application. However, model calibration and validation cannot be carried out without properly curated and documented datasets. Thus, chapter three focuses on documenting the process by which Oklahoma wheat variety trial data were compiled, cleaned and curated for future use with crop modeling analysis. This process resulted in a high-quality integrated wheat, soil, and weather dataset that has been constructed from field-replicate-level Oklahoma wheat variety trial data, NRCS SSURGO soil profile data, and Oklahoma Mesonet weather data. This dataset combines aspects from each data source from 1999-2018 that can be utilized in the DSSAT cropping systems model. The current end-product has been converted into DSSAT standard file formats to be used in future studies.

In the final chapter of this thesis, I summarize the general findings across chapters two and three. In brief, the new gridded approach shows potential to provide wheat production trends across the wheat belt of Oklahoma. Yield estimates tended to have an upward bias, which means that the model is overpredicting yield. Utilizing the wheat production components from chapter three as a source of calibration and validation for wheat genetic modeling parameters could improve the overall accuracy of the gridded approach.

1.1 References

Alderman, P. D. (2021). Parallel gridded simulation framework for DSSAT-CSM (version 4.7.5.21) using MPI and NetCDF. *Geoscientific Model Development Discussions*, *2021*, 1–56. doi:10.5194/gmd-2021-183

CHAPTER II

EVALUATION OF THE PARALLEL GRIDDED DSSAT-CSM FOR OKLAHOMA WINTER WHEAT PRODUCTION

2.1 Abstract

Wheat grain and forage production is an important aspect of many Oklahoma wheat management systems. Given the high interannual variability in rainfall and temperature conditions during the wheat season, agricultural producers and post-harvest processors would benefit from information regarding how these factors interact with soil properties to affect wheat production within different regions over time. The overall goal of this study was to assess the ability of the parallel gridded version of the CROPSIM-CERES-Wheat within the Decision Support System for Agrotechnology Transfer Cropping Systems Model to capture wheat production patterns in wheat grain yield and forage biomass within Oklahoma wheat production systems over space and time. Gridded simulations of winter wheat growth and development were run for 20 seasons (1997-2017) across Oklahoma at a 5-km resolution. Two production systems (grain-only and dual-purpose) and two published model calibrated genotypes (Tam 101 and Jagger) were used for simulation. The 20 year simulated average yield was typically higher than both NASS and Oklahoma Wheat Variety trial yield data. Correlation of grain yield to cumulative season rainfall shows that yield typically goes up when the cumulative rainfall is high. Dual-purpose grain estimates performed similarly to grain-only, however end of season forage biomass estimations performed poorly for all years. Maturity date was reported by the model earlier in the southern

part of the wheat belt and varied from the first of May to the first of June for the wheat belt.

2.2 Introduction

More knowledge is needed to better understand the grain production volume across the state under different management practices, especially considering the increasing concern of crop production under the effect of global climate change. A gridded version of the Decision Support System for Agrotechnology Transfer Cropping Systems Model (DSSAT-CSM) has been designed could potentially assist in identifying areas of high production for the transfer of grain from production to market or co-ops (market advisers), as well as biomass production potential under a changing climate. Agricultural systems modeling can assist in decision making strategies from a big picture view, allowing production opportunities to be explored prior to implementing a system under real-world scenarios. Dual-purpose forage systems, consisting of winter wheat, exist throughout the Southern Great Plains and are an important component of many Oklahoma agricultural management systems for fall biomass, since it is a good source of forage during the fall and winter months, and provides modest returns in cattle weight gain in addition to the return in grain yield at the end of the growing season (Edwards et al., 2012; Hossain, Epplin, & Krenzer, 2003; Maulana, Anderson, Butler, & Ma, 2019; Pinchak et al., 1996). While dual-purpose wheat can be incorporated into most parts of Oklahoma, this practice is most commonly seen in the Wheat Belt, a strip of land that runs from north-central to south-west Oklahoma, where growing conditions are historically most suitable for wheat production under rain-fed conditions(Patrignani, Lollato, Ochsner, Godsey, & Edwards, 2014; Vitale, Godsey, Edwards, & Taylor, 2011).

Effective grain and forage production within grazed wheat management systems requires knowing how much forage is available and how much forage will be produced within the planning horizon. The overall goal of this study is to assess the ability of gridded DSSAT-CSM-CROPSIM-CERES-Wheat to capture higher resolution wheat production patterns in wheat grain yield and forage biomass within Oklahoma wheat production systems over space and time.

2.3 Materials and Methods

2.3.1 DSSAT-CSM

The DSSAT-CSM is a model that can simulate various cropping systems under a wide range of real-world management (Jones et al., 2003; Hoogenboom, Porter, Shelia, et al., 2019; Hoogenboom, Porter, Boote, et al., 2019). A recent version of the DSSAT-CSM has been developed to run in parallel using the Message Passing Interface (MPI) across a grid of points while reading spatially-references input data directly from Network Common Data Form (NetCDF) files (Alderman, 2021). This version seeks to provide a better framework for understanding wheat production potential over large areas of land with higher resolution than county-level averages.

2.3.2 Grazing Representation

To simulate the practice of dual-purpose wheat systems in Oklahoma, a forage clipping module was integrated into the new DSSAT-CSM interface with a use-efficiency that can be adjusted to account for livestock grazing efficiency. End of season biomass is estimated through a cumulative sum of daily simulated grazing removal. Prior to initiation of simulated grazing, 2.7 t ha^{-1} (1 Imperial ton acre^{-1}) of above ground biomass must be accumulated. Once this threshold is crossed, forage removal begins. The model will continue to remove biomass at 16 kg ha^{-1} d^{-1} until Zadoks growth stage 30 is achieved, which is assumed to approximate first hollow-stem (Zadoks, Chang, & Konzak, 1974). Average values for stocking rate, pounds of dry matter per pound of gain, and gain per head were used from a table in a previous study to derive the biomass removal rate (Zhang et al., 2008). To account for the effect of livestock trampling the forage, pounds of dry matter per pound of gain was doubled.

2.3.3 Input data sources

The climate hazards infrared precipitation with stations (CHIRPS) dataset (Funk et al., 2015) 0.05° grid was used to generate a matching grid for simulations. The grid was clipped to the dimensions of Oklahoma, USA, through the use of the Oklahoma state boundary file which was extracted from the TIGER/Line® database (United States Census Bureau, 2016).

Soil data

The National Elevation Dataset (NED; Gesch, Evans, Oimoen, & Arundel, 2018), the 2017 wheat frequency Layer from the Cropland Data Layer dataset (CDL; United States Department of Agriculture-National Agricultural Statistics Service [USDA-NASS], 2017), and the STATSGO2 soil database (United States Department of Agriculture-Natural Resources Conservation Service [USDA-NRCS], 2019) were utilized to derive a gridded soil dataset. A 30m-resolution mask layer was constructed from the CDL data to create a layer of potential wheat producing areas by converting the Wheat Frequency Layer to 32-bit integer from 8-bit integer through the use of the `gdal_translate` command-line utility (GDAL/OGR contributors, 2020). Additionally, the Wheat Frequency Layer was then reprojected to the Albers Equal-Area projection through the use of the `gdalwarp` utility so it matched the projection of the STATSGO2 spatial data. The `gdal_rasterize` utility was used to extract a map unit key (MUKEY) for each grid point in the STATSGO2 database and grid points containing a (MUKEY) that signify water land cover (STATSGO2 MUKEY 657964) were marked as missing data through the `gdal_translate` utility. The reprojected Wheat Frequency Layer was then used to mask the rasterized (MUKEY) with the `gdal_calc.py` utility, resulting in a wheat-specific raster layer containing map unit keys which was then reprojected to the World Geodetic System 84 (WGS84) coordinate system. Spatial resampling to the 0.05° CHIRPS grid was conducted by assigning the most frequently observed (MUKEY) within each grid square, which is known as mode resampling, through the use of the `gdalwarp` utility. The newly assigned (MUKEY) for each grid square was then utilized in extracting the soil component and layer specific data from STATSGO2 for each gridpoint. The `terrain()` function from the `raster` R package was used to calculate slope from the 1/3 second resolution NED, and where then resampled to the 0.05° CHIRPS grid through the `aggregate()` function in the `raster` R package (Hijmans, 2020). Antecedent moisture condition II curve number (SLRO) was determined from point specific slope and hydrologic soil group from STATSGO2 (Ritchie, Godwin, & Singh, 1989).

2.3.4 Fractional Wheat Mask

The spatially transformed wheat frequency mask that was described in the generation of gridded soil data was subsequently utilized to generate a fractional wheat mask. Fractional wheat values were extracted by calculating the fraction of 30 meter grid-points within a 5-km grid-box that had been planted to wheat at any point in the 13 year duration of the CDL Wheat Frequency Layer. The resulting raster layer allowed simulated results to be filtered through a masking operation to areas of high wheat area concentration, or grid-points with a value greater than 0.75. The grid points with values greater than 0.75 are assumed to be representative of what is described as the “Wheat Belt” throughout the results.

Weather data

Gridded weather data that was used for simulations were derived from data that was measured by the Oklahoma Mesonet (DOI: 10.15763/dbs.mesonet). The Oklahoma Mesonet is an automated network of 122 strategically placed meteorological stations that have been collecting data since 1994 (Brock et al., 1995; McPherson et al., 2007). Data is continuously collected by each station and transmitted to the central facility at 5 minute intervals to be quality controlled, distributed, and archived (Shafer, Fiebrich, Arndt, Fredrickson, & Hughes, 2000). From the 5 minute measurements obtained from each station, daily summaries for near-surface cumulative solar radiation (MJ m^{-2} d^{-1}), rainfall (mm d^{-1}), average relative humidity (percent), windspeed (km d^{-1}), as well as maximum and minimum temperature (°C) were calculated. Daily summaries were then merged with the coordinates for each station, which were obtained using `updatestn()`, a function from the `okmesonet` R package (Allred, Hovick, & Fuhlendorf, 2014). Once the daily weather data were spatially referenced, interpolation procedures were conducted using inverse distance weighting (IDW) to the 0.05° CHIRPS through the use of the `idw()` function of the `gstat` R package (Pebesma, 2004; Gräler, Pebesma, & Heuvelink, 2016, 1). For each gridpoint, interpolation was conducted using the 5 nearest Mesonet stations and an IDW power of 2.

2.3.5 County-level Yields

Comparison data were extracted from the National Agricultural Statistics Service (NASS) county-level reported grain yield averages (USDA-NASS, 2021). County level averages were then joined to their respective county shape by extracting TIGER county lines, which were obtained using R `tigris` package (Walker, 2020). The NASS county level yield averages were then extracted for each grid point on the 0.05° CHIRPS grid using the `extract()` function from the `raster` package to provide spatially harmonized yield observations (Hijmans, 2020).

2.3.6 Simulation Configuration

The simulations in this study used the DSSAT-CSM-CROPSIM-CERES-Wheat model with the parameter values for Tam 101 and Jagger cultivars as described by (Zhang et al., 2008). Two winter wheat production systems were simulated in this study: grain-only and dual-purpose. For grain-only simulations, the planting date was set to October 15 of each year with a planting density of 224 plants m^{-2} (60 lb $acre^{-1}$). For dual-purpose simulations, planting date was set to September 15 of each year with a planting density of 448 plants m^{-2} (120 lb $acre^{-1}$). Both systems were simulated with a row spacing of 19 cm. Each seasonal simulation was initialized at 50% plant available water at three months prior to planting to allow time for soil moisture to equilibrate with weather conditions. Crop growth was simulated as rainfed, water-limited production with nitrogen stress disabled. Crop evapotranspiration was simulated using the Priestley-Taylor method and soil evaporation was simulated using the Ritchie method. Automatic harvest was set to trigger at simulated crop maturity. All simulations were run in DSSAT-CSM "seasonal" run mode (i.e. state variables were reinitialized for each season) for 20 seasons from 1997 to 2018. Simulations were run on a 24-core Ubuntu 18.04.3 LTS virtual machine with 130 Gigabytes of RAM hosted on the Interactive Graphical Environment for Research (TIGER) resource at the OSU HPCC Oklahoma State University High-Performance Computing Center.

2.4 Results

2.4.1 Grain-Only estimates

Figures 2.1 and 2.2 show the 20-year temporal average grain yield for each grid-point. The temporal average was calculated as the mean value over 20 years at each grid point. Overall Jagger had higher simulated grain values than Tam101. The temporal average values across the study area, reported in kg ha^{-1}, ranged from 3208 to 5310 for Jagger and 2798 to 4575 for Tam101, excluding 4 failed simulations in the southern wheat-belt. Values for both genotypes tended to be highest in the middle of the wheat-belt.

Figures 2.3 and 2.4 show the Pearson correlation coefficient between simulated and NASS-reported yields for each grid-point over the 20-year period. These values indicate that model simulated yield followed shifts in NASS reported yield for the southern part of the wheat-belt, while the northern portion of the wheat-belt did not. There is a visible pattern of decreasing correlation when moving from the southern portion of the wheat belt to the northern portion. This effect was observed for both Jagger and Tam101.

Harvest index was derived by dividing model simulated harvest weight at maturity by model simulated canopy weight at maturity. As seen in Figure 2.14, grain-only simulations had observed values between 0.20 and 0.36 for most years. In harvest years 2009 and 2017, harvest index was the lowest for the entire wheat belt with values ranging from 0.20 to 0.27.

Inter Annual Variability

Temporal standard deviation (the standard deviation over 20 years at each grid point) of the simulated grain yield for Jagger and Tam101 follow an increasing south to north gradient with the lowest inter annual variability in the southern portion of the wheat-belt. For Jagger, values described in kg ha^{-1}, ranged from 1194 to 1768 and from 1028 to 1510 for Tam101 (Fig. 2.5 and 2.6). Annual variation in simulated grain yield can be observed for both genotypes in Figures 2.7 and 2.8. Simulated harvest years 2011, and 2014 were low-yielding years, while years 2000 and 2008 were high yielding years. An increase in simulated grain yield from South to North was observed for both genotypes in years that produced both high and low overall simulated yield.

Phenology

Maturity date for Jagger simulated wheat varied across all years. For the majority of years, maturity date was achieved earlier in the southern portion of the state, and ranged from 120 to 150 days (Fig. 2.11). Earlier maturity dates start in the south and have a visible south to north gradient with the northern portion of the state achieving maturity later. Duration of grain filling was short for the wheat-belt for most years and areas where duration of grain fill was longer are typically driven by longer duration of cooler weather (Fig. 2.13).

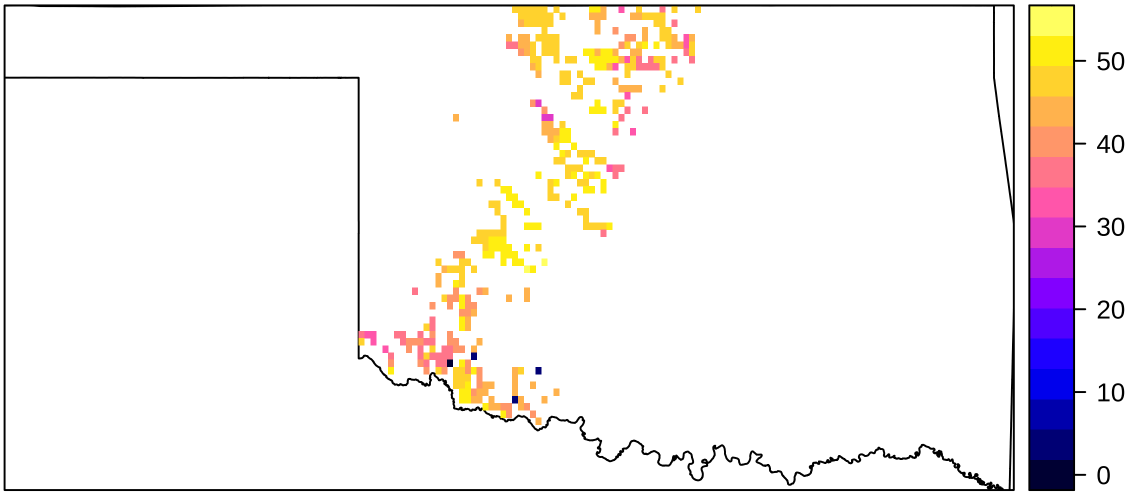

Figure 2.1: Average winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Jagger in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

2.4.2 Dual-Purpose estimates

For dual-purpose wheat, Jagger had higher simulated values for the 20 year average than Tam101 with temporal averages, described in kg ha^{-1}, varying from from 3237 to 5434 for Jagger and 2764 to 4593 for Tam101.

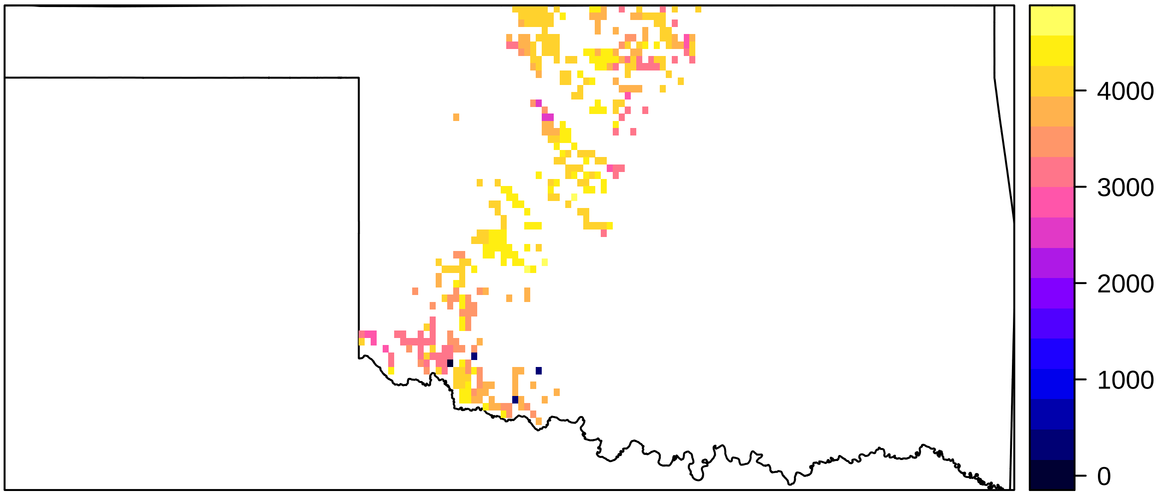

Figure 2.2: Average winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Tam101 in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

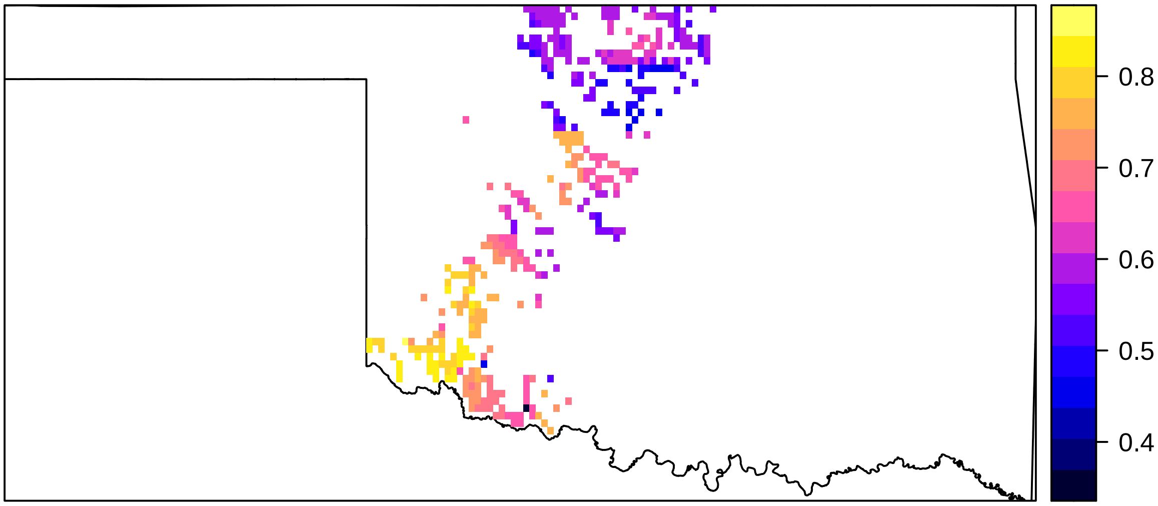

Figure 2.3: Pearson correlation coefficient between National Agricultural Statistics Service county yields and simulated yield for winter wheat across the Oklahoma wheat belt for cultivar Jagger in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model.

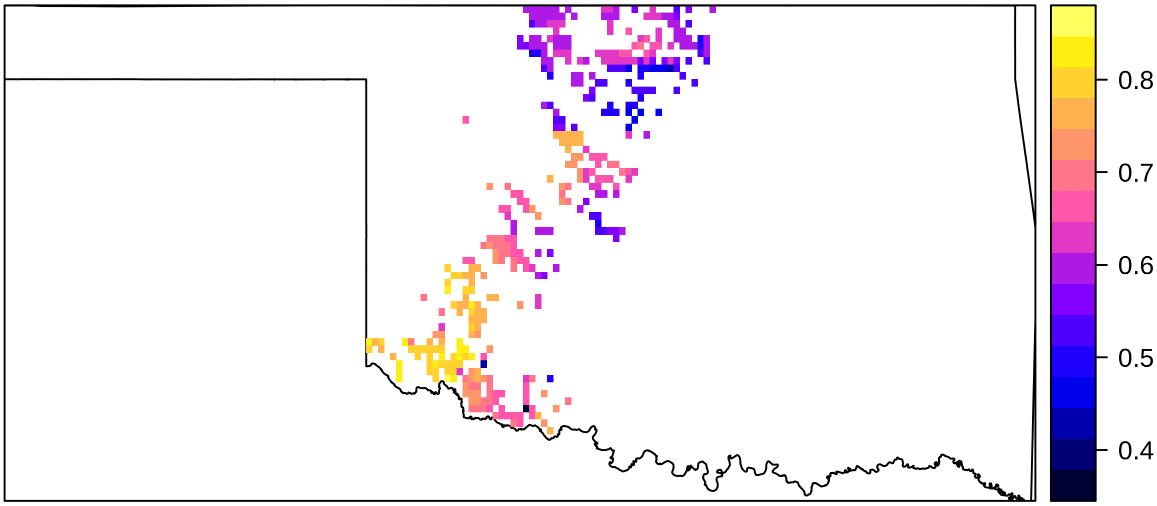

Figure 2.4: Pearson correlation coefficient between National Agricultural Statistics Service county yields and simulated yield for winter wheat across the Oklahoma wheat belt for cultivar Tam101 in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model.

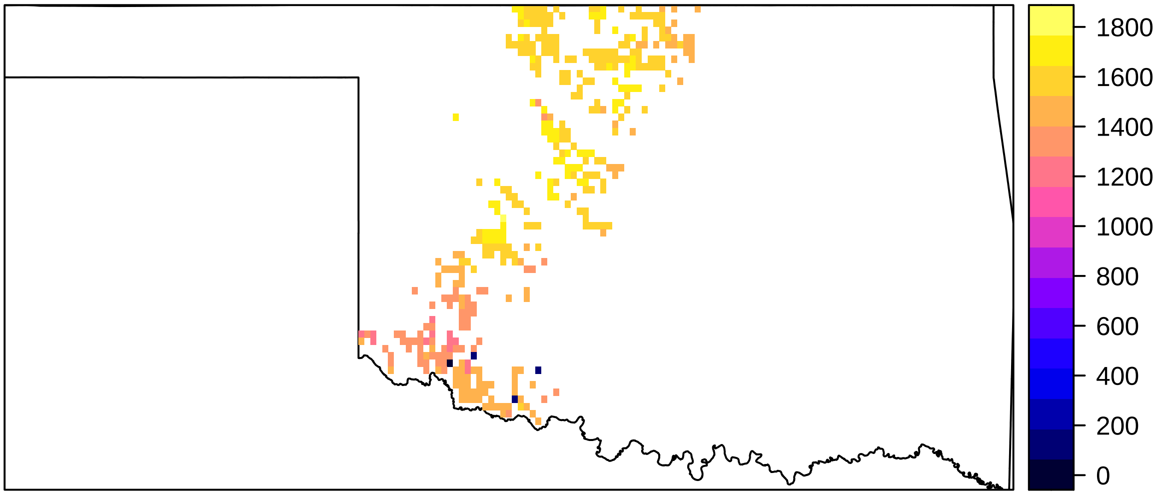

Figure 2.5: Standard deviation of winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Jagger in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

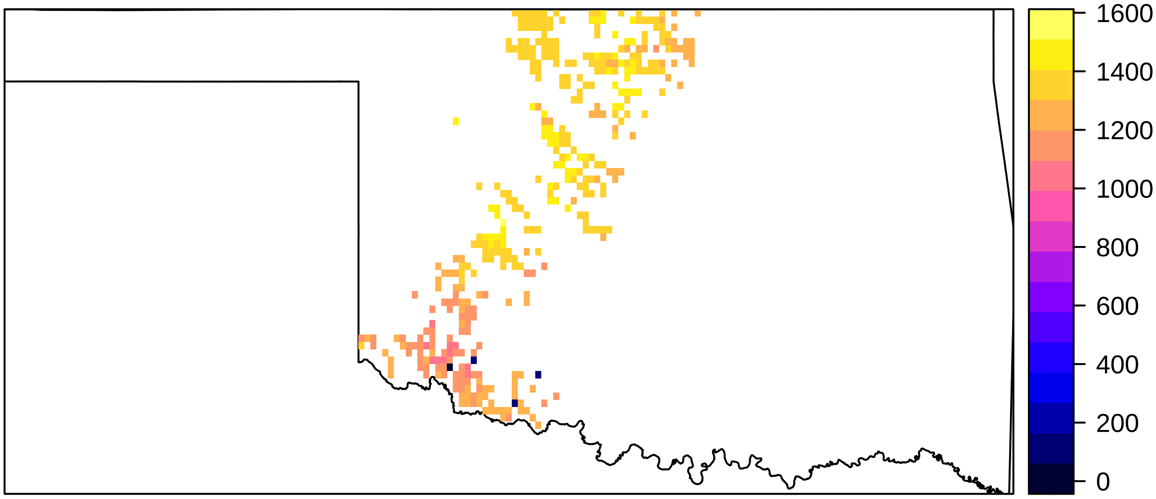

Figure 2.6: Standard deviation of winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Tam101 in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

Pearson correlation coefficient values comparing model simulated yield to NASS-reported yield showed higher values for the southern part of the wheat-belt than the northern portion with values ranging from 0 to 1 for Jagger and 0 to 1 for Tam101 (Fig. 2.17 and 2.18).

The temporal standard deviation of the simulated grain yield for Jagger and Tam101 follow a loosely defined south to north gradient with the lowest inter annual variability in the southern portion of the wheat-belt.

Simulated forage production, described as the 20 year temporal average, for Jagger ranged from 1175 to 1753 kg ha^{-1} and for Tam101 values ranged from 1020 to 1500 kg ha^{-1}. The largest portion of simulated values are found in the southern wheat belt while the higher values reside in the middle and northern region of the wheat belt.

Harvest index as seen in Figure 2.23 for dual-purpose simulations had observed values between 0.20 and 0.35 for most years. In harvest years 2011 and 2017, harvest

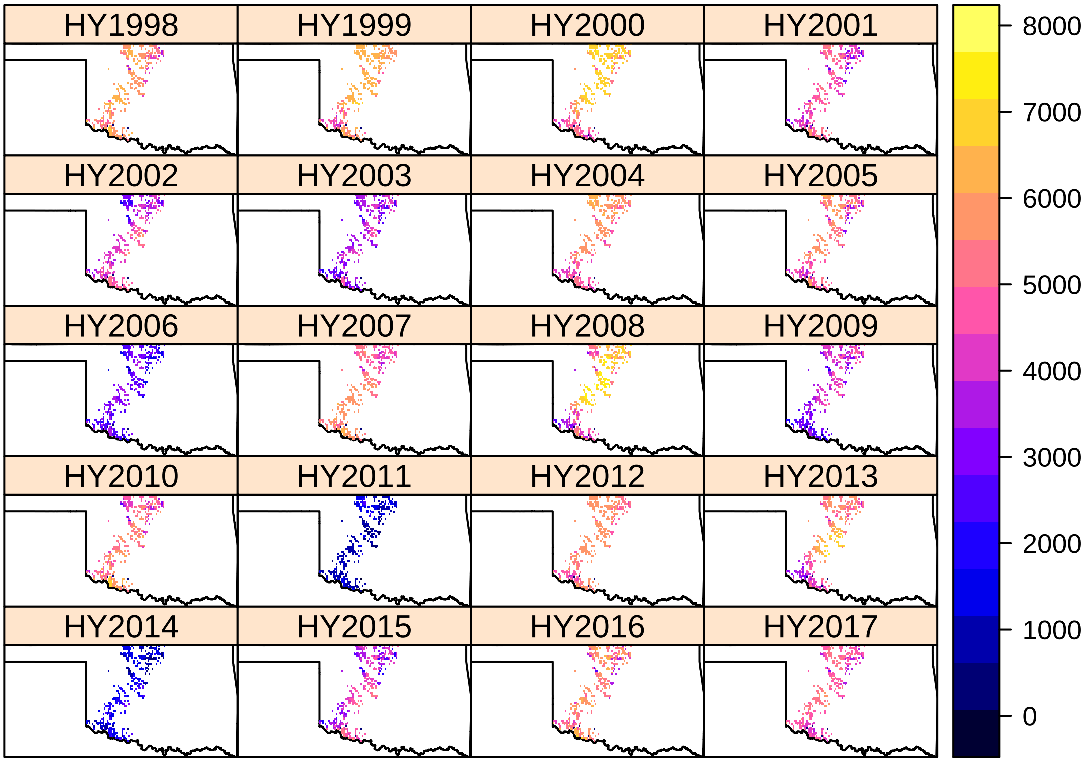

Figure 2.7: Winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Jagger in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

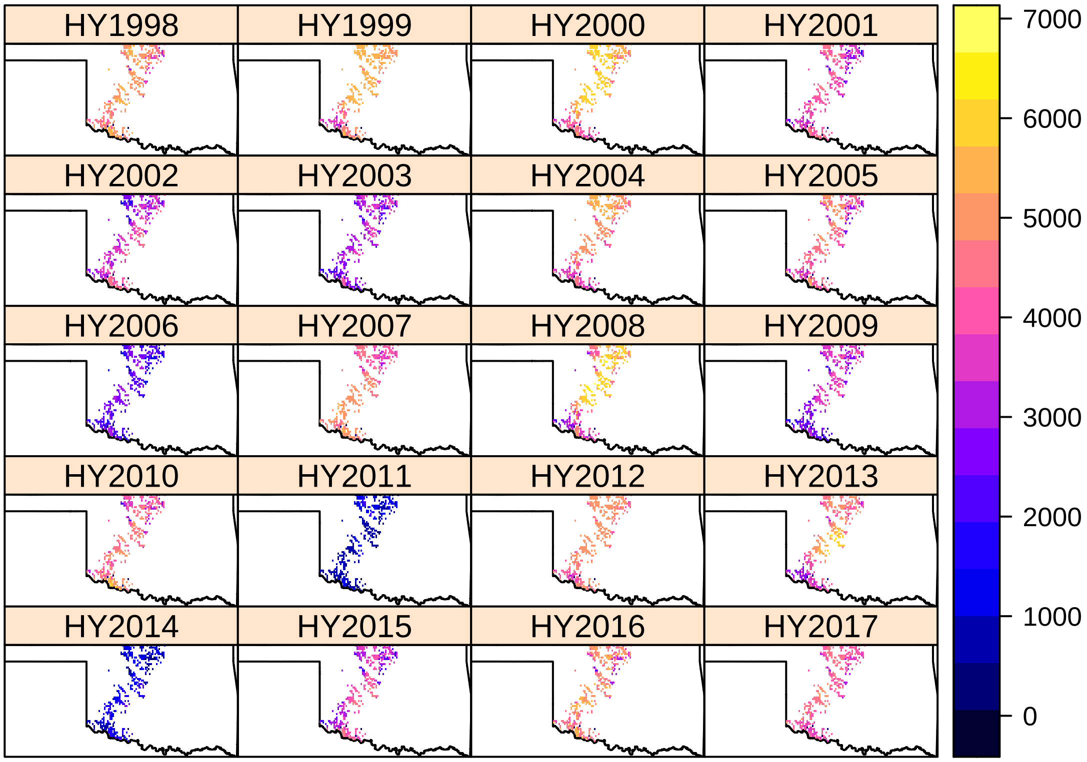

Figure 2.8: Winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Tam101 in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

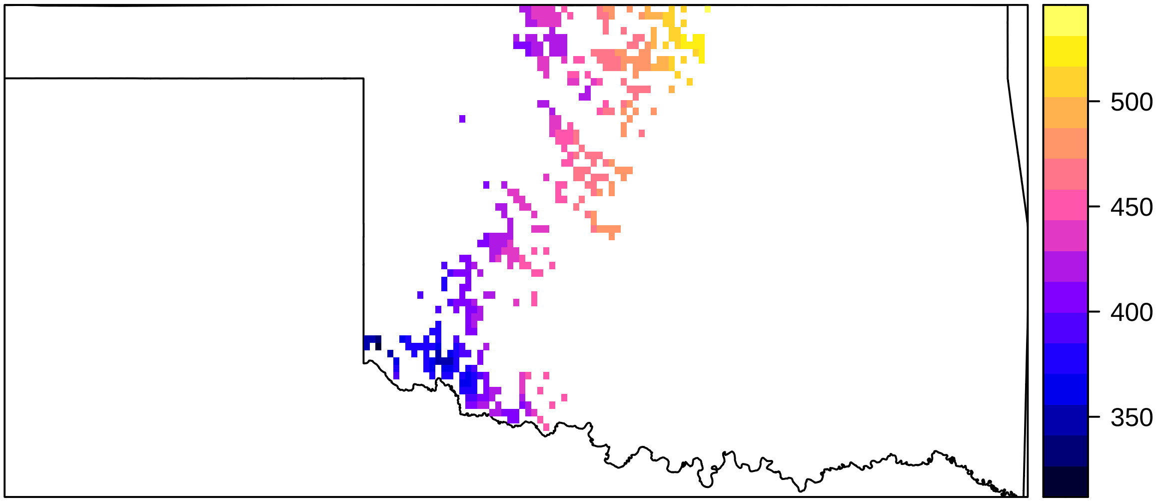

Figure 2.9: Average cumulative seasonal rainfall (mm) across the Oklahoma wheat belt over 20 winter wheat seasons (1997-2017).

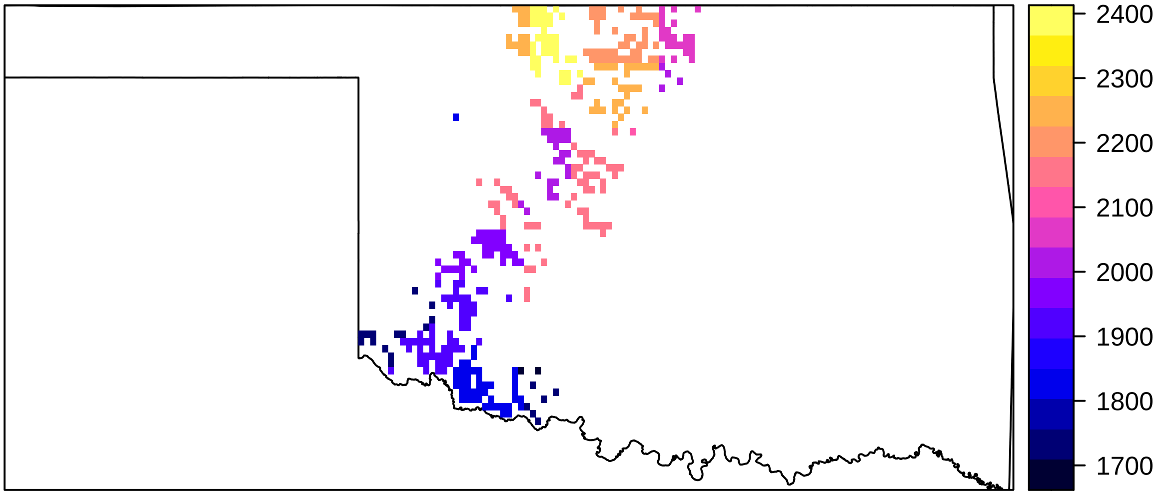

Figure 2.10: Average winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt as reported by National Agricultural Statistics Service over 20 seasons (1997-2017).

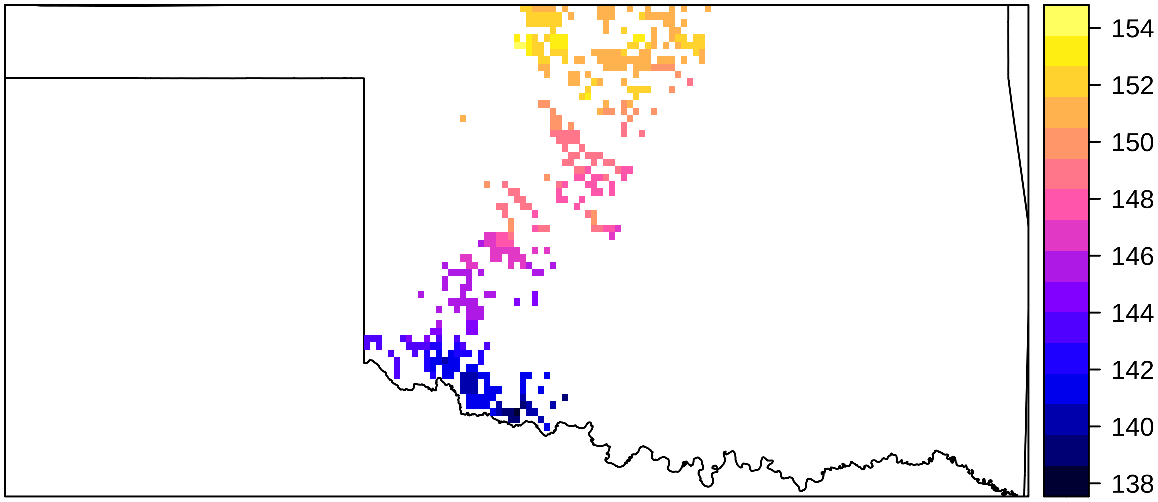

Figure 2.11: Average maturity date (Julian day of year) for winter wheat across the Oklahoma wheat belt for cultivar Jagger in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model.

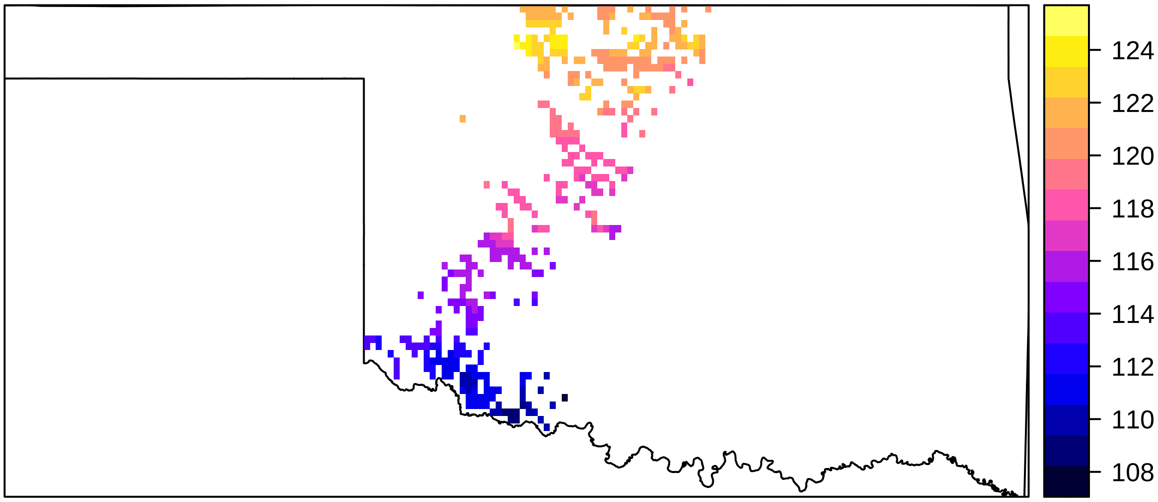

Figure 2.12: Average anthesis date (Julian day of year) for winter wheat across the Oklahoma wheat belt for cultivar Jagger in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model.

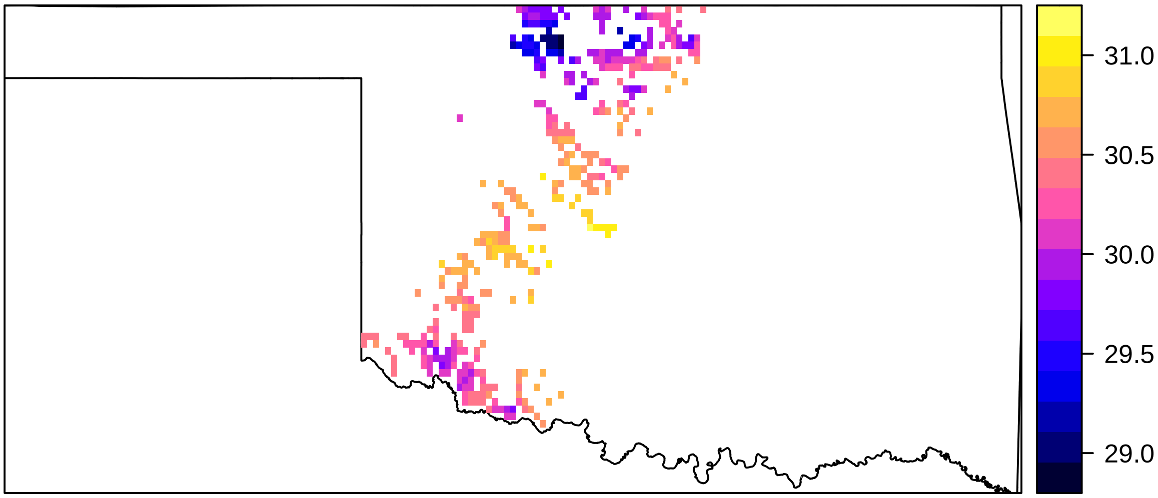

Figure 2.13: Average duration of grain filling (days) for winter wheat across the Oklahoma wheat belt for cultivar Jagger in grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model.

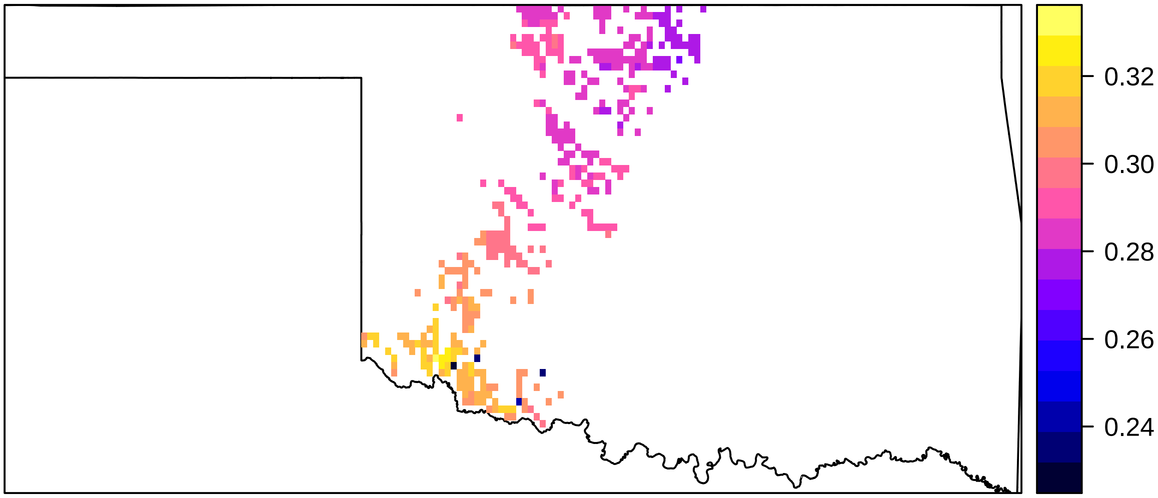

Figure 2.14: Average harvest index for winter wheat across the Oklahoma wheat belt for cultivar Jagger grain-only production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model.

index was the lowest for the entire wheat belt with values ranging from 0.20 to 0.25.

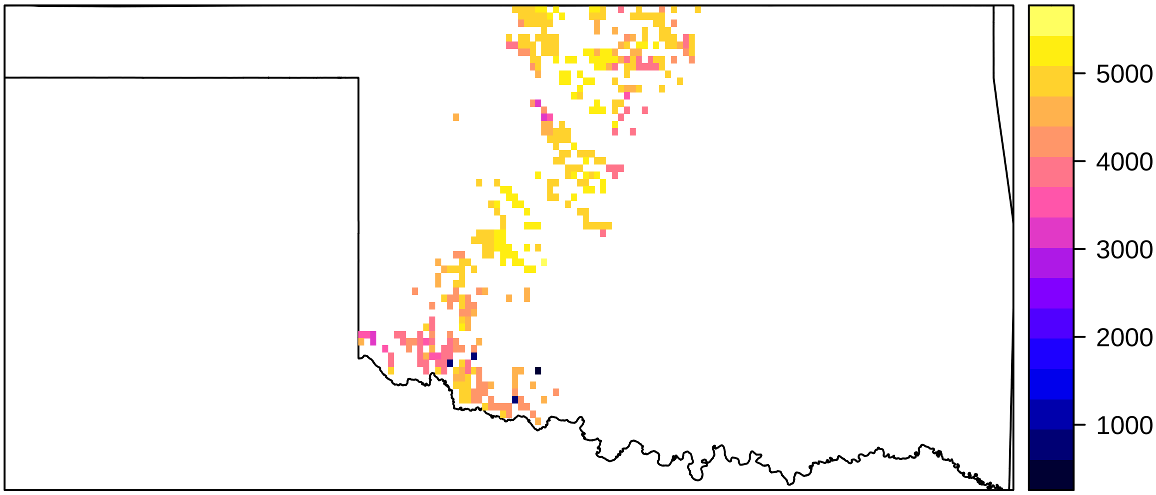

Figure 2.15: Average winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Jagger in dual-purpose production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

2.5 Discussion

Overall, the temporal average of simulated yields for both production systems and both cultivars were roughly twice that of NASS-reported yields over the 20 year period (Fig. 2.1, 2.2, 2.15, 2.16, 2.10). There are several possible reasons for these results. First, nitrogen stress was not factored into simulated yield due to the limited availability of state-wide information about producer fertilizer practices. In reality, it is possible that producers with a conservative management practices may have under-applied fertilizer in high-yielding years resulting in some nutrient limitations in the NASS reported yields. Drought, extreme heat, and extreme cold are accounted for in the model to some extent and are reflected in the variety trial reports for simulation years that performed poorly. Abiotic (non-living) factors not represented in the model

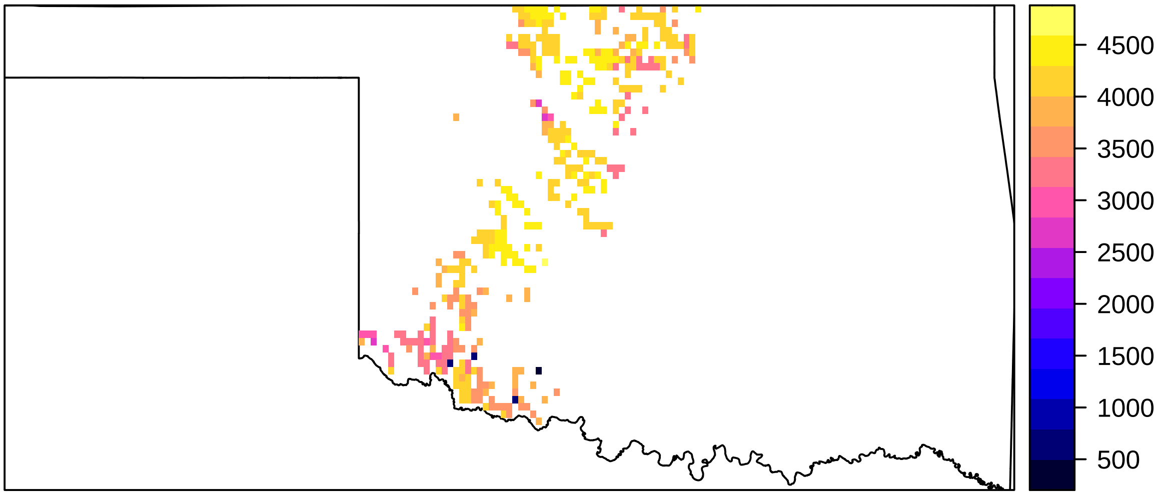

Figure 2.16: Average winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Tam101 in dual-purpose production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

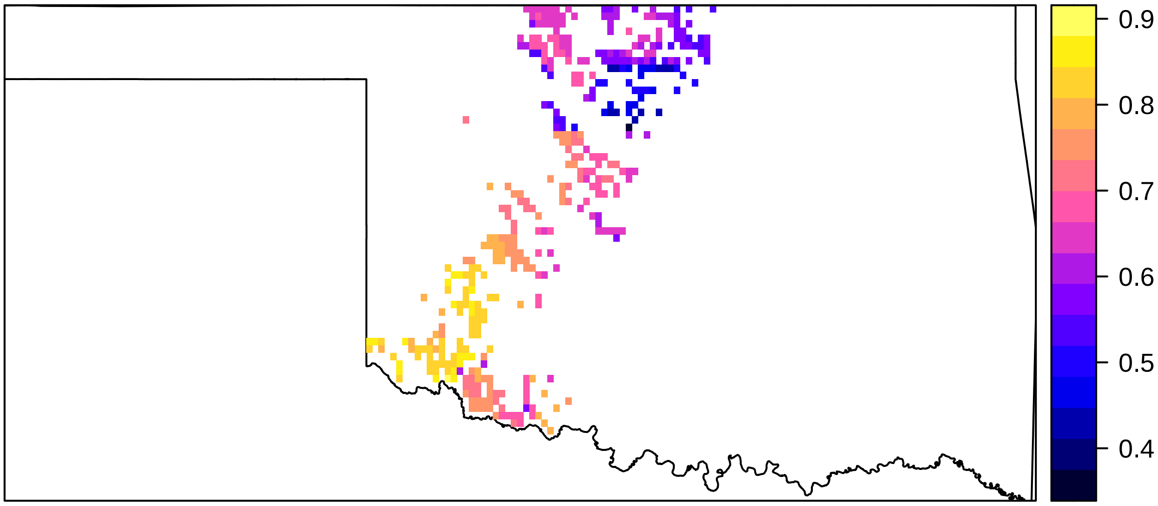

Figure 2.17: Pearson correlation coefficient between National Agricultural Statistics Service county yields and simulated yield for winter wheat across the Oklahoma wheat belt for cultivar Jagger in dual-purpose production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model.

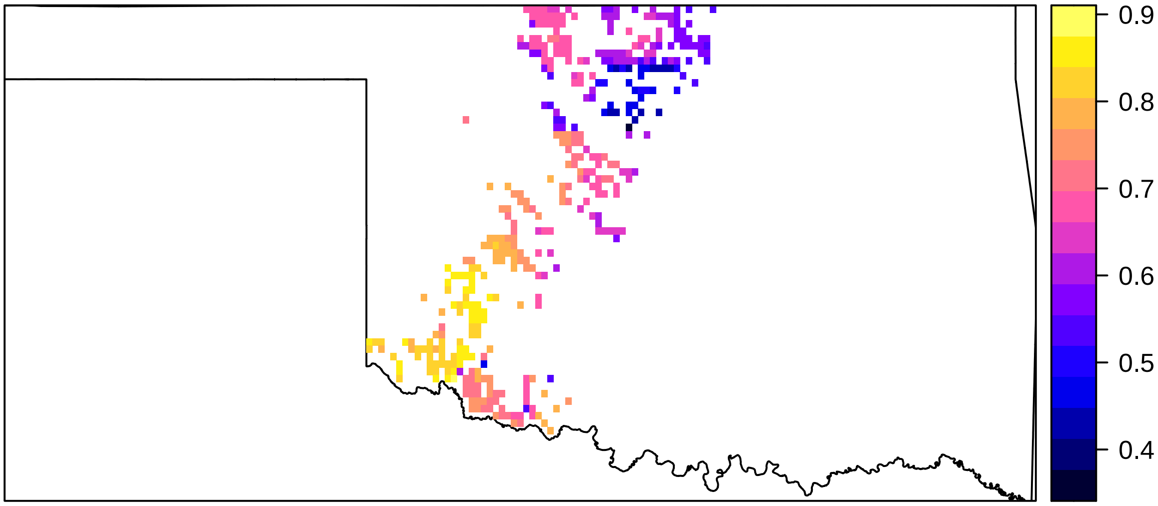

Figure 2.18: Pearson correlation coefficient between National Agricultural Statistics Service county yields and simulated yield for winter wheat across the Oklahoma wheat belt for cultivar Tam101 in dual-purpose production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model.

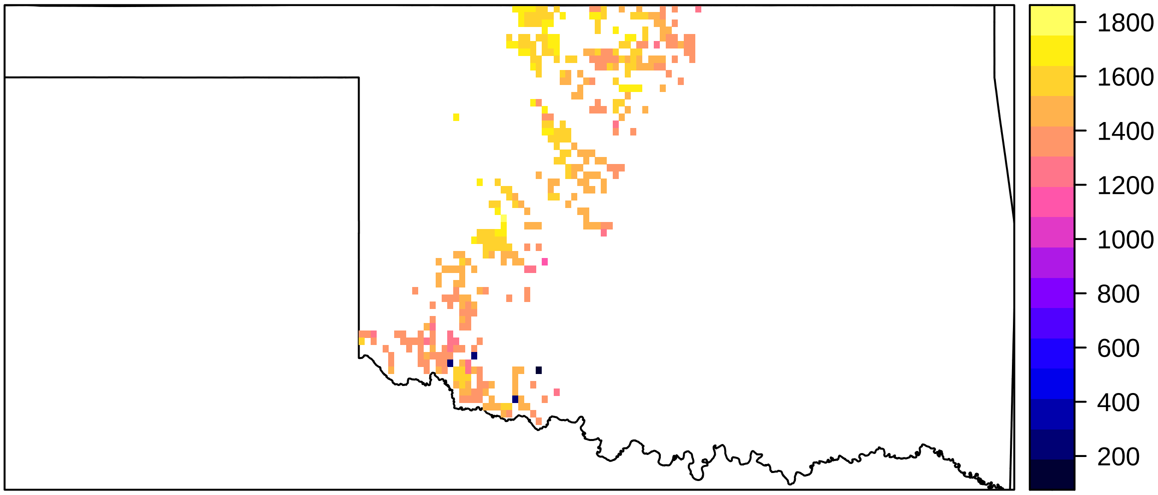

Figure 2.19: Standard deviation of winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Jagger in dual-purpose production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

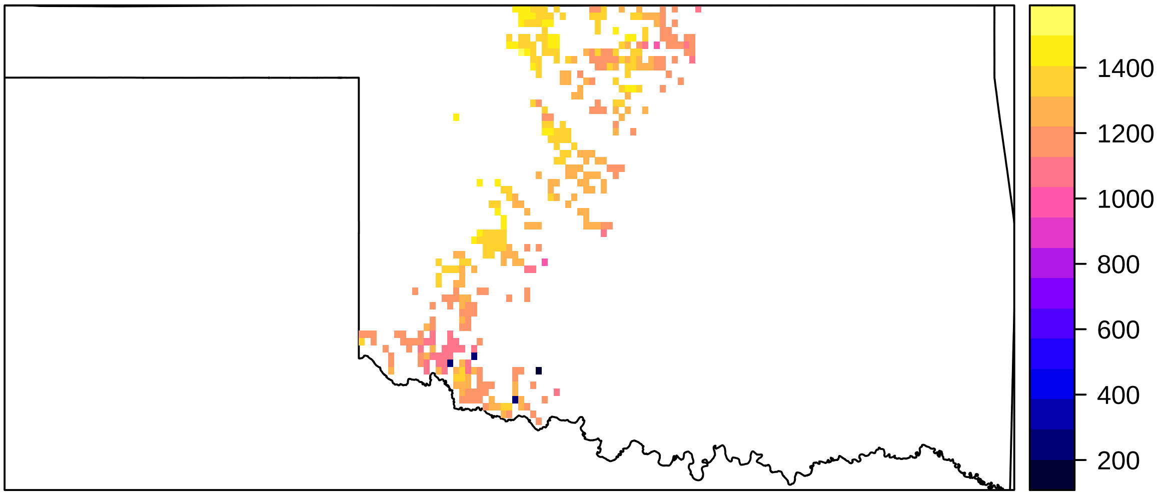

Figure 2.20: Standard deviation of winter wheat yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Tam101 in dual-purpose production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

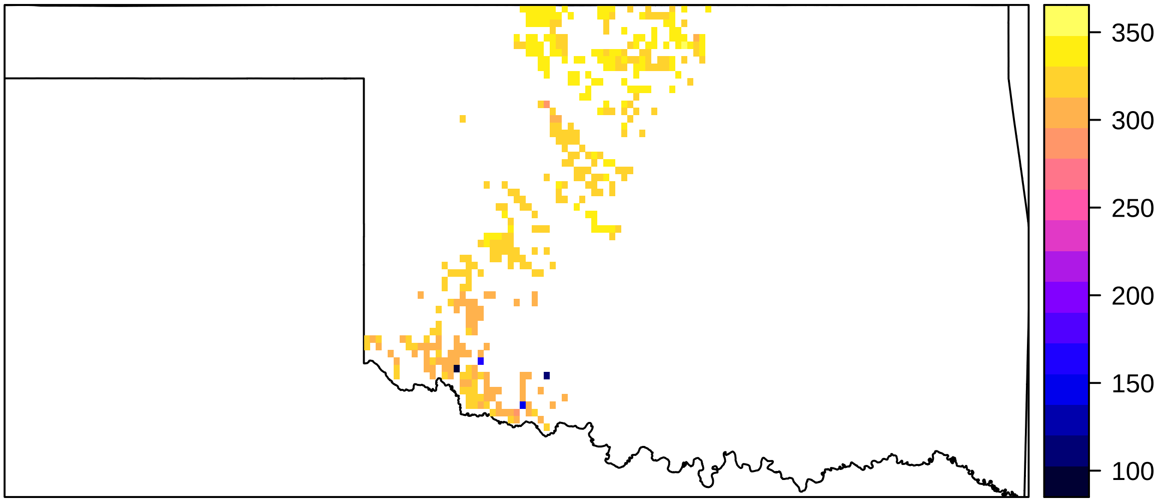

Figure 2.21: Average winter wheat forage yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Jagger in dual-purpose production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

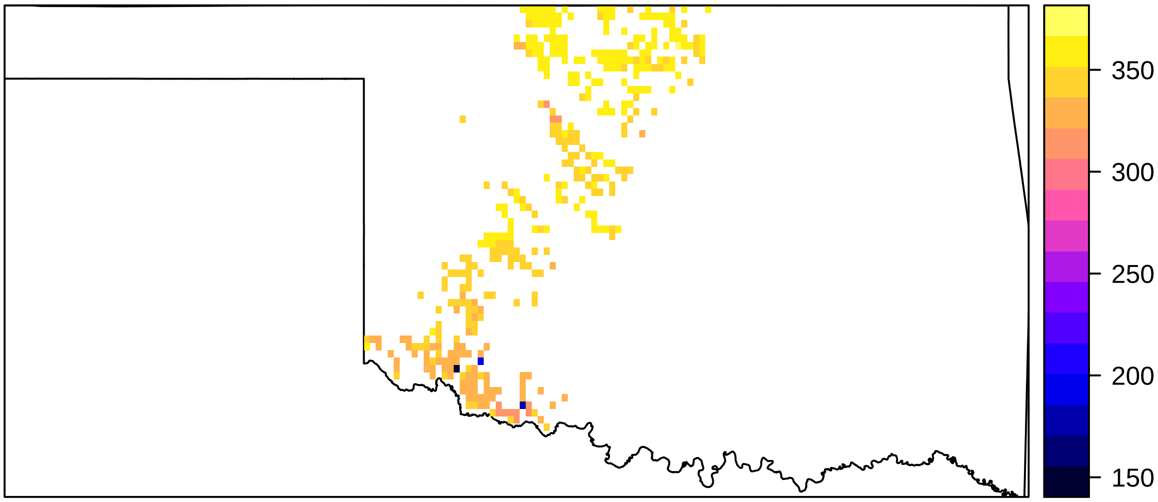

Figure 2.22: Average winter wheat forage yield (kg ha^{-1}) across the Oklahoma wheat belt for cultivar Tam101 in dual-purpose production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model. Scale goes to zero due to 4 failed simulations in southern wheat-belt

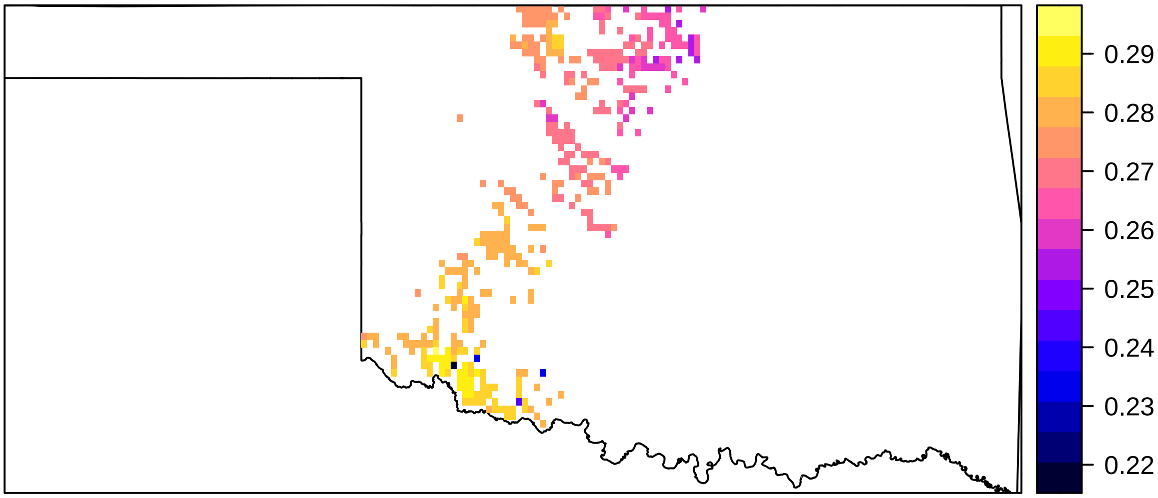

Figure 2.23: Average harvest index for winter wheat across the Oklahoma wheat belt for cultivar Jagger dual-purpose production as simulated over 20 seasons (1997-2017) using the CERES-Wheat model within the Decision Support System for Agrotechnology Transfer Cropping Systems Model.

(e.g. hail damage and lodging) and biotic factors not represented (e.g. foliar fungal diseases and pest damage) are all yield-reducing factors that may have affected NASS yields that were not accounted for in the model simulations.

Despite the significant overall bias in simulated yield, reasonably high correlations between simulated and NASS reported yields over time were present for most regions (Fig. 2.3, 2.4, 2.17, 2.18). This suggests that the predominant drivers in interannual yield variability were at least partially captured by the model. Cumulative seasonal rainfall is one of the factors that influence wheat production, and within Oklahoma it varies significantly from West to East. Typically drier conditions are experienced in the western part of the state, with a gradient of increased annual rainfall moving to the eastern part. It also can be highly variable from year to year. The model responded to the year to year variations in rainfall as shown by the low simulated yields in 2011 and 2014 (below average rainfall seasons) and high simulated yield in 2000 and 2008 (above average rainfall seasons). Cumulative seasonal rainfall, however, only partially describes low and high yielding simulations, which could be due to the timing of rainfall during the growing season, or to some of the previously mentioned biotic or abiotic variables. For example, the report for harvest year 2011 suggests record drought, cold, and heat fluctuations (Edwards et al., 2011). Similarly, the 2014 report describes drought and freeze kill, with record low yields for the entire state (Edwards et al., 2014). Year 2000's yield report was unavailable, however for 2008 grain yield had reached 70-100 bu acre^{-1} in some places, and was an above average year for wheat production. For the years where simulated yield was low, it appears that drought or freeze may be the largest contributor, while the high performing years possibly achieved adequate rainfall prior to grain-fill to produce higher yielding wheat for most of the wheat-belt. This assumption is based on the correlation between model simulated grain yield and cumulative season rainfall being higher in regions in the north wheat belt where adequate rainfall is typically received (data not shown).

Higher simulated grain yield, however, does not necessarily mean that the model accurately represents realistic grain values. The southern portion of the state had the lower average simulated grain yield, but more closely followed year-to-year trends when looking at the NASS reported grain yield correlation. Additionally, the standard deviation plots show higher variability in the northern portion of the wheat-belt, which further directs the hypothesis that one of the earlier mentioned factors such as rainfall is contributing to the variability in simulated grain production from year to year. This is true for both grain-only and dual-purpose. Additionally, simulated grain values were typically 2 times higher than NASS reported yield.

Both grain-only and dual-purpose cumulative end of season grain yield exceeded values reported in Oklahoma wheat variety trials in some years, as well as the NASS 20 year average (min: 1694, max:2824, med: 2118) kg ha^{-1}, which suggests that the model currently over-estimates grain yield (Fig. 2.10). This could be due to inadequate model calibration for wheat growth parameters, or abiotic and biotic factors that are unaccounted for in the model. Future studies that utilize the framework of this study should consider parameterizing through the use of high resolution wheat data for the entire wheat-belt. However, since NASS data are strictly available as a county level average, and more reliable validation data are not available for the entire state, the NASS reported data only allow for a quasi-validation and do not allow for direct comparisons.

The poor simulation of forage production is most likely related to the criteria associated with the initiation of simulated grazing. The simulated yield under dual-purpose systems was as high as grain-only systems indicating that biomass production was not the issue. The current formulation utilizes a threshold which initiates grazing in response to a critical biomass threshold being achieved. Future work should explore a phenology-based trigger for initiation of grazing as well as evaluating early-season biomass accumulation.

The spatial pattern of higher simulated yields in the northern part of the wheat belt and lower simulated yields in the southern part of the wheat belt follows trends that have been reported in the Wheat Variety Trial reports. Additionally, the parameter set that was used for this study could potentially be improved, as 9 more years of wheat data are available to use for calibration since the original study was published.

2.6 Conclusion

The parallel gridded version of DSSAT-CSM can represent inter-annual patterns in yield for the Oklahoma wheat belt using published cultivar parameter values. However, the current model configuration shows a large positive bias that would have to be corrected in some way before the model results could be used by stakeholders. The model simulated yield estimates with the current configuration are higher than the Oklahoma Wheat Variety Trial yields. This over estimation is likely due to the inability for the model to account for biotic factors, and some abiotic factors that can be highly influential on yield. Wheat forage estimates in the dual-purpose simulations were unreliable. The model estimates for forage appear to have an issue with initiation of grazing or termination. Further work needs to be conducted to isolate the causes of the poor performance of the grazing routine and develop solutions before the model can be used to predict forage availability.

2.7 References

Alderman, P. D. (2021). Parallel gridded simulation framework for DSSAT-CSM (version 4.7.5.21) using MPI and NetCDF. *Geoscientific Model Development Discussions*, *2021*, 1–56. doi:10.5194/gmd-2021-183

Allred, B., Hovick, T., & Fuhlendorf, S. (2014). *okmesonet: Retrieve Oklahoma Mesonet climatological data*. R package version 0.1.5. Retrieved from https://CRAN.R-project.org/package=okmesonet

Brock, F. V., Crawford, K. C., Elliott, R. L., Cuperus, G. W., Stadler, S. J., Johnson, H. L., & Eilts, M. D. (1995). The Oklahoma Mesonet: a technical overview. *Journal of Atmospheric and Oceanic Technology*, *12*(1), 5–19.

Edwards, J. T., Hunger, R. M., Smith, E. L., Horn, G. W., Chen, M.-S., Yan, L., . . . Carver, B. F. (2012). 'DUSTER' wheat: A durable, dual-purpose cultivar adapted to the southern Great Plains of the USA. *Journal of Plant Registrations*, *6*(1), 37–48.

Edwards, J. T., Kochenower, R. D., Austin, R. E., Ladd, J. D., Carver, B. F., Hunger, R. M., . . . Lollato, R. P. (2011). 2010-11 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2011-wheatvarietytrial

Edwards, J. T., Kochenower, R. D., Calhoun, S. R., Knori, M. W., Lollato, R. P., Cruppe, G., . . . Hunger, R. M. (2014). 2013-14 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2014-wheatvarietytrial

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., . . . Michaelsen, J. (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data*, *2*(1), 1–21.

GDAL/OGR contributors. (2020). *GDAL/OGR geospatial data abstraction software library*. Open Source Geospatial Foundation. Retrieved from https://gdal.org

Gesch, D. B., Evans, G. A., Oimoen, M. J., & Arundel, S. (2018). The National Elevation Dataset. In D. F. Maune & A. Nayegandhi (Eds.), *Digital elevation model technologies and applications: The DEM users manual 3rd edition* (Chap. 4, pp. 83–110). American Society for Photogrammetry and Remote Sensing.

Gräler, B., Pebesma, E., & Heuvelink, G. (2016). Spatio-Temporal Interpolation using gstat. *The R Journal*, *8*, 204–218. Retrieved from https://journal.r-project.org/archive/2016/RJ-2016-014/index.html

Hijmans, R. J. (2020). *raster: Geographic Data Analysis and Modeling*. R package version 3.3-13. Retrieved from https://CRAN.R-project.org/package=raster

Hoogenboom, G., Porter, C. H., Boote, K. J., Shelia, V., Wilkens, P. W., Singh, U., … Jones, J. W. (2019). The DSSAT crop modeling ecosystem. In K. Boote (Ed.), *Advances in crop modeling for a sustainable agriculture* (pp. 173–216). Cambridge, United Kingdom: Burleigh Dodds Science Publishing.

Hoogenboom, G., Porter, C. H., Shelia, V., Boote, K. J., Singh, U., White, J. W., … Jones, J. W. (2019). *Decision Support System for Agrotechnology Transfer (DSSAT) version 4.7.5*. Gainesville, Florida, USA: DSSAT Foundation. Retrieved from https://DSSAT.net

Hossain, I., Epplin, F. M., & Krenzer, E. G. (2003). Planting date influence on dual-purpose winter wheat forage yield, grain yield, and test weight. *Agronomy Journal*, *95*(5), 1179–1188.

Jones, J. W., Hoogenboom, G., Porter, C. H., Boote, K. J., Batchelor, W. D., Hunt, L. A., … Ritchie, J. T. (2003). The DSSAT cropping system model. *European Journal of Agronomy*, *18*(3-4), 235–265.

Maulana, F., Anderson, J. D., Butler, T. J., & Ma, X.-F. (2019). Improving dual-purpose winter wheat in the Southern Great Plains of the United States. In *Recent advances in grain crops research* (pp. 1–16). IntechOpen.

McPherson, R. A., Fiebrich, C. A., Crawford, K. C., Kilby, J. R., Grimsley, D. L., Martinez, J. E., … Sutherland, A. J. (2007). Statewide monitoring of the mesoscale environment: A technical update on the Oklahoma Mesonet. *Journal of Atmospheric and Oceanic Technology*, *24*(3), 301–321. doi:10.1175/JTECH1976.1

Patrignani, A., Lollato, R. P., Ochsner, T. E., Godsey, C. B., & Edwards, J. T. (2014). Yield gap and production gap of rainfed winter wheat in the Southern Great Plains. *Agronomy Journal*, *106*(4), 1329–1339.

Pebesma, E. J. (2004). Multivariable geostatistics in s: The gstat package. *Computers & Geosciences*, *30*, 683–691.

Pinchak, W. E., Worrall, W. D., Caldwell, S. P., Hunt, L. J., Worrall, N. J., & Conoly, M. (1996). Interrelationships of forage and steer growth dynamics on wheat pasture.

Ritchie, J. T., Godwin, D. C., & Singh, U. (1989). Soil and weather inputs for the IBSNAT crop models. In *Proceedings of the IBSNAT symposium: Decision Support System for Agrotechnology Transfer* (pp. 31–45).

Shafer, M. A., Fiebrich, C. A., Arndt, D. S., Fredrickson, S. E., & Hughes, T. W. (2000). Quality assurance procedures in the Oklahoma Mesonetwork. *Journal of Atmospheric and Oceanic Technology*, *17*(4), 474–494.

United States Census Bureau. (2016). TIGER/Line® shapefiles and TIGER/Line® files. Accessed March 30, 2017. Retrieved from https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html

United States Department of Agriculture-National Agricultural Statistics Service. (2017). *Cropland data layer*. United States Department of Agriculture. Washington, DC. Retrieved from https://nassgeodata.gmu.edu/CropScape

United States Department of Agriculture-National Agricultural Statistics Service. (2021). NASS - Quick Stats. Accessed: 2021-06-30. Retrieved from https://data.nal.usda.gov/search/type/dataset/nass-quick-stats

United States Department of Agriculture-Natural Resources Conservation Service. (2019). U.S. General Soil Map (STATSGO2). Retrieved from https://sdmdataaccess.sc.egov.usda.gov

Vitale, J. D., Godsey, C., Edwards, J., & Taylor, R. (2011). The adoption of conservation tillage practices in Oklahoma: Findings from a producer survey. *Journal of Soil and Water Conservation*, *66*(4), 250–264.

Walker, K. (2020). *tigris: Load census tiger/line shapefiles*. R package version 0.9.2. Retrieved from https://CRAN.R-project.org/package=tigris

Zadoks, J. C., Chang, T. T., & Konzak, C. F. (1974). A decimal code for the growth stages of cereals. *Weed Research*, *14*(6), 415–421.

Zhang, X.-C., Hunt, L. A., Phillips, W. A., Horn, G., Edward, J., & Zhang, H. (2008). A wheat grazing model for simulating grain and beef production: Part II—model validation. *Agronomy Journal*, *100*(5), 1248–1258. doi:10.2134/agronj2007.0373. eprint: https://acsess.onlinelibrary.wiley.com/doi/pdf/10.2134/agronj2007.0373

CHAPTER III

OKLAHOMA WHEAT VARIETY TRIAL DATA PAIRED WITH WEATHER AND SOIL DATA FOR CROP MODELING ANALYSIS

This chapter introduces a spatially diverse temporal data set including weather data spanning 1997 to 2018 from the Oklahoma Mesonet, paired with wheat variety trial data spanning 1999 to 2018, as well as soil data from SSURGO. The database is a robust combination of genetic information such as yield from over 100 wheat genotypes, soil, weather, and management. The resulting data structure provides detailed insight on wheat production across Oklahoma over roughly 20 years, into a single condensed dataset that has potential to be used for crop simulation modeling and exploring the effects of genotype, environment, and management interactions (G x E x M).

Multiple data sources have been combined to create a comprehensive dataset that is both spatially and temporally diverse. The data that were combined have been obtained from a long-term Oklahoma State University wheat variety trial study, as well as a long term grazing research study, for varieties that originate from Texas, Oklahoma, and Kansas. The variety trial data spans 19 years, 32 locations, and includes a range of management practices that are common in Oklahoma wheat production. The grazing trial spans 12 years, 4 locations, and were clipped and grazed for the duration of the trial. The objective of this chapter is to provide a comprehensive documentation of the dataset for crop-model calibration within Oklahoma.

- Key words: Oklahoma, Southern Great Plains, Oklahoma Wheat Variety Trial, Oklahoma Wheat Quality, Oklahoma Mesonet, SSURGO, Calibration, Crop Model, Wheat, Triticum aestivum, DSSAT, spatial, temporal

3.1 Oklahoma Wheat Variety Trial

The wheat variety trial studies have been conducted every year since the 1960s and are ongoing. The study seeks to provide an understanding of genetic performance of different wheat varieties across the state, and aims to inform producers of the genetic potential of said varieties across varying growing conditions with consistent, non-nutrient-limited management practices. The trials cover wheat production practices that are most common amongst producers in the state. The research locations are located mostly throughout the Oklahoma wheat belt, with the exception of the Goodwell location, which resides in the Oklahoma panhandle.

The experiment, led by the Small Grains Extension Program at Oklahoma State University, has been carried out by a large group of cooperators, technicians, graduate students, and collaborators over the years. This group has been primarily coordinated by the Small Grains Extension Specialist, a position which has been held by Jeff Edwards, David Marburger, and Amanda de Oliveira Silva over the last twenty years. Rick Kochenower, Richard Austin, Brett Carver, and Robert Hunger have also played consistent roles in designing and carrying out the trials over multiple years.

The research conducted by this experiment have been funded by multiple organizations over the years, and include: Oklahoma Wheat Commission, Oklahoma Wheat Research Foundation, OSU Cooperative Extension service, OSU Agricultural Experiment Station, as well as entry fees from participating seed companies.

The overarching objective of the wheat variety trials at Oklahoma State University is to provide outreach and extension regarding genetic potential of wheat varieties, and various management practices that can affect yield, directly to Oklahoma wheat producers, as well as producers in neighboring states. This information is typically provided in tabular form for each research location, which includes yield, soil nutrient levels, supplemental nutrient application rates, irrigated and rainfed production, and tillage method.

3.1.1 Study area

The study area for the combined database consists of numerous locations across the state, and can be found in close proximity to strategically located Mesonet stations across Oklahoma Figure 3.1. Not all research stations are continuous over the 19 year trial period and management practices can vary when considering planting date, tillage, utilization, and number of cultivars. Additionally, the later planting dates are indicative of grain-only (GO), while earlier planting dates are indicative of dual-purpose (DP) as seen in Table 3.4. The number of research locations range from 13-22 across the 19 year period with highly variable temperature and rainfall, across active locations within a growing season, as seen in Table 3.2. The variability can be further expressed for the season when considering location by location differences in temperature and rainfall as seen in Table 3.1, which summarizes the temperature and rainfall by location for all seasons. The study as a whole captures interactions across a large area of Oklahoma, including management practices and climate impacts on yield.

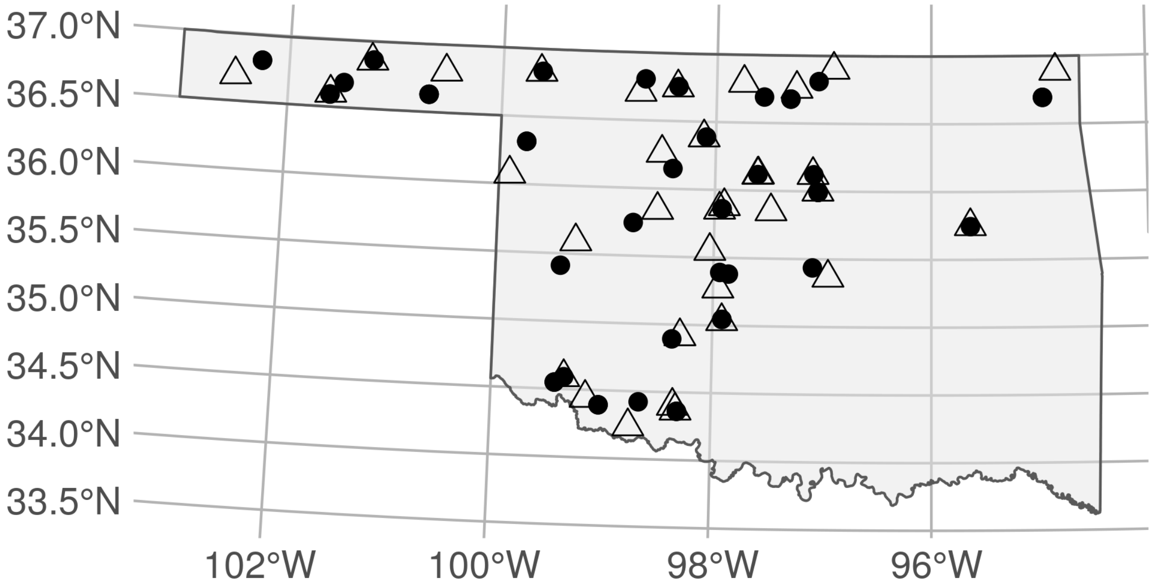

Figure 3.1: Site description for the area of study. Triangles represent Oklahoma Mesonet stations, and points represent variety trial locations across the state.

Table 3.1: Summary data of locations included in the Oklahoma wheat variety trial dataset including three-digit abbreviation code (LLL), latitude (Lat, decimal degrees), longitude (Long, decimal degrees), number of years in the dataset (Years), mean and standard deviation (SD) of seasonal average temperature (Temperature, °C), mean and standard deviation (SD) of seasonal cumulative rainfall (Rainfall, mm).

					Temperature		**Rainfall**	
Location	**LLL**	**Lat**	**Long**	**Years**	**Mean**	**SD**	**Mean**	**SD**
Afton	AFT	36.69	-94.96	10	11.4	1.2	828	157
Altus	ALT	34.59	-99.34	7	13.8	0.8	520	193
Alva	ALV	36.81	-98.67	17	11.5	0.9	500	142
Apache	APC	34.89	-98.37	16	13.0	0.8	566	192
Balko	BLK	36.63	-100.68	14	10.9	0.8	361	109
Buffalo	BFF	36.84	-99.63	14	11.4	0.9	397	100
Chattanooga	CHT	34.42	-98.66	2	14.6	0.9	445	159
Cherokee	CHR	36.75	-98.36	15	11.7	0.9	489	130
Chickasha	CHC	35.05	-97.91	10	12.7	0.9	622	149
El Reno	ELR	35.38	-97.86	8	12.6	0.6	660	294
Elk City	ELC	35.41	-99.40	10	12.3	0.6	462	194
Frederick	FRD	34.39	-99.02	8	13.6	0.9	464	158
Gage	GAG	36.32	-99.76	13	11.5	0.9	395	157
Goodwell	GDW	36.59	-101.61	16	10.2	0.9	303	98
Guymon	GYM	36.68	-101.48	1	9.4	0.0	337	0
Haskell	HSK	35.74	-95.64	11	12.4	0.7	799	211
Homestead	HMS	36.15	-98.39	10	12.2	0.8	512	121

Table 3.1: Summary data of locations included in the Oklahoma wheat variety trial dataset including three-digit abbreviation code (LLL), latitude (Lat, decimal degrees), longitude (Long, decimal degrees), number of years in the dataset (Years), mean and standard deviation (SD) of seasonal average temperature (Temperature, °C), mean and standard deviation (SD) of seasonal cumulative rainfall (Rainfall, mm). *(continued)*

					Temperature		**Rainfall**	
Location	**LLL**	**Lat**	**Long**	**Years**	**Mean**	**SD**	**Mean**	**SD**
Hooker	HKR	36.86	-101.21	12	10.3	0.8	264	121
Keyes	KYS	36.81	-102.26	7	9.3	0.8	182	106
Kildare	KLD	36.81	-97.05	11	11.5	1.0	646	159
Kingfisher	KNG	35.86	-97.93	18	12.1	0.9	590	179
Lahoma	LHM	36.39	-98.09	18	11.7	0.9	486	124
Lamont	LMN	36.69	-97.56	13	11.4	0.9	539	146
Marshall	MRS	36.12	-97.61	19	12.1	0.8	605	153
McLoud	MCL	35.44	-97.09	5	12.9	1.2	693	364
Olustee	OLS	34.55	-99.42	10	13.6	0.8	435	128
Perkins	PRK	35.99	-97.05	7	12.7	1.0	624	93
Stillwater	STL	36.12	-97.09	13	12.4	0.9	636	192
Thomas	THM	35.74	-98.75	7	12.4	1.0	532	125
Tonkawa	TNK	36.68	-97.31	2	11.9	0.7	568	88
Union City	UNC	35.39	-97.94	3	13.3	1.0	691	270
Walters	WLT	34.36	-98.31	6	14.0	0.9	567	223

Table 3.2: Summary of growing season weather across locations for the Oklahoma wheat variety trial dataset including number of locations (Locations), mean and standard deviation (SD) of location-specific seasonal average temperature (°C), mean and standard deviation (SD) of location-specific seasonal cumulative rainfall (mm).

		Temperature		**Rainfall**	
Season	**Locations**	**Mean**	**SD**	**Mean**	**SD**
1999-2000	17	12.9	1.0	592	135
2000-2001	15	10.8	0.9	614	142
2001-2002	16	12.2	0.7	423	167
2002-2003	17	10.9	1.0	551	102
2003-2004	18	12.4	1.1	542	161
2004-2005	17	12.1	1.0	567	105
2005-2006	15	13.0	0.8	289	86
2006-2007	13	11.5	1.2	808	331
2007-2008	17	11.7	1.0	601	247
2008-2009	19	11.6	0.9	439	123
2009-2010	20	10.5	1.1	523	159
2010-2011	22	12.0	1.2	296	152
2011-2012	22	13.2	1.1	540	163
2012-2013	15	11.7	1.0	502	188
2013-2014	13	10.7	0.8	385	99
2014-2015	21	11.6	0.9	725	216
2015-2016	18	12.9	0.9	650	158
2016-2017	18	13.4	0.9	574	137
2017-2018	20	12.2	0.9	432	137

Table 3.3: Citations for Oklahoma Wheat Variety Trial reports by season for grain yield and heading date (Yield), and fall forage production and first hollow stem date (Forage). Reports prior to 2004-2005 were unavailable.

Season	**Yield**	**Forage**
2004-2005	J. Edwards, Kochenower, Austin, Carver, and Hunger, 2005	J. Edwards, Austin, Carver, and Kochenower, 2005
2005-2006	J. T. Edwards et al., 2006	J. Edwards et al., 2006
2006-2007	J. T. Edwards et al., 2007	J. Edwards, Austin, Inda, Carver, and Tipton, 2007
2007-2008	J. T. Edwards et al., 2008	J. Edwards et al., 2008
2008-2009	J. T. Edwards et al., 2009	J. Edwards, Austin, and Ladd, 2009
2009-2010	J. T. Edwards et al., 2010	J. Edwards, Austin, and Ladd, 2010
2010-2011	J. T. Edwards et al., 2011	J. Edwards, Austin, and Ladd, 2011
2011-2012	J. T. Edwards et al., 2012	J. Edwards, Austin, and Lollato, 2012
2012-2013	J. T. Edwards et al., 2013	J. Edwards, Austin, Knori, Lollato, and Cruppe, 2013
2013-2014	J. T. Edwards et al., 2014	J. Edwards, Calhoun, Knori, Lollato, and Cruppe, 2014
2014-2015	J. T. Edwards et al., 2015	J. Edwards, Calhoun, Knori, Lollato, and Cruppe, 2015

Table 3.3: Citations for Oklahoma Wheat Variety Trial reports by season for grain yield and heading date (Yield), and fall forage production and first hollow stem date (Forage). Reports prior to 2004-2005 were unavailable. *(continued)*

Season	**Yield**	**Forage**
2015-2016	D. A. Marburger et al., 2016	D. Marburger, Edwards, and Calhoun, 2016
2016-2017	D. Marburger, Calhoun, Beedy, Carver, et al., 2017	D. Marburger, Calhoun, Beedy, Leach, and Watson, 2017
2017-2018	D. Marburger, Calhoun, Carver, et al., 2018	D. Marburger, Calhoun, Pugh, Watson, and Gillespie, 2018

Table 3.4: Summary data of locations included in the Oklahoma wheat variety trial dataset including three-digit abbreviation code (LLL), earliest (Early) and latest (Late) planting dates, tillage practices (conventional tillage, CT; no-till, NT), production system (grain-only, GO; fall forage, FF; dual-purpose, DP), and management practices (conventional practice, CP; fungicide applied, FG; intensive management, IN; irrigated, IR; clipped and grazed, CG).

		Planting Date				
Location	**LLL**	**Early**	**Late**	**Tillage**	**System**	**Management**
Afton	AFT	30 Sep	12 Nov	CT, NT	GO	CP, FG
Altus	ALT	8 Oct	21 Nov	CT	GO	CP
Alva	ALV	24 Sep	29 Oct	CT	GO	CP
Apache	APC	6 Oct	22 Nov	CT, NT	GO	CP, FG
Balko	BLK	19 Sep	18 Oct	CT, NT	GO	CP, FG

Table 3.4: Summary data of locations included in the Oklahoma wheat variety trial dataset including three-digit abbreviation code (LLL), earliest (Early) and latest (Late) planting dates, tillage practices (conventional tillage, CT; no-till, NT), production system (grain-only, GO; fall forage, FF; dual-purpose, DP), and management practices (conventional practice, CP; fungicide applied, FG; intensive management, IN; irrigated, IR; clipped and grazed, CG). *(continued)*

		Planting Date				
Location	**LLL**	**Early**	**Late**	**Tillage**	**System**	**Management**
Buffalo	BFF	23 Sep	8 Nov	CT, NT	GO	CP
Chattanooga	CHT	9 Oct	24 Oct	NT	GO	CP
Cherokee	CHR	20 Sep	26 Oct	CT	DP, FF, GO	CP, FG
Chickasha	CHC	9 Sep	9 Nov	CT	DP, FF, GO	CP, IN
El Reno	ELR	12 Sep	29 Sep	CT, NT	DP, FF, GO	CP, FG
Elk City	ELC	12 Sep	21 Oct	CT, NT	DP, GO	CP
Frederick	FRD	17 Sep	17 Nov	CT, NT	DP, GO	CP
Gage	GAG	14 Sep	14 Nov	CT, NT	DP, GO	CP
Goodwell	GDW	14 Sep	17 Oct	CT, NT	GO	CP, IR
Guymon	GYM	3 Sep	17 Oct	CT	DP, GO	IR
Haskell	HSK	11 Sep	13 Nov	CT	FF, GO	CP
Homestead	HMS	7 Oct	3 Nov	CT, NT	GO	CP
Hooker	HKR	24 Sep	28 Oct	CT, NT	GO	CP
Keyes	KYS	25 Sep	12 Oct	NT	GO	CP, FG
Kildare	KLD	2 Oct	2 Nov	CT, NT	GO	CP, FG
Kingfisher	KNG	1 Oct	17 Nov	CT	GO	CP

Table 3.4: Summary data of locations included in the Oklahoma wheat variety trial dataset including three-digit abbreviation code (LLL), earliest (Early) and latest (Late) planting dates, tillage practices (conventional tillage, CT; no-till, NT), production system (grain-only, GO; fall forage, FF; dual-purpose, DP), and management practices (conventional practice, CP; fungicide applied, FG; intensive management, IN; irrigated, IR; clipped and grazed, CG). *(continued)*

		Planting Date				
Location	**LLL**	**Early**	**Late**	**Tillage**	**System**	**Management**
Lahoma	LHM	27 Sep	17 Nov	CT	GO	CP, FG
Lamont	LMN	19 Sep	8 Nov	CT	DP, GO	CP, FG
Marshall	MRS	31 Aug	6 Nov	CT	DP, FF, GO	CG, CP
McLoud	MCL	10 Oct	19 Nov	CT	GO	CP, FG
Olustee	OLS	4 Oct	14 Nov	CT, NT	GO	CP
Perkins	PRK	5 Sep	5 Nov	CT	DP, FF, GO	CP
Stillwater	STL	14 Sep	24 Sep	CT	FF	CP
Thomas	THM	30 Sep	31 Oct	CT	GO	CP, FG
Tonkawa	TNK	13 Oct	3 Nov	CT	GO	CP
Union City	UNC	14 Sep	1 Oct	CT	DP	CP
Walters	WLT	11 Sep	19 Oct	CT, NT	DP	CP

Table 3.5: Summary of management practices included in the Oklahoma wheat variety trial dataset by growing season including number of cultivars (Cultivars), earliest (Early) and latest (Late) planting dates, tillage practices (conventional tillage, CT; no-till, NT), production system (grain-only, GO; fall forage, FF; dual-purpose, DP), and other management practices (conventional practice, CP; fungicide applied, FG; intensive management, IN; irrigated, IR; clipped and grazed, CG).

		Planting Date				
Season	**Cultivars**	**Early**	**Late**	**Tillage**	**System**	**Management**
1999-2000	33	9 Sep	9 Nov	CT	GO, DP, FF	CP, IR
2000-2001	30	17 Sep	22 Nov	CT	GO, DP	CP, IR
2001-2002	18	10 Sep	17 Nov	CT	GO, DP	CP, FG, IR
2002-2003	37	3 Sep	12 Nov	CT	GO, DP, FF	CP, IR
2003-2004	24	5 Sep	22 Oct	CT	GO, DP, FF	CP, IR
2004-2005	36	31 Aug	8 Nov	CT	GO, DP, FF	CP, FG, IR
2005-2006	37	7 Sep	25 Oct	CT	GO, DP, FF	CP, FG
2006-2007	37	5 Sep	26 Oct	CT, NT	GO, DP, FF	CP, IR
2007-2008	32	14 Sep	2 Nov	CT, NT	GO, DP, FF	CP, FG
2008-2009	35	16 Sep	4 Nov	CT, NT	GO, DP, FF	CP, FG
2009-2010	38	17 Sep	13 Nov	CT, NT	GO, DP, FF	CP, FG, IR
2010-2011	43	14 Sep	1 Nov	CT, NT	GO, DP, FF	CP, FG, IR
2011-2012	45	20 Sep	28 Oct	CT, NT	GO, DP, FF	CP, FG, IR
2012-2013	45	17 Sep	24 Oct	CT, NT	GO, DP, FF	CP, FG, IR
2013-2014	46	20 Sep	19 Nov	CT, NT	GO, DP, FF	CP, FG, IN, IR
2014-2015	56	12 Sep	31 Oct	CT, NT	GO, DP, FF	CP, FG, IN, IR
2015-2016	58	11 Sep	29 Oct	CT, NT	GO, DP, FF	CP, FG, IN, IR

Table 3.5: Summary of management practices included in the Oklahoma wheat variety trial dataset by growing season including number of cultivars (Cultivars), earliest (Early) and latest (Late) planting dates, tillage practices (conventional tillage, CT; no-till, NT), production system (grain-only, GO; fall forage, FF; dual-purpose, DP), and other management practices (conventional practice, CP; fungicide applied, FG; intensive management, IN; irrigated, IR; clipped and grazed, CG). *(continued)*

		Planting Date				
Season	**Cultivars**	**Early**	**Late**	**Tillage**	**System**	**Management**
2016-2017	66	12 Sep	21 Oct	CT, NT	GO, DP, FF	CP, FG, IN, IR
2017-2018	60	11 Sep	30 Oct	CT, NT	GO, DP, FF	CP, FG, IN, IR

3.1.2 Experimental methods

Conventional-till plots consisted of eight planted rows in width with 15 cm (6 inches) space between each row. No-till plots consisted of seven planted rows in width, with 20 cm (7.5 inches) between each row. Plot lengths for conventional-till and no-till treatments were planted to 7.6 meters (25 feet) in length and trimmed down to 6 meters (20 feet) prior to harvest resulting in a harvested area of 7.2 m^2 for conventional till and 8.4 m^2 for no-till. Locations in the Panhandle, specifically Goodwell, were planted to 10.5 meters (35 feet) long and trimmed down to 9 meters (29 feet) length and 1.5 meter width (60 inches) prior to harvest, resulting in 13.5 m^2 harvested area. Both conventional-till and no-till plots are seeded at 67 kg ha^{-1} (60 lb $acre^{-1}$) for grain-only trials, however for dual purpose trials the seeding rate was 135 kg ha^{-1} (120 lb $acre^{-1}$). Trials were managed based on soil test values to avoid nutrient limitations. Conventional-till trials typically received 56 kg ha^{-1} (50 lb/acre) of 18-20-0 (N-P-K) in-furrow at planting, while no-till plots typically received 5 gal $acre^{-1}$ of 10-34-0

(N-P-K) at planting. Intensive wheat management trials receive additional 45 kg ha^{-1} (40 lb acre^{-1}) nitrogen, as well as one or two fungicide applications. For dual-purpose trials stocking rate and grazing duration was collected in addition to management practices and varied depending on the climatic factors of a growing season.

Grain Yield and Heading Date Data

Yield data and heading dates for this study were taken from a dataset of the Oklahoma Wheat Variety trial, an ongoing investigation of wheat performance across Oklahoma that has been conducted over approximately the last 20 years. For reference to these reports by season, refer to the Yield column of Table 3.3. The experiment is managed by Area and County extension staff using farming practices that are relevant for the state. The variety yield performance is recorded at the field replicate level (3-5 replications) for each genotype at each location, which is then used to generate regional summaries in bushels per acre. Additional management inputs such as fungicide application, planting density, supplemental fertilizer application, irrigation, tillage, and fertilizer are also recorded and provided. Heading date is recorded for each variety when 50 percent of the plants in the plot have achieved a wheat head.

Wheat Quality Data

The Oklahoma wheat quality data spans harvest years 2014-2016 at Lahoma and Chickasha intensive wheat management locations, and provides lab analysis results of grain quality for flour production quality (Carver, Estes-Shelton, & Edwards, 2014, 2015; D. Marburger, Carver, Estes-Shelton, Miller, & Chen, 2016). The Perten SKCS 4100 was used to collect grain parameters such as kernel hardness, kernel weight, and kernel diameter that are typically used for determining milling quality (Instruments, 1995).

Fall Forage and First Hollow Stem

First hollow-stem and fall forage production are available at 5 locations and spans 16 years of data collection. For reference to these reports by season, refer to the Forage column of Table 3.3. Fall-forage trials include simulated grazing pressure through the use of a mower on one or two clipping dates in November and December, as well as the date of first hollow stem which typically falls between February and March. Wheat above ground biomass was clipped to 1 cm above the soil from one or two rows per plot for a combined 1 meter length sample. Samples are dried in a forced-air dryer for up to one week to provide fall forage production totals as dry weight. First hollow stem was collected by digging a 20 cm section of one row in the plot, and splitting the largest wheat tiller length-wise to determine seed-head height in the plant. First hollow stem is determined when there is a 1.5 cm space between head and crown root (i.e. Hollow Stem), and is based on a random sample average of 10 wheat plants

3.2 Data acquisition and quality control

3.2.1 Variety Trial Data

Data was captured using manual data entry into a spreadsheet from harvest reports for each location. Unique variable names were generated for each column to correspond with DSSAT input variables. For entries that have a reported harvest date and corresponding yield, but no planting date, a filtering step was performed to exclude them.

Summaries of the wheat variety trial components are available within the reports for each location year. The summaries provide additional metadata describing weather events or biological events such as pest or disease pressure that severely impacted wheat performance within each report.

All data sources were analyzed, corrected, and re-formatted using R version 3.6.3, under Ubuntu 18.04.4 LTS (R Core Team, 2019). From this paragraph onward, the term 'packages' will refer directly to R packages that are freely available for use at the time of writing. Package `tidyverse` was used to assist the process of correcting text-data that caused duplications in the original variety data such as spelling, and capitalization errors in wheat variety names, soil names, and location names. Each variable of the database was screened for duplications or spelling errors. Spelling inconsistencies in variety, location, and soil names were standardized and corrected when necessary. Numerical variable units were converted to standard SI units. All modifications to text and numerical data were performed using R code to avoid introducing manual typographical errors and to ensure reproducibility of the workflow.

Coordinates for research station locations (Perkins, Stillwater, Chickasha, Haskell, Altus, Marshall, Goodwell, and El Reno) were obtained visually using Google Maps (https://www.google.com/maps). Other research locations that were conducted on farmer-owned land or off site locations, were determined by passing the location names provided in the wheat variety trial data to the `geo_osm()` function of the `tidygeocoder` package for R (Cambon, Hernangómez, Belanger, & Possenriede, 2021). The coordinates returned for each location were then used to extract corresponding SSURGO profile and Oklahoma Mesonet station data, which will be discussed in further detail in each section.

3.2.2 Soil Data

Soil names were provided in the wheat variety trial data that correspond with each location. These names were used to pull SSURGO (USDA-NRCS, 2020) soil profiles for each location through a custom utility function `pull_profile_by_name()`. The function first queries the SSURGO database for the soil name provided using the `SDA_query()` function from the package `soilDB`, Version 2.5 (Beaudette, Skovlin, & Roecker, 2020). If multiple entries are returned, the function filters the provided map unit keys by constructing a spatial query based on the specified location coordinates. The overlap of the spatial query and the list of map unit keys associated with the soil name is further filtered by pulling the corresponding spatial data and selecting the map unit key of the nearest feature as determined by the `st_nearest_feature()` function of the `sf` package (Pebesma, 2018). The identified map unit key is then used to pull component- and horizon-specific soil property data.

Soil input data were derived by either using SSURGO data directly, deriving approximate equivalent values or using a pedotransfer function. Soil albedo (SALB) values were taken directly from SSURGO (albedodry_r). Soil organic carbon (SLOC) was set to the SSURGO value for soil organic matter (om_r) divided by 1.724. Soil drainage (SLDR) was estimated based on the SSURGO value for drainagecl_r, from "Excessively drained" soils being assigned a value of 0.85 to "Very poorly drained" soils being assigned a value of 0.01. The Soil Conservation Service runoff curve number for antecedent soil moisture condition II (SLRO) was set based on the SSURGO values for hydrologic soil group (hydgrp) and slope (slope_r). The depth to base of layer (SLB) was pulled from the corresponding SSURGO variable (hzdepb_r). The soil coarse fraction (SLCF) was taken from the SSURGO variable fragvol_r. Where fragvol_r contained missing values and the horizon name indicated presence of bedrock, SLCF was assigned a value of 99. It was otherwise assumed that missing values were 0. To calculate the soil root growth factor (SRGF) the SLCF was divided by 100 and subtracted from 1. The SSURGO data for VWC at -0.33 bar (wthirdbar_r) and 15 bar (wfifteenbar_r) bulk density (dbovendry_r), percent silt (silttotal_r), and percent clay (claytotal_r) were extracted for each soil profile and fed into the Rosetta3 pedotransfer function (Zhang & Schaap, 2017) to generate estimates of the saturated conductivity and the van Genuchten soil water retention curve equation parameters. These van Genuchten parameters were used to calculate values for the DSSAT soil parameters where soil lower limit (SLLL) was set equal to the van Genuchten equation value of volumetric soil water content (VWC) at matric potential of -1500 kPa, soil drained upper limit (SDUL) was set equal to the van Genuchten equation value of VWC at -33 kPa, and soil saturated limit (SSAT) was set equal to the saturated VWC as estimated by the Rosetta3 algorithm. The soil saturated hydraulic conductivity (SSKS) was set to the value estimated by the Rosetta3 algorithm except for conversion from cm d^{-1} to cm h^{-1} to ensure proper units as required by the DSSAT variable definition. Coordinates were set to values assigned to that location. The values for soil mineralization factor (SLNF) and soil photosynthesis factor (SLPF) were both assumed to be 1 and the soil evaporation limit (SLU1) was set to 6 mm. Parameters indicating method of extraction (SMHB, SMPX, and SMKE) were set to nominal values of IB001. All other soil input data values were set as missing. A full description of soil variables and units is provided in Table 3.7. Soil input data were written to the DSSAT standard soil file format using the `write_sol()` function from the `DSSAT` version 0.0.2 R package (Alderman, 2020).

3.2.3 Weather data

Rainfall, soil moisture, wind-speed, and relative humidity data were obtained from the Oklahoma Mesonet, which is a network of weather stations that comprises 122 locations strategically placed around the state with a station density average of three per county [McPherson2007; Brock1995]. Coordinates for Oklahoma Mesonet stations were obtained using the `updatestn()` function of the `okmesonet` package (Allred, Hovick, & Fuhlendorf, 2014). Each variety trial location was paired with a neighboring Mesonet station as determined through the use of the `st_nearest_feature()` function of the `sf` package (Pebesma, 2018). This allowed relevant weather data to be matched approximately to each respective city containing a variety trial.

Sub-daily 5 minute interval weather data for all Mesonet locations are pulled to a local workstation with a shell scripted ftp query. The script constantly checks for new daily data from the Mesonet data portal, and any rectifications that may have been made by the Mesonet staff since the last data download. Any new observations and changes to the original data are added to the copies that exist on the local workstation to maintain integrity of data. Additionally, the script applies unit conversions from imperial to metric, which occurs when the data are pulled from the server. The rainfall data is reported in units of millimeters of water per day. Missing data were filled using inverse distance weighting with a power of 2 for rainfall, soil moisture, wind-speed, and relative humidity utilizing the 3 nearest neighbor weather station matches. The sub-daily values were summarized to daily values for maximum (TMAX) and minimum temperature (TMIN), cumulative solar radiation (SRAD), cumulative rainfall, average wind speed, and average relative humidity. Full variable definitions and units are provided in Table 3.8. The daily summary data were then written in DSSAT standard weather file format using the `write_wth()` function of the `DSSAT` R package (Alderman, 2020).

3.2.4 Generation of Model input files

The DSSAT R package was used to convert variety trial data, forage trial data, and wheat quality data into DSSAT standard experiment files. The package is designed to facilitate reproducible crop modeling workflows with the DSSAT cropping systems model (Alderman, 2020).

Summary File

The summary file (FileA) is used to record end of season average performance of the crop, as well as phenological observations. Kernel weight from the wheat quality studies returns thousand kernel weight in milligrams, which was converted to grams to represent thousand-kernel-weight for DSSAT. Each replication, location, and year the data were subset to contain the recorded yield, and TKW, which were then written to DSSAT standard format FileA parameter estimation files through the use of the `write_filea()` function of the `DSSAT` package.

Time Course File

Each time course file (FileT) contains replication level, final clipping date, cumulative biomass, and growth stage dates for first hollow-stem, and heading. These variables were then stored as days to first hollow stem, days to heading, clipping date, and cumulative biomass that was obtained from the variety trial data through the use of the `write_filet()` function of the `DSSAT` package.

3.3 Data File Description

The overall data table contains six columns: Location, Year, filex_code, SOILID, plant_date, and harvest_date. The Location column specifies the location. The Year column specifies the year of harvest. The filex_code column provides an eight-digit code (discussed below) unique to each location, year and management combination that links to the data file names for wheat and weather data. The SOILID column links the soil type in the soil data file to the location and year. The plant_date and harvest_date columns provide the planting and harvest dates, respectively, for the specific location, year and management combination.

The unique values of filex_code from the overall data table were used to generate filenames for each site-management-year according to the following pattern LLLYYMMM.XXX, where LLLYYMMM is the eight-digit filex_code comprised of LLL (the three-digit location code as shown in Table 3.4, YY (the two-digit year), and MMM (a three-digit management code), and XXX is a three-digit file extension indicating the DSSAT standard file type. Within the three-digit management code, the first digit is production system (D for dual-purpose, G for grain-only, or F for fall forage), second digit is tillage method (C for conventional or N for no-till) and the third digit is for other specific management practices (0 for no special management, 1 for clipped and grazed, I for intensive management, F for fungicide applied, and R for irrigated). Files with extension WHA contain end of season observations and files with extension WHT contain time series observations within a season. The DSSAT standard file format for both of these file types is an ASCII text-based file with fixed column widths of 6 characters. Each file has a header prepended with the `@` character to represent the column names for variables. FileA does not have a date column. FileT has a date column since it contains measurements over time. All variables provided in these files are defined in Table 3.6. In total there are 391 WHA files, 60 WHT files, 425 weather files, and 1 soil file. The FileA (extension WHA) and FileT (extension WHT) formats can be imported into R using the `read_filea()` and `read_filet()` functions from the `DSSAT` R package.

Soil entries are stored in a DSSAT-formatted soil file (extension SOL), which stores whole-profile and layer-specific soil variables described in Table 3.7. Soils for each location are referenced by the SOILID. The soil data file can be read into R using the `read_sol()` function from the `DSSAT` R package. Similarly, weather data is stored in DSSAT-formatted weather files, and each weather file corresponds to a specific location, management and year combination. Files are consistently labeled according to the pattern described for FileA and FileT (LLLYYMMM.XXX) with the file extension set to WTH. Weather files can be read into R using the `read_wth()` function of the `DSSAT` R package. Variable descriptions for weather files are found in Table 3.8.

Table 3.6: Name, definitions and units for variables reported in FileA and FileT formatted files.

Name	**Description**	**Units**
CWAD	Tops weight	kg ha^{-1}
DATE	Date of measurement	YYJJJ*
GSTD	Zadoks growth stage	stage number
HWAM	Yield at harvest maturity	kg ha^{-1}
HWUM	Unit grain weight at maturity	g $unit^{-1}$
TRNO	Treatment Number	number

* YYJJJ, two-digit year followed by three-digit Julian day of year.

Table 3.7: Name, definitions and units for variables reported in SOL formatted file.

Name	**Description**	**Units**
COUNTRY	Country of soil profile location	–
LAT	Latitude	decimal degrees north
LONG	Longitude	decimal degrees east
SADC	Soil adhesion coefficient	0 to 1 scale
SALB	Albedo	fraction
SBDM	Bulk density	g cm^{-3}
SCEC	Cation exchange capacity	cmol kg^{-1}
SCOM	Color	Munsell hue
SCS FAMILY	Soil Conservation Service soil family	–
SDUL	Upper limit	cm^3 cm^{-3}
SITE	Site name	Site name
SLB	Depth	cm

Table 3.7: Name, definitions and units for variables reported in SOL formatted file. *(continued)*

Name	**Description**	**Units**
SLCF	Coarse fraction (>2 mm)	percent
SLCL	Clay (<0.002 mm)	percent
SLDR	Drainage rate	fraction day^{-1}
SLHB	pH in buffer	pH in buffer
SLHW	pH in water	pH in water
SLLL	Lower limit	cm^3 cm^{-3}
SLMH	Master horizon	Master horizon
SLNF	Mineralization factor	0 to 1 scale
SLNI	Total nitrogen	percent
SLOC	Organic carbon	percent
SLPF	Photosynthesis factor	0 to 1 scale
SLRO	Soil Conservation Service runoff curve number	number
SLSI	Silt (0.05 to 0.002 mm)	percent
SLU1	Evaporation limit	mm
SMHB	pH in buffer determination method	code
SMKE	Potassium determination method	code
SMPX	Phosphorus determination code	code
SRGF	Root growth factor	0 to 1 scale
SSAT	Upper limit	cm^3 cm^{-3}
SSKS	Saturated hydraulic conductivity	cm h^{-1}

Table 3.8: Name, definitions and units for weather variables reported in WTH formatted file.

Name	**Description**	**Units**
AMP	Temperature amplitude	°C
CO2	Carbon dioxide concentration	ppm
DATE	Date of observation	YYJJJ[*]
ELEV	Elevation	m
INSI	Institute and site code	code
LAT	Latitude	decimal degrees north
LONG	Longitude	decimal degrees east
RAIN	Daily rainfall	mm d^{-1}
REFHT	Reference height for weather measurements	m
RHUM	Relative humidity	percent
SRAD	Daily solar radiation	MJ m^{-2} d^{-1}
TAV	Temperature average for whole year	°C
TMAX	Daily temperature maximum	°C
TMIN	Daily temperature minimum	°C
WIND	Daily wind speed	km d^{-1}
WNDHT	Reference height for windspeed measurements	m

[*] YYJJJ, two-digit year followed by three-digit Julian day of year.

3.4 Summary

Wheat variety trial data has been collected over the last 20 years and provided to wheat producers as a tool for outreach and extension, however the values were previously only available in tabular regional averages. This dataset combines rep-level wheat data from multiple aspects of wheat production systems from the Oklahoma wheat variety trials, including yield, management practices (fertilizer, fungicide, tillage, planting rates, etc.), and phenological measurements such as heading date and first hollow stem date. Soil layer data from SSURGO and weather data from the Oklahoma Mesonet have been combined for each location and growing season to create a spatially and temporally harmonized source of model forcing data. There is potential for the data to be used in crop additional simulation modeling studies pertaining to the effects of genotype, environment, and management practices, and could potentially be utilized for calibration and validation of cropping systems models.

3.5 References

Alderman, P. D. (2020). A comprehensive R interface for the DSSAT Cropping Systems Model. *Computers and Electronics in Agriculture*, *172*, 105325. doi:https://doi.org/10.1016/j.compag.2020.105325

Allred, B., Hovick, T., & Fuhlendorf, S. (2014). *okmesonet: Retrieve Oklahoma Mesonet climatological data*. R package version 0.1.5. Retrieved from https://CRAN.R-project.org/package=okmesonet

Beaudette, D., Skovlin, J., & Roecker, S. (2020). *soilDB: Soil database interface*. R package version 2.5. Retrieved from https://CRAN.R-project.org/package=soilDB

Cambon, J., Hernangómez, D., Belanger, C., & Possenriede, D. (2021). tidygeocoder: geocoding made easy. R package version 1.0.3. Zenodo. doi:10.5281/zenodo.4686074

Carver, B., Estes-Shelton, C., & Edwards, J. (2014). 2013-14 Wheat and Flour Quality for Varieties Tested in the 2014 OSU Wheat Variety Performance Tests, CR-2165 Rev. 0135. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/wheat-quality-1/previous-wheat-grain-and-flour-quality/2014-cr-2165-web-final2014

Carver, B., Estes-Shelton, C., & Edwards, J. (2015). 2014-15 Wheat and Flour Quality for Varieties Tested in the 2015 OSU Wheat Variety Performance Tests, CR-2165 Rev. 0216. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/wheat-quality-1/previous-wheat-grain-and-flour-quality/2015-cr-2165-web2015

Edwards, J. T., Calhoun, S. R., Lollato, R. P., Cruppe, G., Carver, B. F., & Hunger, R. M. (2015). 2014-15 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2015-wheatvarietytrial

Edwards, J. T., Kochenower, R. D., Austin, R. E., Carver, B. F., Hunger, R. M., & Ladd, J. D. (2008). 2007-08 Small Grains Variety Performance Tests, PT-2008-2 Vol. 20, No. 2. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2008-wheatvarietytrial

Edwards, J. T., Kochenower, R. D., Austin, R. E., Inda, M. K., Carver, B. F., & Hunger, R. M. (2006). 2005-06 Oklahoma Small Grains Performance Tests, PT-2006-5 Vol. 18, No. 5. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2006-wheatvarietytrial

Edwards, J. T., Kochenower, R. D., Austin, R. E., Inda, M. K., Carver, B. F., Hunger, R. M., & Rayas-Duarte, P. (2007). 2006-07 Oklahoma Small Grains Performance Tests, PT-2007-6 Vol. 19, No. 6. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2007-wheatvarietytrial-1

Edwards, J. T., Kochenower, R. D., Austin, R. E., Ladd, J. D., Carver, B. F., Hunger, R. M., … Andrews, C. J. (2009). 2008-09 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2009-wheatvarietytrial

Edwards, J. T., Kochenower, R. D., Austin, R. E., Ladd, J. D., Carver, B. F., Hunger, R. M., … Andrews, C. J. (2010). 2009-10 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2010-wheatvarietytrial

Edwards, J. T., Kochenower, R. D., Austin, R. E., Ladd, J. D., Carver, B. F., Hunger, R. M., … Lollato, R. P. (2011). 2010-11 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2011-wheatvarietytrial

Edwards, J. T., Kochenower, R. D., Austin, R. E., Lollato, R. P., Carver, B. F., & Hunger, R. M. (2012). 2011-12 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2012-wheatvarietytrial

Edwards, J. T., Kochenower, R. D., Austin, R. E., Knori, M. W., Lollato, R. P., Cruppe, G., … Hunger, R. M. (2013). 2012-13 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2013-wheatvarietytrial

Edwards, J. T., Kochenower, R. D., Calhoun, S. R., Knori, M. W., Lollato, R. P., Cruppe, G., … Hunger, R. M. (2014). 2013-14 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2014-wheatvarietytrial

Edwards, J., Austin, R., Carver, B., & Kochenower, R. (2005). 2004-05 Fall Forage Production by Winter Wheat Varieties in Oklahoma, PT-2005-4 Vol. 17, No. 4. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2004-pt2005-4-vol-17-no-4

Edwards, J., Austin, R., Carver, B., Tipton, B., Butchee, D., & Sanders, J. (2008). 2007-08 Fall Forage Production by Winter Wheat Varieties in Oklahoma, PT-2008-1 Vol. 20, No. 1. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2007-pt2008-1-vol-20-no-1

Edwards, J., Austin, R., Carver, B., Tipton, B., Henson, A., & Gregory, M. (2006). 2005-06 Fall Forage Production by Winter Wheat Varieties in Oklahoma, PT-2006-3 Vol. 18, No. 3. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2005-pt2006-3-vol-18-no-3

Edwards, J., Austin, R., Inda, M., Carver, B., & Tipton, B. (2007). 2006-07 Fall Forage Production by Winter Wheat Varieties in Oklahoma, PT-2007-2 Vol. 19, No. 2. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2006-pt2007-2-vol-19-no-2

Edwards, J., Austin, R., Knori, M., Lollato, R., & Cruppe, G. (2013). Fall forage production and date of first hollow stem in winter wheat varieties during the 2012-2013 crop year, CR-2141 Rev. 0513. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2013-cr2141-2012-2013

Edwards, J., Austin, R., & Ladd, J. (2009). Fall forage production and date of first hollow stem in winter wheat varieties during the 2008-2009 crop year, CR-2141 Rev. 0409. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2008-cr2141-2008-2009

Edwards, J., Austin, R., & Ladd, J. (2010). Fall forage production and date of first hollow stem in winter wheat varieties during the 2009-2010 crop year, CR-2141 Rev. 0409. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2009-cr2141-2009-2010

Edwards, J., Austin, R., & Ladd, J. (2011). Fall forage production and date of first hollow stem in winter wheat varieties during the 2010-2011 crop year, CR-2141 Rev. 0411. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2010-cr2141-2010-2011

Edwards, J., Austin, R., & Lollato, R. (2012). Fall forage production and date of first hollow stem in winter wheat varieties during the 2011-2012 crop year, CR-2141 Rev. 0412. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2012-cr2141-2011-2012

Edwards, J., Calhoun, R., Knori, M., Lollato, R., & Cruppe, G. (2014). Fall forage production and date of first hollow stem in winter wheat varieties during the 2013-2014 crop year, CR-2141 Rev. 0514. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2014-cr2141-2013-2014

Edwards, J., Calhoun, R., Knori, M., Lollato, R., & Cruppe, G. (2015). Fall forage production and date of first hollow stem in winter wheat varieties during the 2014-2015 crop year, CR-2141 Rev. 0514. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2015-cr2141-2014-2015

Edwards, J., Kochenower, R., Austin, R., Carver, B., & Hunger, R. (2005). 2004-05 Oklahoma Small Grains Performance Tests, PT-2005-10 Vol. 17, No. 10. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2005-wheatvarietytrial

Instruments, P. (1995). SKCS 4100 Single Kernel Characterization System. *Instruction Manual*.

Marburger, D. A., Edwards, J. T., Beedy, T., Calhoun, S. R., Carver, B. F., & Hunger, R. M. (2016). 2015-16 Small Grains Variety Performance Tests, CR-2143. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143-2016-wheatvarietytrial

Marburger, D., Calhoun, R., Beedy, T., Carver, B., Hunger, B., Watson, B., & Gillespie, C. (2017). 2016-17 Small Grains Variety Performance Tests, CR-2143 Rev. 0917. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/CR2143web2017.pdf

Marburger, D., Calhoun, R., Beedy, T., Leach, J., & Watson, B. (2017). Fall forage production and date of first hollow stem in winter wheat varieties during the 2016-2017 crop year, CR-2141 Rev. 0617. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2017-cr2141-2016-2017

Marburger, D., Calhoun, R., Carver, B., Hunger, B., Watson, B., & Gillespie, C. (2018). 2017-18 Small Grains Variety Performance Tests, CR-2143 Rev. 0718. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/grain-yield-previous-yrs/cr-2143web2018-small-grains-vt

Marburger, D., Calhoun, R., Pugh, B., Watson, B., & Gillespie, C. (2018). Fall forage production and date of first hollow stem in winter wheat varieties during the 2016-2017 crop year, CR-2141 Rev. 0618. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2018-cr2141-2017-2018

Marburger, D., Carver, B., Estes-Shelton, C., Miller, R., & Chen, R. (2016). 2015-16 Wheat and Flour Quality for Varieties Tested in the 2016 OSU Wheat Variety Performance Tests, CR-2165 Rev. 0216. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/wheat-quality-1/previous-wheat-grain-and-flour-quality/2016-cr-2165-web2016

Marburger, D., Edwards, J., & Calhoun, R. (2016). Fall forage production and date of first hollow stem in winter wheat varieties during the 2015-2016 crop year, CR-2141 Rev. 0716. Stillwater: Oklahoma State University. Accessed: 2020-08-13. Retrieved from http://wheat.okstate.edu/variety-testing/forage-yield-1/2016-cr2141-2015-2016

Pebesma, E. (2018). Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal*, *10*(1), 439–446. doi:10.32614/RJ-2018-009

R Core Team. (2019). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. Vienna, Austria. Retrieved from https://www.R-project.org/

United States Department of Agriculture-Natural Resources Conservation Service. (2020). Soil Survey Geographic (SSURGO) Database for Oklahoma. Available Online. Accessed: 2020-08-13. Retrieved from https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627

Zhang, Y. & Schaap, M. G. (2017). Weighted recalibration of the rosetta pedotransfer model with improved estimates of hydraulic parameter distributions and summary statistics (rosetta3). *Journal of Hydrology*, *547*, 39–53.

CHAPTER IV

GENERAL CONCLUSIONS

The new parallel gridded version of DSSAT-CSM can be utilized to represent inter-annual patterns in wheat grain yield for the Oklahoma wheat belt, however the current model configuration shows a large positive bias that needs to be corrected before being utilized by market advisers or stakeholders. The model was able to follow inter-annual trends in wheat production when compared to NASS and wheat variety trial grain yield, which means that model simulated grain yield was high where reported yield was high, and low where reported yield was low. Additionally, drought years were reflected in simulated grain yield with an overall reduction throughout the wheat belt. Model simulated yield estimates under the current configuration are higher than observed yield throughout the wheat belt, which causes a positive bias in yield estimates and could be due to the inability of the model to represent certain abiotic and biotic factors discussed further in chapter two. Additional calibration and validation of crop parameters for each genotype could potentially improve grain yield estimates. Model estimates for wheat forage biomass production are not currently suitable for use in the current implementation. Further work needs to be conducted to isolate the causes of poor performance of the grazing routine.

The resulting dataset discussed in chapter three could potentially be used to generate high quality calibration and validation sets for genotypes that have been utilized over the last 20 years in the wheat variety trials conducted by Oklahoma State University. The dataset contains measurements from many different aspects of wheat production in Oklahoma, such as planting dates, harvest dates, grain yield, biomass, and stocking rates, and is an untapped source of genetic performance that could be used in future studies to create robust genetic parameters for cropping systems models. Further calibration and validation could potentially help to reduce the upward model bias in grain yield estimates that was identified in chapter two.

To conclude this study, a modeling framework has been created to utilize a new gridded version of DSSAT-CSM to analyze wheat production in the Oklahoma wheat belt. The new framework could be helpful in assessing grain production volume as well as forage biomass estimates at high resolution within a large wheat producing region of Oklahoma. More work needs to be done in order to fine-tune the crop simulation framework, and could potentially be improved with the data available from the Oklahoma wheat variety trials, the Oklahoma Mesonet, and soil information from SSURGO.

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