Farm management implications of uncertainty in the number of days suitable for fieldwork in corn production

by

MICHELLE MENSING

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Major Professor
Dr. Terry Griffin

ABSTRACT

Weather uncertainty plays a large role in farm management decisions. Changes in weather trends or increased variability during the growing season may alter the optimal farm management choices regarding machinery purchases, crop allocation to available acreage, varietal trait selection, and crop management practices. These farm management decisions impact the expected length of time available from planting to harvest. The dates that farmers most actively plant and harvest crops changes from year to year based on annual weather patterns that affect the number of days suitable to conduct fieldwork.

This research analyzed corn planting and harvest progress, as well as the number of days suitable for fieldwork in Iowa, Kansas, and Missouri. Variability of days suitable for fieldwork across crop reporting districts within each state was reported. The total number of days suitable for fieldwork during the 'most active' planting and harvest weeks in each state were then analyzed to determine if increasing or decreasing trends exist and estimated as ordinary least squares (OLS) regression. The outcomes presented in this research indicated a statistically significant decreasing trend in days suitable for spring planting in Iowa, and positive trend in Missouri during fall harvest. However, no statistically significant trends were observed in Kansas for either time period.

Farm management implications were examined in relation to the results of the days suitable for fieldwork analysis, specifically regarding machinery sizing decisions. Profit maximizing producers must manage machinery such that they are not over-equipped, but have adequate equipment capacity to plant and harvest all acreage within the available days suitable for fieldwork. Results of these analyses are directly of interest to farmers desiring

to optimally equip their farms, agricultural lenders providing farmers with financing of equipment, and equipment manufacturers.

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I also appreciate USDA NASS and the respective state and regional Field Offices for providing days suitable for fieldwork data and crop progress data via the weekly Crop Progress and Condition Reports.

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CHAPTER I: INTRODUCTION

Decision Innovation Solutions (DIS) provides economic research and data analysis for clients focused in the agriculture industry. Some of the clients of DIS consist of state and national commodity groups, private agri-business companies and State Farm Bureau offices. Part of their mission is to serve their members, many of which are farmers, and help them make the most informed decisions for their operations. Weather plays a large role in machinery utilization, and knowing if weather patterns are changing can help prepare farmers to make better decisions. Decision Innovation Solutions conducts research to help provide their clients with additional knowledge on weather-based farm issues and many other topics.

1.1 Background

Climate is an important topic across the world, so understanding the changes in weather patterns can help farmers explain it to policymakers and the non-farm community, as well as plan for changes themselves. The number of days suitable for fieldwork (DSFW) can shift planting and harvest dates that affect a wide variety of decisions like machinery and seed purchasing options. Analysis of days suitable for fieldwork to assist in farm management decisions is not a new idea, and has been tracked since the 1970's (Edwards 1979). "This is a particularly important piece of information for production agriculture and agricultural extension focused on practical decision-making about farm machinery investment and different facets of cropping systems management" (Gramig and Yun 2016, 2). The dates that farmers most actively plant and harvest crops changes from year to year based on annual weather patterns which determines the number of days suitable for conducting fieldwork. If changes in the number of DSFW are occurring within the expected most active dates for planting, the length of the growing season may be affected. Changes in weather trends or increased variability during the growing season may alter the optimal farm management choices regarding machinery purchases, crop allocation to available acreage, and varietal trait selection (Griffin 2009). These farm management decisions impact the expected length of time available for the crop to reach maturation. Profit maximizing producers must manage machinery such that they are not over-equipped, but have adequate equipment capacity to plant and harvest all acreage within the available days suitable for fieldwork. The size of machinery needed to complete fieldwork varies depending on how many days it can be used (Hanna and Edwards 2014). Machinery purchases are large investments and are used for a relatively short period of time each year, but if farmers are under-equipped or without enough harvest capacity, crops could be left in the field unharvested or suffer a yield penalty for conducting essential field activities outside of the preferred time period. Additionally, if a farmer does not have enough planter capacity, they may not be able to plant all of their farmland during years with a reduced number of days suitable for fieldwork in the spring. Leaving a field unplanted has implications including not fully utilizing a farmer's land resources, negative landowner relations especially if in a crop share arrangement, and not providing cover on the land for weed control. On the other hand, a farmer could also be over-equipped and be paying for more machinery than is needed to plant or harvest their farmland in the given timeframe. "The decision to size equipment to crop acreage under weather uncertainty has been complicated and continues to evade the best decision makers. It is intuitive that having sufficient equipment capacity to harvest all acreage in a timely manner during a bad year is needed, although the magnitude of the bad year to plan for is illusive" (Griffin et al. 2015, 10).

1.2 Problem Statement

Weather patterns have an effect on many aspects of farming operations and decision-making, so the question is, have there been changes in days suitable and crop progress over time? How bad of a year should a farmer plan for when equipping a farm?

1.3 Research Objectives

The primary research objective of this project was to determine if there have been historic changes in days suitable for fieldwork during corn planting and harvesting across the Corn Belt in the Midwestern USA which affect machinery capacity decisions. Specifically this includes:

1. Analysis of days suitable for fieldwork trends for state-level and sub- state-level crop reporting districts in Iowa, Kansas, and Missouri;
2. Estimate any changes in the time farmers typically plant and harvest corn in these states over the last 30+ years
3. Calculate the optimal days suitable for fieldwork (DSFW) percentile to select machinery using a benefit-cost analysis

1.4 Thesis Outline

Discussed in this chapter is background information about the need for data analysis on changing weather patterns, as well as decisions that rely on this information. The second chapter provides a literature review of other related studies looking at crop progress, days suitable for planting and harvest and other relevant information from changing weather patterns. Chapter three summarizes the economic theory, the data for the analysis of days suitable and historical crop progress, and the methods used to analyze it. The fourth chapter includes the results from this study and how this information can be applied to farm machinery decision making. Chapter V includes the conclusions and suggestions for further analysis to expand and enhance this study.

CHAPTER II: LITERATURE REVIEW

Agricultural production is affected by an extremely large number of factors, many of which are out of the farmer's control, such as weather. While farmers cannot control the weather, they can work to better understand the historical and predicted weather trends to make the most informed decisions possible for their farming operation. Weather affects the growing season, and knowledge of weather patterns helps determine what crops to grow, seed varieties to choose, irrigation needs, fertilizer applications, machinery decisions, and much more.

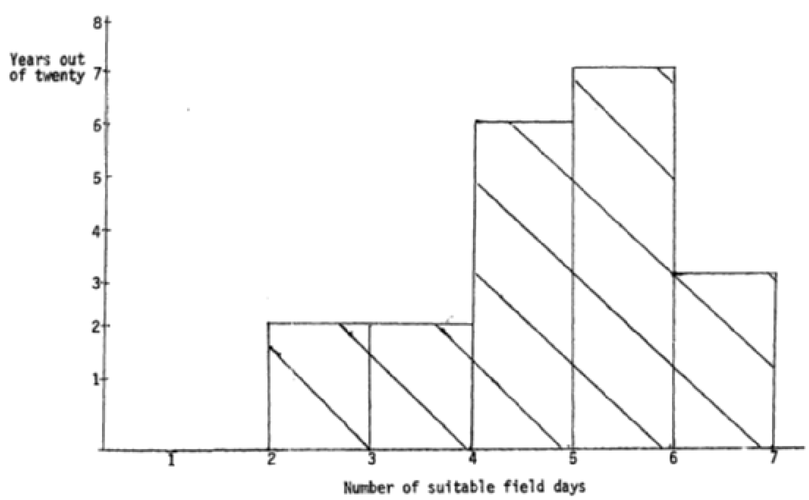
The distribution of days suitable for fieldwork is highly variable due to changes in weather from year to year (Edwards 1979, 3). By understanding these fluctuations and patterns, farmers can mitigate risk. For example, a group called Useful to Useable says their goal is to help make better long-term plans to maximize yields with minimal environmental damage because weather is such a factor in the Corn Belt (Useful to Usable 2016).

Days suitable for planting and harvest can vary substantially from year to year, and DSFW have previously been evaluated in many states such as Iowa (Edwards 1979), Kansas (Williams and Llewelyn 2013), and Missouri (Massey 2007). Many farmers own machinery that is larger than necessary most years in order to avoid large losses when unfavorable weather causes late planting or harvesting (Edwards 1979, 3). For example, in Kansas, all crop reporting districts for corn planting had less than 10 days suitable during at least once over the last 35 years during the respective dates (Griffin, Ciampitti and Torrez 2016). As shown by these fluctuations, if farmers can better understand this variability for their specific location, they can determine if it is a financially sound decision to have more machinery than they need most years.

The infinite combination of options in machinery brands, types, sizes and cost make selection of farm machinery a very complex decision (Edwards 1979, 1). In addition to farm machinery, these options and combinations apply to a number of input decisions including seed and fertilizer purchases.

Distributions for suitable field days demonstrate more uncertainty when observations are further from the mean, similar to frequency distributions for machinery costs. (Edwards 1979, 22-24).

Figure 2.1: Number of days suitable for field work in Iowa, week of May 3-9 from 1958-1977



Source: (Edwards 1979, 23)

As shown in Figure 2.1, for Iowa the number of days suitable for planting from 1958 to 1977 was most likely around 5 and 6 days per week. Machinery decisions, however, are often made to accommodate for those lower days suitable even though they are not as likely. In addition to the implications these factors have for farmers, it can also affect many other stakeholders such as policymakers, lenders and equipment manufacturers. Days suitable for fieldwork are important to policy relating to climate (Gramig and Yun 2016, 14). Farmers have a financial incentive to better understand weather patterns, but with climate variability and water quality issues becoming more important, there is interest in this topic for many people besides farm operators.

CHAPTER III: DATA AND METHODS

In this chapter, days suitable for fieldwork (DSFW) and crop progress data for the states of Iowa, Kansas and Missouri are described. Additionally, the methods used to analyze the days suitable trends are discussed. This chapter is divided into three sections – the first describes the theoretical model, the second section describes the data acquired on DSFW and crop planting and harvest progress, and the third section discusses the methods used to analyze the data.

3.1 Theoretical Model

One of the objectives was to analyze DSFW trends in Iowa, Kansas and Missouri. The number of available DSFW could affect the typical planting and harvest timeframe for corn in these states. Regression analysis was used to demonstrate if there have been changes in the number of DSFW over time by analyzing movements in a dependent variable based on the independent variable. In this analysis, the number of DSFW during the most active planting and harvest time periods was the dependent variable (y) with time being the independent variable (x). This regression analysis estimated whether there was a statistically significant trend in the number of DSFW over time for Iowa, Kansas, and Missouri during spring planting and fall harvest.

$$Y = \beta_0 + \beta_1 X$$

β_0 represents the number of DSFW at the y-intercept, and β_1 indicates the possible change in DSFW (y) that farmers can expect for each additional year. The t-statistic or p-value can be used to determine if the estimated slope coefficient is statistically significant, or different from zero. If the regression results in a $p< 0.05$, then the estimated coefficient is statistically significant at the 95% level. The t-statistic is an additional indicator of the statistical significance of a regression. “When the absolute value of the t-statistic is greater than 2, the manager can be 95 percent confident that the true value of the underlying parameter in the regression is not zero" (Baye and Prince 2014, 104). Farmers can then use this knowledge to understand if their farm machinery and input decisions are being adjusted properly over time to meet their production potential within the available DSFW. Many farmers base decisions on past experiences and intuition. If changing trends exist, and future predictions differ from historic levels, the farmers who base their decisions only on past experiences may be at a disadvantage. Using empirical evidence may help farmers make better decisions.

A benefit-cost analysis was used to estimate the percentile from the DSFW distribution to plan for when equipping a farm. A farmer can use this benefit-cost analysis to determine the yield penalty realized from being improperly equipped based on their specific machinery capacity and costs. One would want to find the optimal DSFW to plan for that minimizes the total cost of yield penalties and equipment costs.

3.2 Data Description

Data on DSFW, crop planting and harvesting progresses are publicly available from the United States Department of Agriculture, National Agricultural Statistics Service (USDA/NASS) in the weekly Crop Progress and Condition Report. "Each state maintains a list of reporters, largely extension agents and Farm Service Agency staff, who report progress and conditions of selected crops in their area for the current week" (United States Department of Agriculture 2017). Summarized data can be accessed from the USDA NASS QuickStats online tool, reports on the USDA/NASS website, or directly from the USDA/NASS regional offices. The NASS QuickStats online query tool (United States Department of Agriculture 2016) has state level data available but does not provide data for individual crop reporting districts. As explained in *Acquiring and Applying Days Suitable* *for Fieldwork for your State*, “Although USDA data are released on Monday for the previous week, the exact month and day may differ from year to year such that the data must be sorted by some standardized procedure. In addition, the date that the first data is reported in a given year may differ from year to year” (Griffin 2009, 36). Due to this, the data collected are adjusted using the following, “… such that week number 2 begins on Sunday following January 1, the default definition used by MS Excel as called by the =weeknum function (=weeknum(DATE))” (Griffin 2009, 36).

Once the data were collected and standardized, econometric analyses were conducted to evaluate data on weather and farmer’s field practices. The three main metrics were closely intertwined and included DSFW, planting progress, and harvest progress. For example, in the spring if there are relatively few days suitable to plant the corn crop due to the soil being too wet, crop planting progress may be delayed. Since corn needs a certain amount of accumulated heat units over time to reach maturation, a farmer may instead choose to plant a different crop or different hybrid to accommodate for the shortened growing season. Weather variation from year to year is expected, however knowledge of the average trends and changes over time impacts the farm management plan.

3.3 Methods

Corn planting and harvest progress are reported as percentage complete each week which allows a comparison from year to year for when planting and harvest begins, the length of time the planting or harvest takes, and when planting and harvest concludes. Corn planting and harvest progress can also be analyzed during the most active dates. “The ‘most active’ range indicates when between 15 and 85 percent of the crop is planted or harvested”

(NASS 2010, 5). Table 3.1 shows the most active planting and harvest dates as reported by USDA/NASS as of 2010. [1]

Table 3.1: USDA NASS Corn for Grain Usual Planting and Harvest Dates

	Usual Planting Dates			*Usual Harvest Dates*		
	Begin	**Most Active**	**End**	**Begin**	**Most Active**	**End**
Iowa	April 19	Apr 25-May 18	May 26	Sep 21	Oct 5-Nov 9	Nov 21
Kansas	April 5	Apr 15-May 15	May 25	Sep 1	Sep 10-Oct 25	Nov 10
Missouri	April 3	Apr 11-May 27	Jun 12	Aug 29	Sep 8-Nov 3	Dec 22

Source: (NASS 2010, 9)

The 'most active' dates are when farmers are conducting fieldwork, but not necessarily the most ideal days to maximize yields (Griffin, Ciampitti and Torrez 2016). In order to provide a 'most active' timeframe that included more recent years than the 2010 NASS estimates, a new 'most active' range was calculated for each state. The updated 'most active' range for this analysis was based on a 5-year average from the 2010-2016 time period at the 15-85 percent completion rate of planting and harvest progress for each of state.

Once the crop progress and DSFW datasets were adjusted to a standardized calendar system, the descriptive methods and statistical analysis for these data were completed. For each state and crop reporting district the total number of DSFW during most active plant and harvest dates were summed for each year. See Appendix for summarized data. Using these totals, it was determined if the total number of DSFW during the 'most active' planting or harvesting periods changed over time in the respective locations. Histograms were created for each of the states and crop reporting districts

[1] "The dates shown indicate the periods in which the crops are planted and harvested in most years based on 20 years of historical crop progress estimates, as well as the knowledge of industry specialists. Beginning dates indicate when planting or harvesting is about 5 percent complete and ending dates when operations are about 95 percent complete. The 'most active' range indicates when between 15 and 85 percent of the crop is planted or harvested" (NASS 2010).

showing the distribution of DSFW over the time period studied. Not only do the DSFW within a study area provide value, but the comparisons between crop reporting districts, or from state to state were also of interest.

Changes in the number of days suitable for fieldwork over time were estimated as ordinary least squares (OLS) regression. If there were no change, the estimated slope would not be statistically different from zero. If changes were occurring, the regression analysis could possibly be taken a step further to predict the coming years and help farmers proactively plan for the future instead of making adjustments post hoc. The OLS regression indicated if DSFW have remained fairly consistent over time, or have increased or declined.

The conclusions from the summarized DSFW and crop progress data were then applied to optimize machinery working rate and many other farm management decisions. Theoretical field capacity (TFC) demonstrates the maximum possible field capacity and was defined by Hanna (2016, 4).

$$TFC = \frac{speed\ (mph) \times width\ (feet)}{8.25}$$

This equation can be taken a step further to include field efficiency, which accounts for delays during operation including turns, overlapping, or filling a planter. “Although wider equipment operated at the same speed covers more acres per hour, measurements in the field document slightly lower field efficiency of wider equipment. With wider equipment, turns at headlands are longer with raised implements not in use and headland areas are often larger” (Hanna 2016).

While some farmers may choose to be more conservative on their machinery expenses, other farmers may prefer to have more than enough capacity for years when

DSFW are lower. "The range between the minimum and the median set the bounds that farm managers make decisions; the rational farm manager would not size equipment by planning for years better than the median. However, it remains uncertain which level of probability between the 1st and 50th percentile is optimum" (Griffin and Barnes Forthcoming). Using the Purdue PC-LP Farm Plan as a guideline, this analysis reports DSFW data assuming a farmer planed for the 20th percentile of DSFW in the spring, and the 40th percentile in the fall.[2]

[2] "Because yield penalties for late planting or harvest are generally severe in the Eastern Cornbelt, the 75th-85th worst year in 100 in the spring and the 55th-60th worst year in 100 in the fall was chosen as the appropriate estimate for good field days when evaluating timeliness" (Doster, et al. 2006, 6)

CHAPTER IV: RESULTS

4.1 Crop Progress and 'Most Active' Weeks

The 'most active' weeks for planting and harvesting in each state were calculated by determining the weeks in which the progress was between 15 and 85 percent complete. The 'most active' start week is the week that planting or harvest progress was nearest to 15% complete, and the 'most active' end week was when progress was nearest 85% complete. The 5-year average 'most active' start and end dates for each state are shown in Table 4.1 and 4.2 for planting and harvest, respectively.

In Iowa, the 'most active' planting date estimates for 2016 have shifted forward one week relative to the 1983 estimates. In Kansas, the 'most active' estimated start week for planting moved from week 17 in 1983 to week 16 in 2016, and the 'most active' ending week for planting moved ahead two weeks, showing that Kansas farmers are completing corn planting in a shorter timeframe in 2016 than in 1983. Missouri's 'most active' planting start week now begins two weeks earlier, and the end week has moved three weeks earlier.

Table 4.1: Calculated 'most active' Weeks for Planting by State

	5-yr avg start week	5-yr avg end week
Iowa - 1983	18	21
Iowa - 2016	17	20
Kansas - 1983	17	22
Kansas - 2016	16	20
Missouri - 1983	17	22
Missouri - 2016	15	19

When looking at the changes in 'most active' weeks for harvest, Iowa's average 'most active' starting week remained the same when compared 1985 average to 2016, however the ending week now occurs two weeks earlier. The 'most active' starting week in

Kansas has moved ahead two weeks over time, while the ending week has only shifted one week earlier. In Missouri, the average start week has moved from week 38 to week 36. The ‘most active’ ending week is now occurring four weeks earlier, so harvest is being completed in less time than in 1985.

Table 4.2: Calculated ‘most active’ Weeks for Harvest by State

	5-yr avg start week	5-yr avg end week
Iowa - 1985	40	46
Iowa - 2016	40	44
Kansas - 1985	38	44
Kansas - 2016	36	43
Missouri - 1985	38	46
Missouri - 2016	36	42

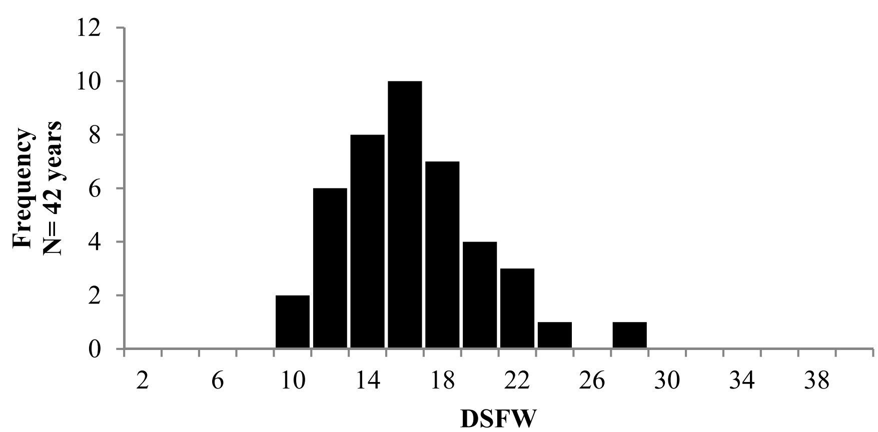
These changes in corn planting and harvest times can be due to many factors in addition to weather such as changing crop price ratios, seed technology, no-till or machinery advances such as floatation tires. Seed technology, e.g. shorter day hybrids, over time has also helped improve dry-down time allowing harvest to begin earlier than in the past.

4.2 Analysis of Days Suitable for Fieldwork

When analyzing the DSFW over time, the 2016 state-level 'most active' estimates were applied to each crop reporting district in the respective state. The distributions for DSFW during both planting and harvest in each state and crop reporting district follows.

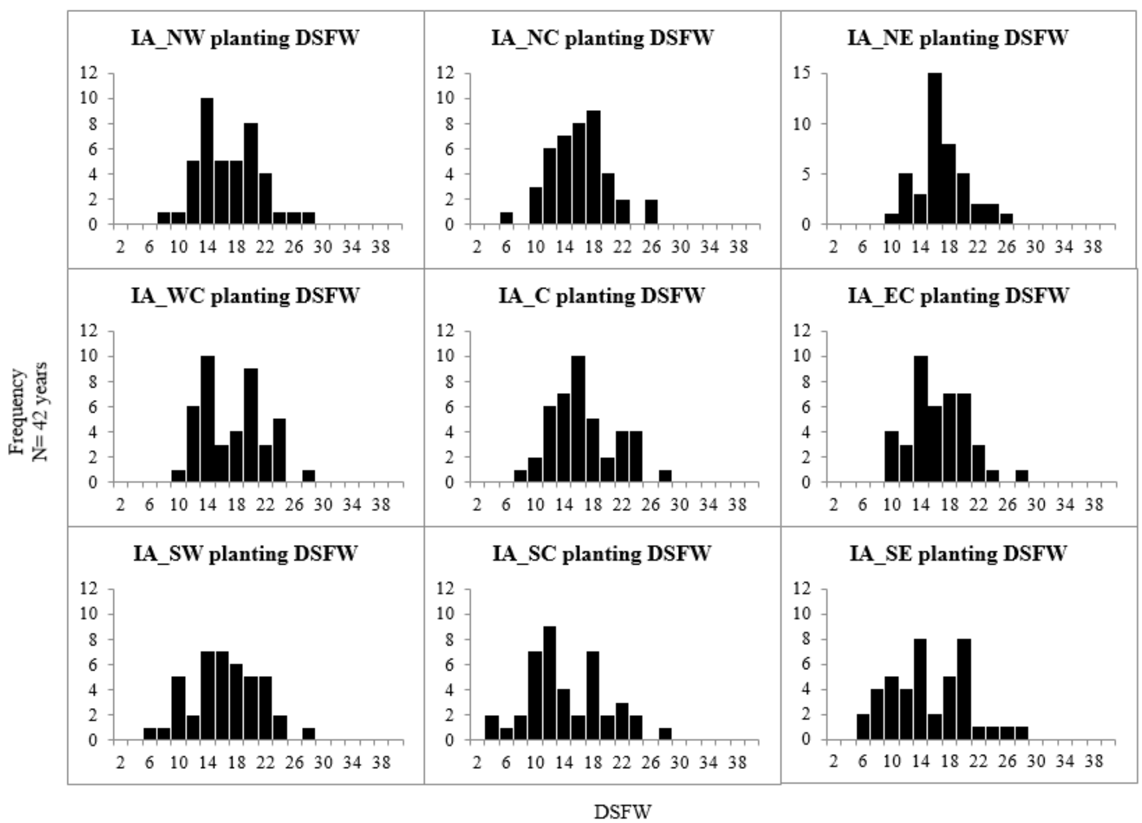
During the four most active weeks for corn planting in Iowa, the most frequent number of DSFW was between 14 and 16 days for 1974-2016, excluding 1992 for lack of data (Figure 4.1). However, two years had 10 or fewer DSFW during the most active corn planting window. The median number of DSFW during the 'most active' planting weeks in Iowa was 15 days, and the 20th percentile was 12 days. When determining planter size, a farmer would likely plan to minimize their planter expense while aiming to have adequate capacity for somewhere between the minimum and median number of DSFW.

Figure 4.1: Iowa DSFW distribution during 'most active' planting weeks



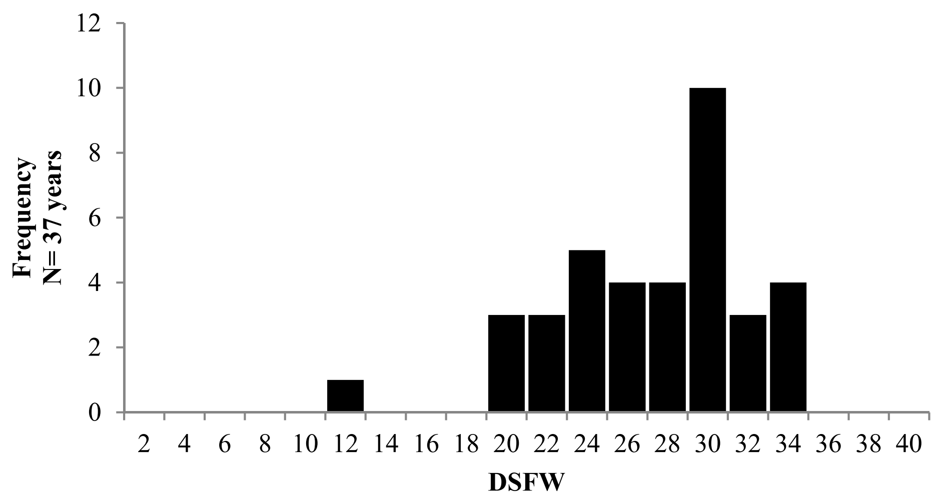
The distribution for DSFW during the 'most active' planting weeks by crop reporting district in Iowa are presented in Figure 4.2. The south central district has the largest range of DSFW from 3 days to 28 days, and also has the lowest median at 12 days. The west central crop reporting district recorded the highest median DSFW over the 42 year period at 16 days. If a farmer wanted to plan for planter capacity based on the 20th percentile of DSFW, they would make different choices based on their location in the state. For example, if the farmer was located in the northeast crop reporting district the 20th percentile of DSFW they would plan for would be 13 days, whereas in the southwest crop reporting district he would plan for only 11 DSFW at the 20th percentile.

Figure 4.2: Distribution of Iowa DSFW during 'most active' planting weeks by crop reporting district



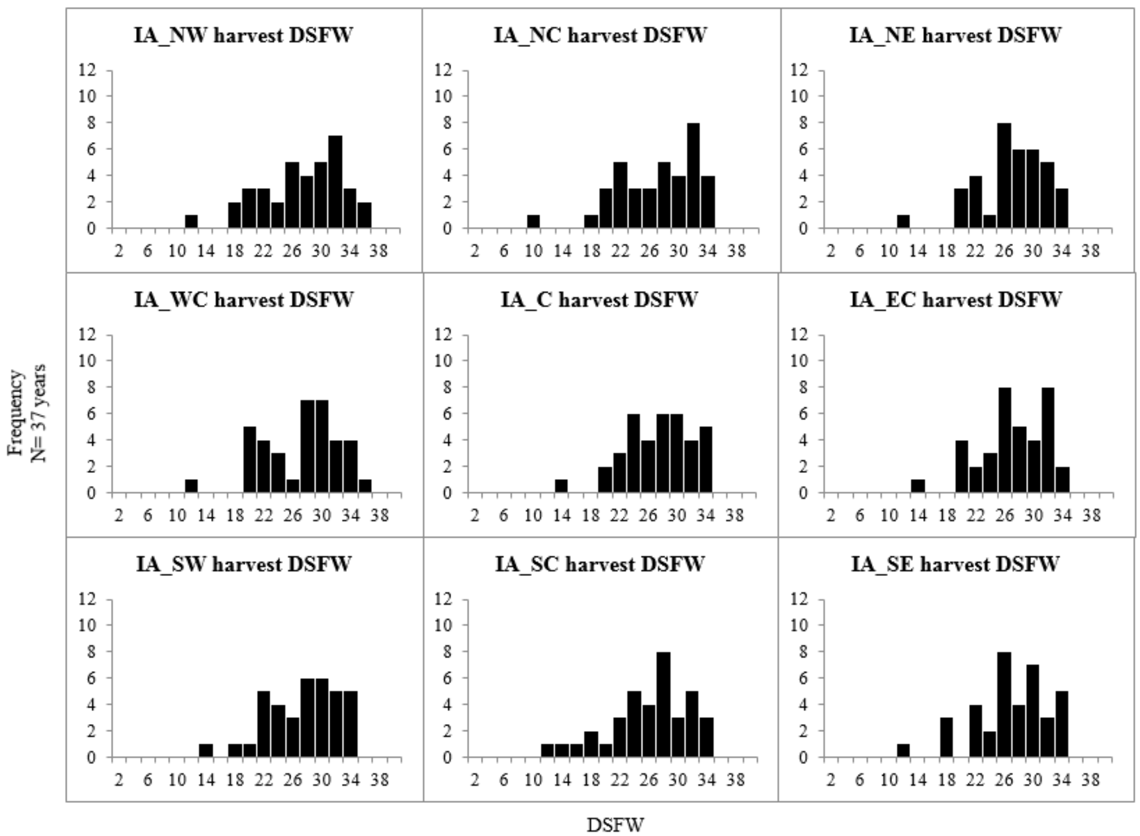
During the five 'most active' weeks for corn harvest in Iowa from 1975-2016 (excluding 1989, 1990, 1991, 1992, and 2013 for lack of complete data), the most frequent number of DSFW was between 28 and 30 days which occurred 10 times (Figure 4.3). The lowest number of DSFW of 11.5 was an anomaly; the second lowest total was 18 days. The median number of DSFW during the 5-week 'most active' harvest period in Iowa was 27 days, and the 40th percentile was 25 days.

Figure 4.3: Iowa DSFW during 'most active' harvest weeks



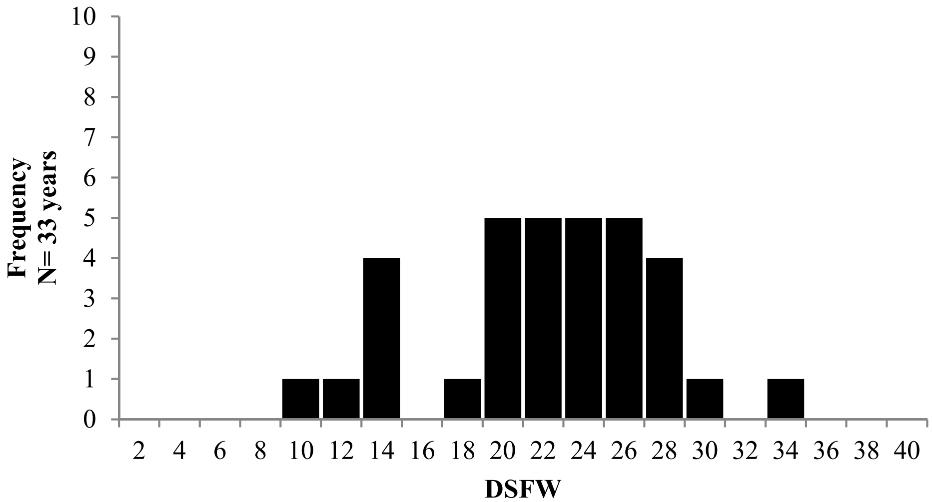
The distribution of DSFW during the 'most active' harvest weeks by crop reporting district for Iowa are presented in Figure 4.4. All of the crop reporting districts ranged from 24 to 26 DSFW at the 40th percentile. At the 50th percentile, crop reporting districts ranged from 26 to 27 days. These indicate that there is less variation across the state of Iowa for DSFW during harvest compared to planting.

Figure 4.4: Distribution of Iowa DSFW during 'most active' harvest weeks by crop reporting district



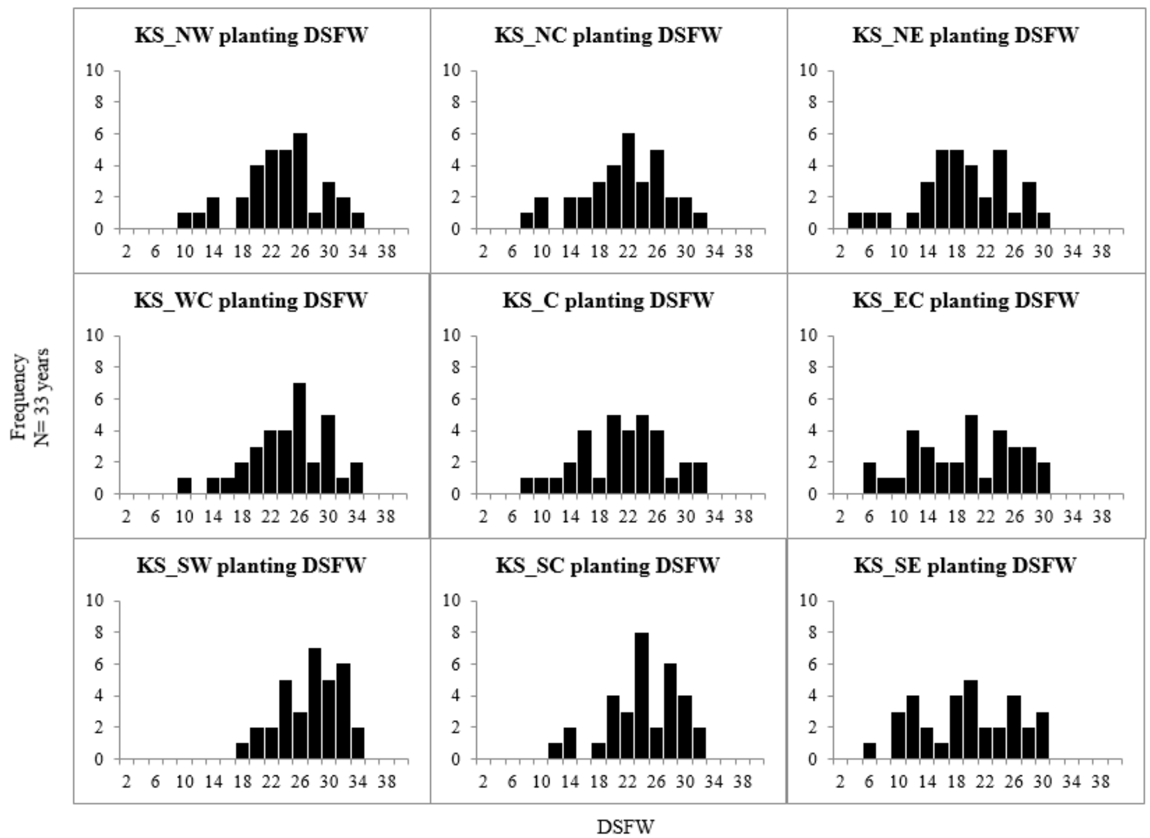
During the five most active weeks for corn planting in Kansas, the most frequent number of DSFW was a fairly wide range between 18 and 26 days for 1981-2016, excluding 1983, 1984, and 1985 for lack of complete data (Figure 4.5). The lowest total was 9 days, the median number of DSFW during the 'most active' planting weeks in Kansas was 22 days, and the 20th percentile was 16 days.

Figure 4.5: Kansas DSFW during 'most active' planting weeks



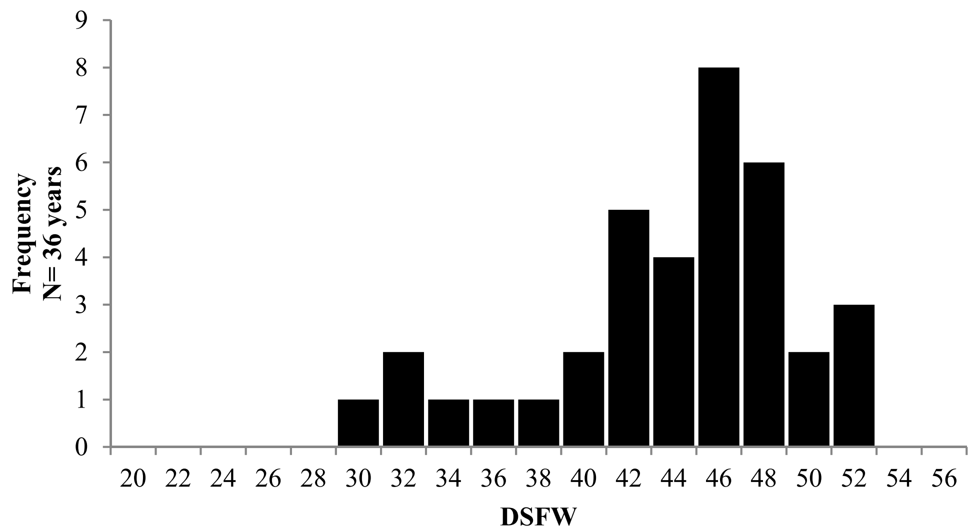
The distribution for DSFW during the 'most active' planting weeks by crop reporting district for Kansas are presented in Figure 4.6. The northeast crop reporting district has the largest range in DSFW from 4 days to 29.5 days. The southwest crop reporting district had the lowest range going from 17 to 34 days, and also recorded the highest median DSFW over the 33 years analyzed at 27 days.

Figure 4.6: Distribution of Kansas DSFW during 'most active' planting weeks by crop reporting district



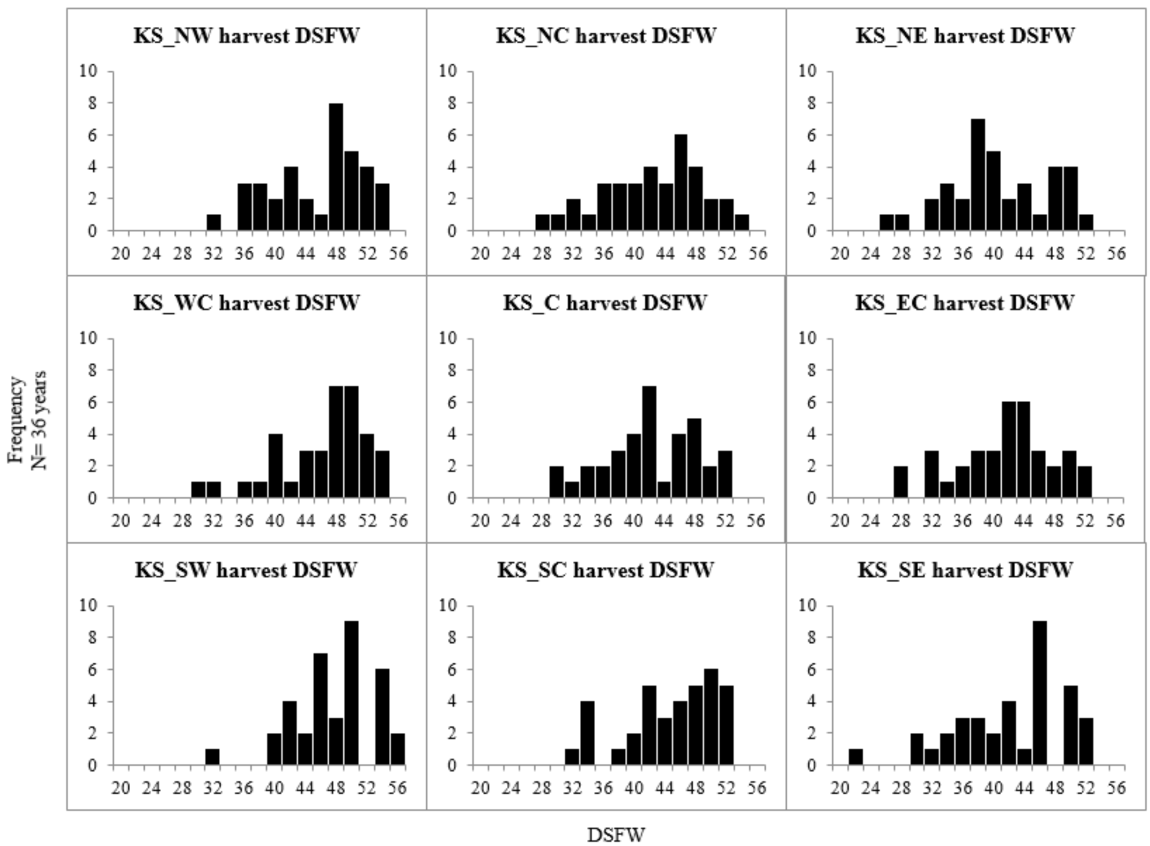
The length of the 'most active' weeks for corn harvest in Kansas is three weeks longer than in Iowa. As shown in Figure 4.7, during the eight most active weeks for corn harvest in Kansas from 1980-2016 (excluding 2013), the most frequent number of DSFW was between 44 and 46 days. The median number of DSFW during the 'most active' harvest weeks in Kansas was 44.5 days, and the 40^{th} percentile was 42 days. If a farmer were to size their combine based on the 40^{th} percentile of DSFW, they would expect 42 days suitable out of the eight weeks that are most active for corn harvest in Kansas.

Figure 4.7: Kansas DSFW during 'most active' harvest weeks



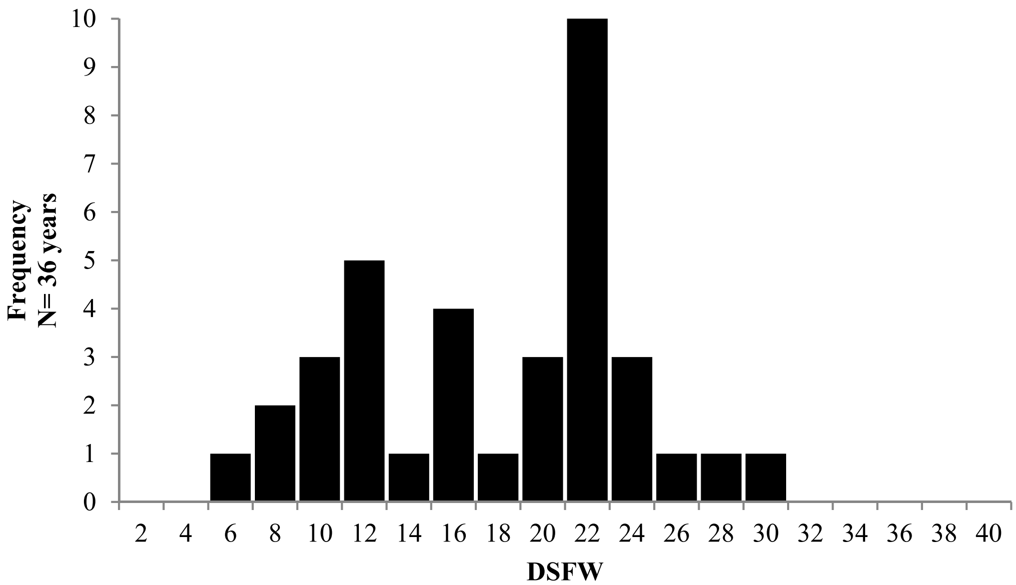
The distribution for DSFW during the ‘most active’ harvest weeks by crop reporting district for Kansas are presented in Figure 4.8. The southeast crop reporting district has the largest range in DSFW during harvest from 22 to 51.5 days, but also has a large number of years concentrated between 44 and 46 days. The southwest crop reporting district recorded the highest median DSFW over the 36 years analyzed at 47.5 days out of the eight week ‘most active’ harvest time.

Figure 4.8: Distribution of Kansas DSFW during ‘most active’ harvest weeks by crop reporting district



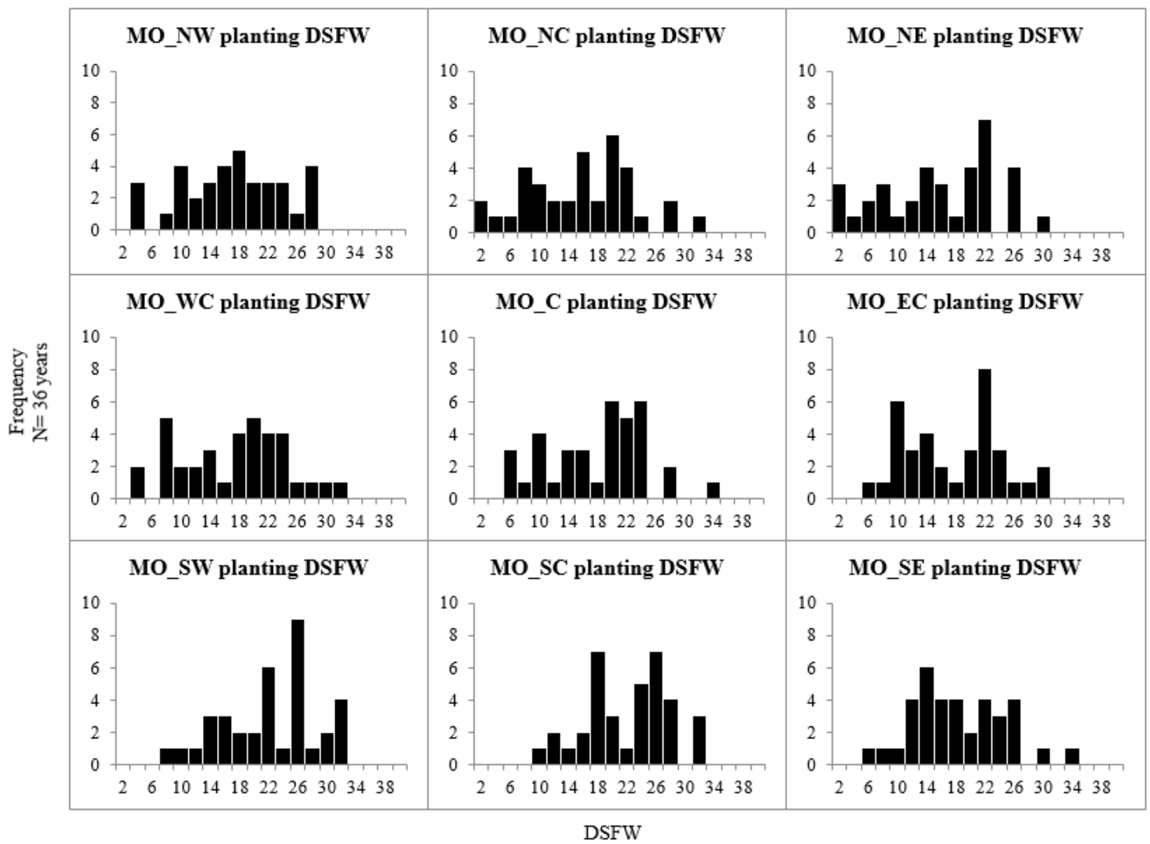
As shown in Figure 4.9, during the five most active weeks for corn planting in Missouri during the 36 years analyzed, the most frequent number of DSFW was between 20 and 22 days. However, in six years there were less than 10 DSFW during the most active corn planting window. The median number of DSFW during the 'most active' planting weeks in Missouri was 18.5 days, and 10.5 days at the 20th percentile. Although there is a high frequency between 20 and 22 days it can be deceiving. A farmer would not want to plan for that many DSFW since the median is below that at 18.5 days. Sizing a planter for the median year of DSFW would mean that half of the time you would not have adequate capacity, so you would expect most farmers to plan for DSFW less than the median.

Figure 4.9: Missouri DSFW during 'most active' planting weeks



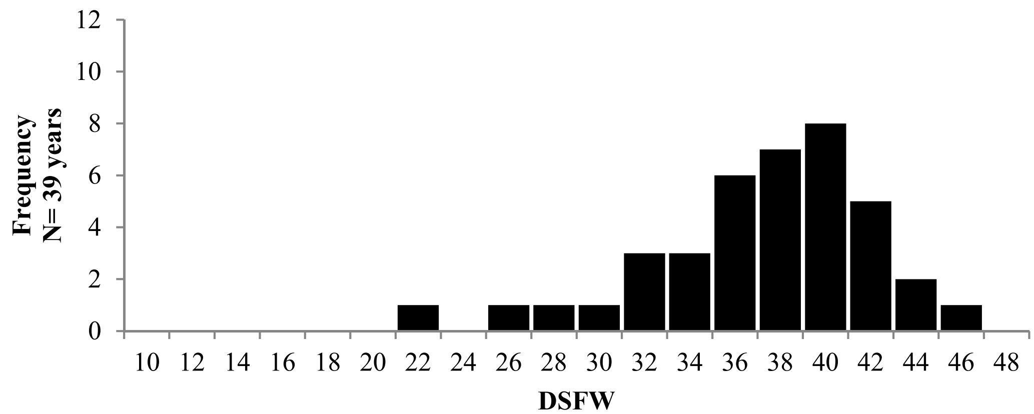
The distribution for DSFW during the 'most active' planting weeks by crop reporting district for Missouri are presented in Figure 4.10. The south central district has the smallest range in DSFW from 9.8 days to 31.6 days, and also the highest median at 22.75 days. The northeast crop reporting district had the lowest median DSFW over the 36 years analyzed at 15 days.

Figure 4.10: Distribution of Missouri DSFW during 'most active' planting weeks by crop reporting district



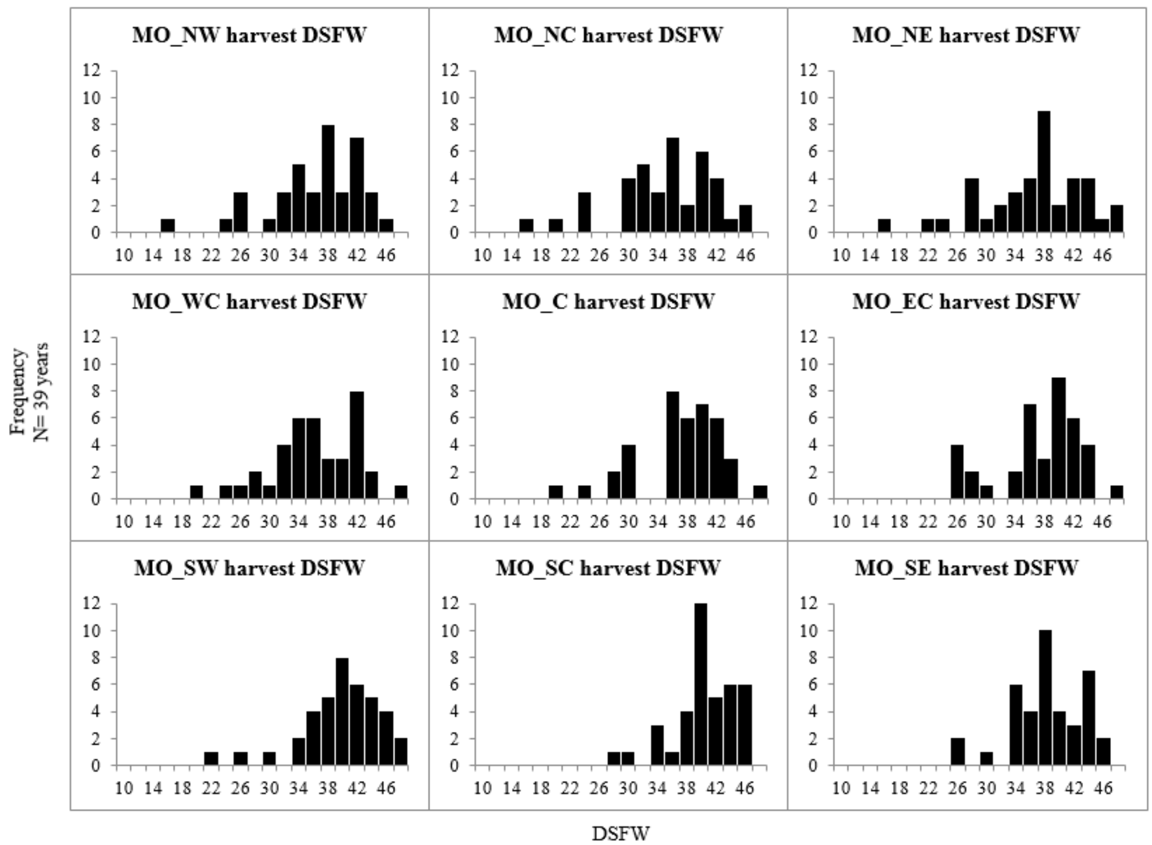
As shown in Figure 4.11, during the seven most active weeks for corn harvest in Missouri from 1977-2016 (excluding 2013 for lack of data), the most frequent number of DSFW was between 38 and 40 days. DSFW for harvest in Missouri ranged from 21 to 45 days. The median number of DSFW during the 'most active' harvest weeks in Missouri is 37 days, and the 20th percentile is 36 days.

Figure 4.11: Missouri DSFW during 'most active' harvest weeks



The distribution for DSFW during the 'most active' harvest weeks by crop reporting district for Missouri for the 39 years analyzed are presented in Figure 4.12. The northeast district had the largest range in DSFW from 15.2 to 47.1 days, while the south central crop reporting district had the smallest range from 27 to 46 days and also the highest median at 40 days.

Figure 4.12: Distribution of Missouri DSFW during 'most active' harvest weeks by crop reporting district



The total number of DSFW during the 'most active' planting and harvest weeks in each state were analyzed to determine if trends exist with respect to increasing or decreasing the total number of suitable days to conduct fieldwork. The available DSFW data are imperfect so not all years or weeks were always available for various reasons (ex. 2013 U.S. government shutdown). Incomplete years were excluded, and were noted for each state.

Table 4.3: Slope and significance of trends in DSFW during most active planting dates

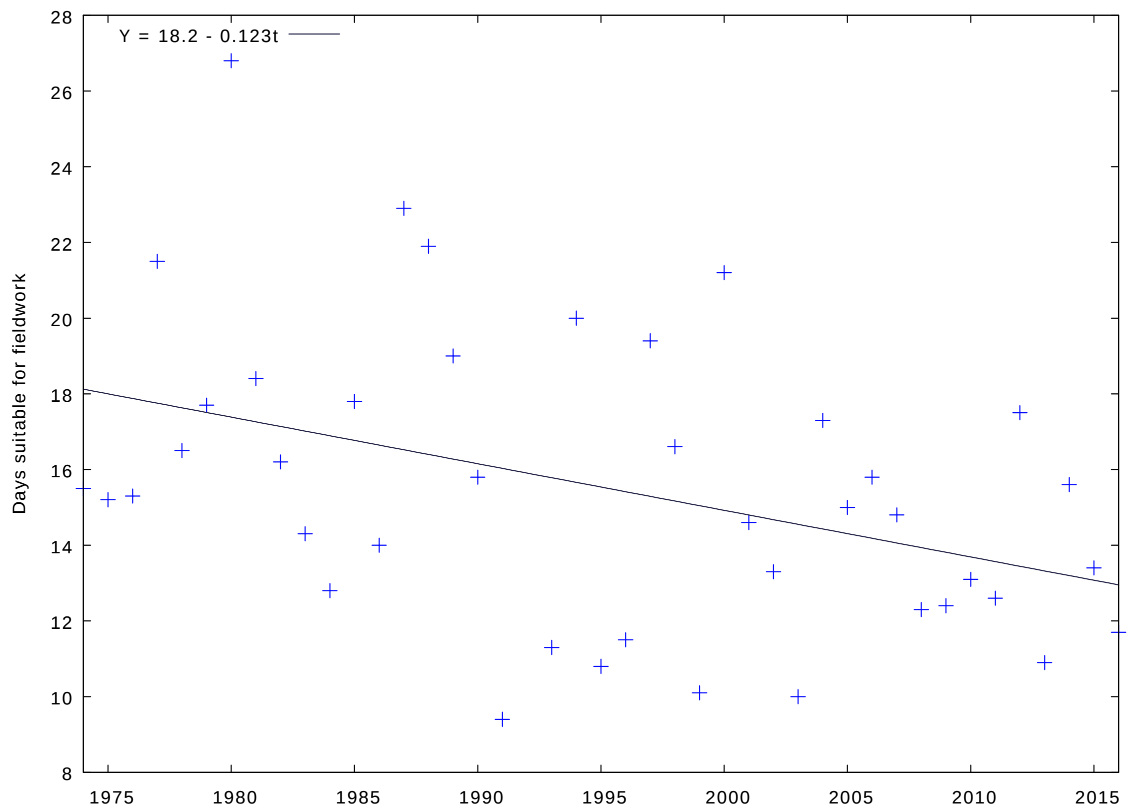
	Slope	*SE*	*t-stat*	*P-value*
Iowa	-0.12	0.04	-2.79	0.01
Kansas	0.03	0.10	0.26	0.79
Missouri	0.001	0.09	0.01	0.99

Table 4.4: Slope and significance of trends in DSFW during most active harvest dates

	Slope	*SE*	*t-stat*	*P-value*
Iowa	-0.01	0.06	-0.16	0.88
Kansas	0.09	0.09	1.04	0.30
Missouri	0.16	0.07	2.31	0.03

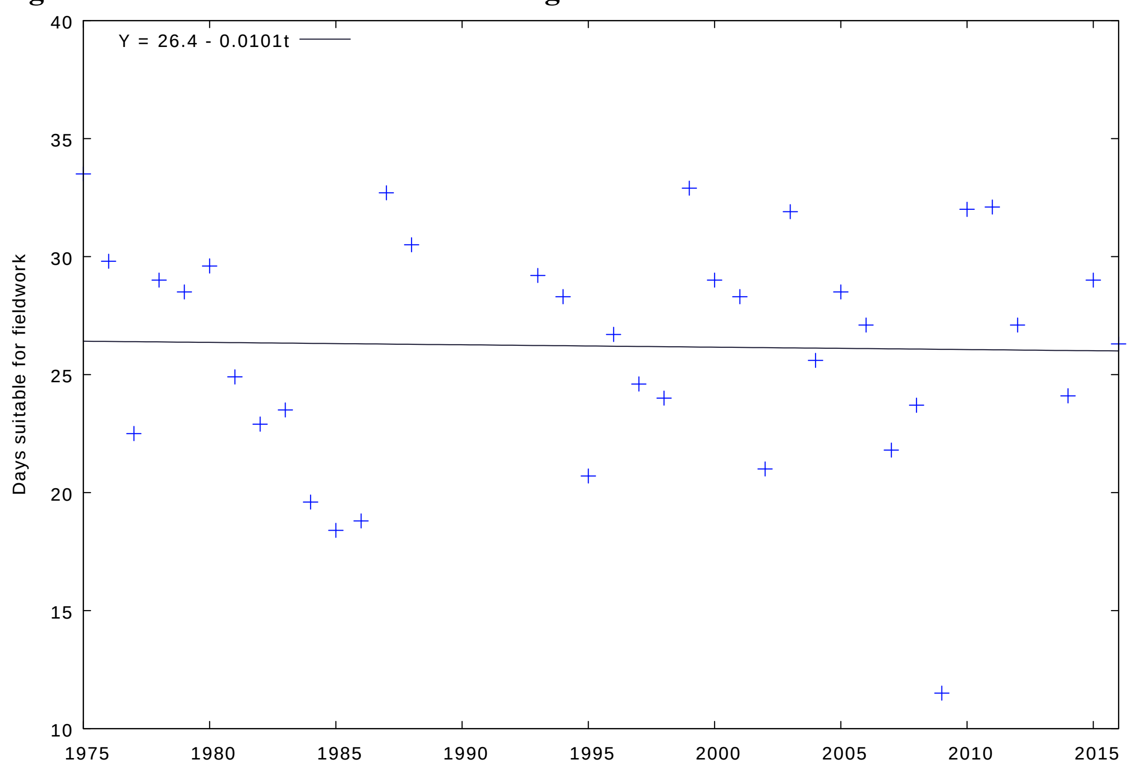
The model was estimated using ordinary least squares (OLS) regression using data from the 1974 to 2016 time period for Iowa (excluding 1992 for lack of data). The estimated slope of the regression line was statistically significant at -0.123 with a p-value of 0.01, which indicated that total number of DSFW in Iowa during the 'most active' weeks in the spring for corn planting has declined over time. Iowa is the leading state for corn production in the U.S., and therefore is responsible for planting a large number of acres of corn in a shrinking timeframe. Additionally, as farms become larger in size and smaller in numbers, farm operators need to be aware of this diminishing number of DSFW as they manage their machinery capacity.

Figure 4.13: Trend in Iowa DSFW during most active planting dates



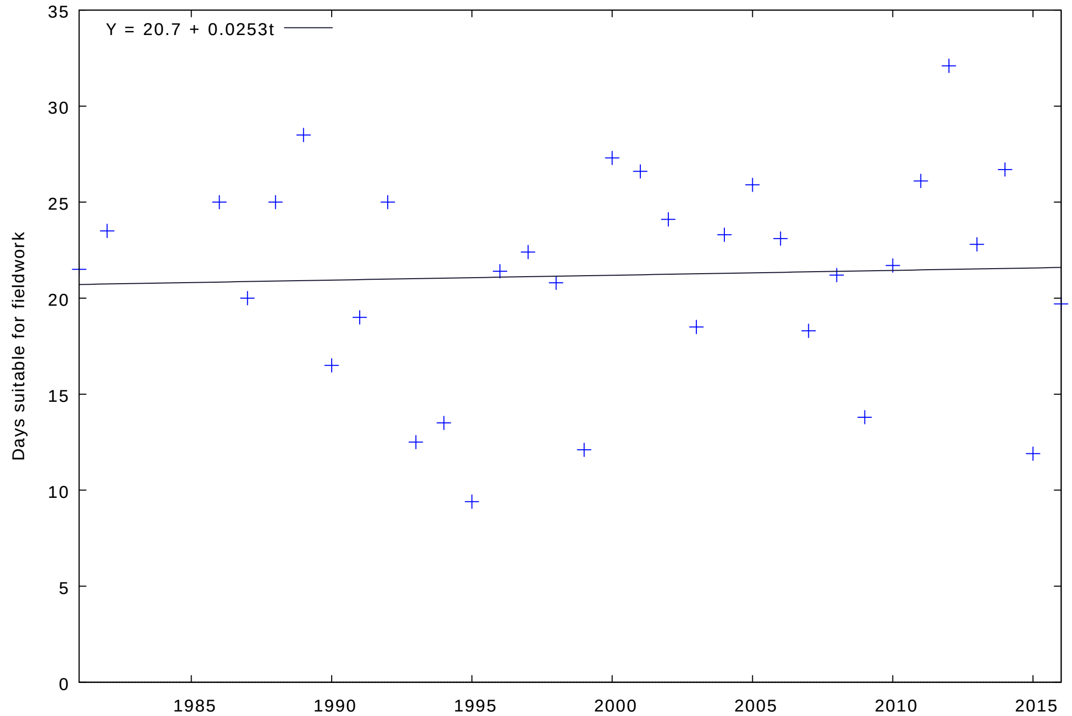
Although the number of DSFW during the spring in Iowa is declining, the same rate of decline does not carry through into the fall. The slope was estimated using ordinary least squares (OLS) regression from 1975 to 2016 (excluding 1989, 1990, 1991, 1992, and 2013 for lack of data). The estimated slope of -0.01 was not statistically significant at any conventional confidence level.

Figure 4.14: Trend in Iowa DSFW during the most active harvest dates



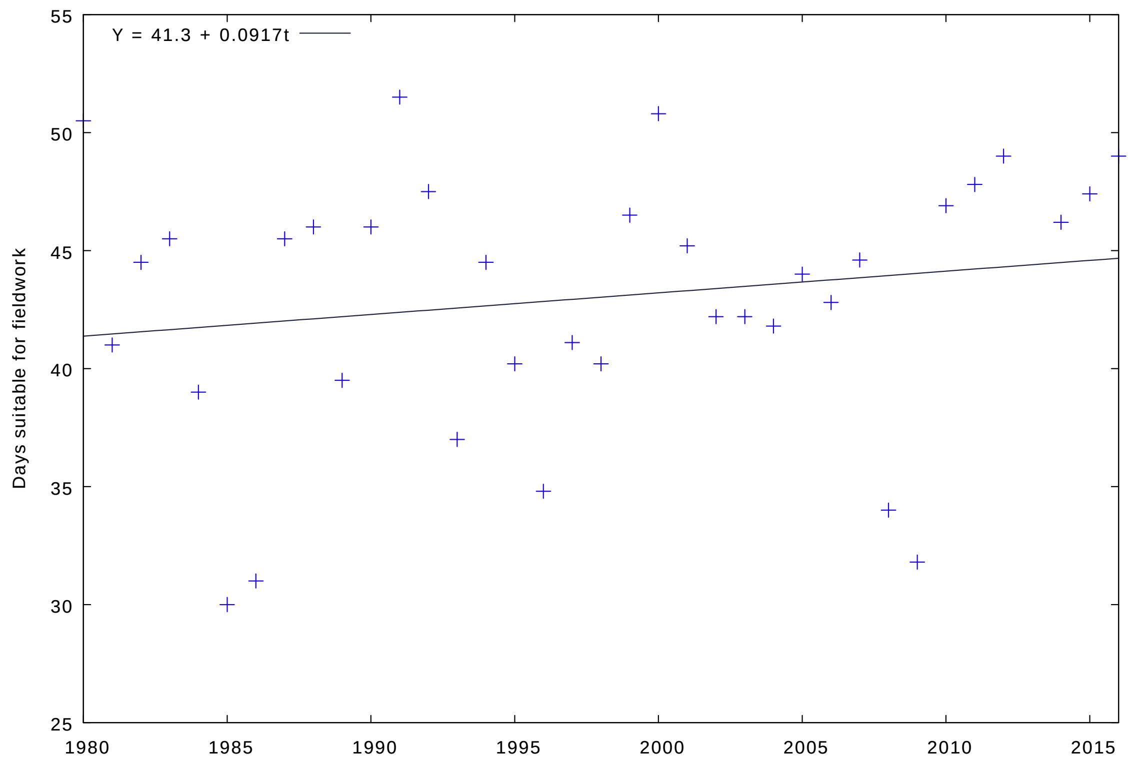
The slope was estimated as ordinary least squares (OLS) regression over the 1981 to 2016 time period (excluding 1983, 1984, and 1985 for lack of data). The DSFW in Kansas during the 'most active' weeks for planting had a positive estimated slope of 0.025, but was not statistically significantly different from zero.

Figure 4.15: Trend in Kansas DSFW during most active planting dates



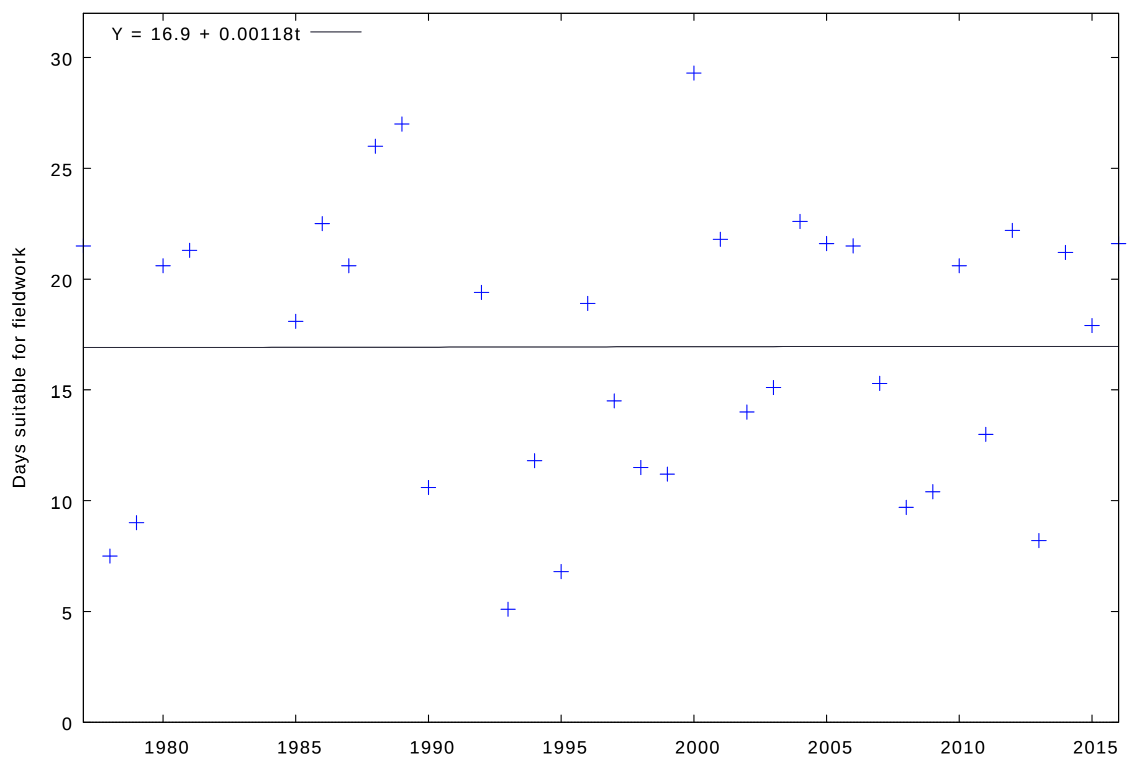
The slope was estimated using ordinary least squares (OLS) regression from 1980 to 2016 (excluding 2013 for lack of data). The positive trend of DSFW continues into the fall harvest season in Kansas, but it was not statistically significant.

Figure 4.16: Trend in Kansas DSFW during most active harvest dates



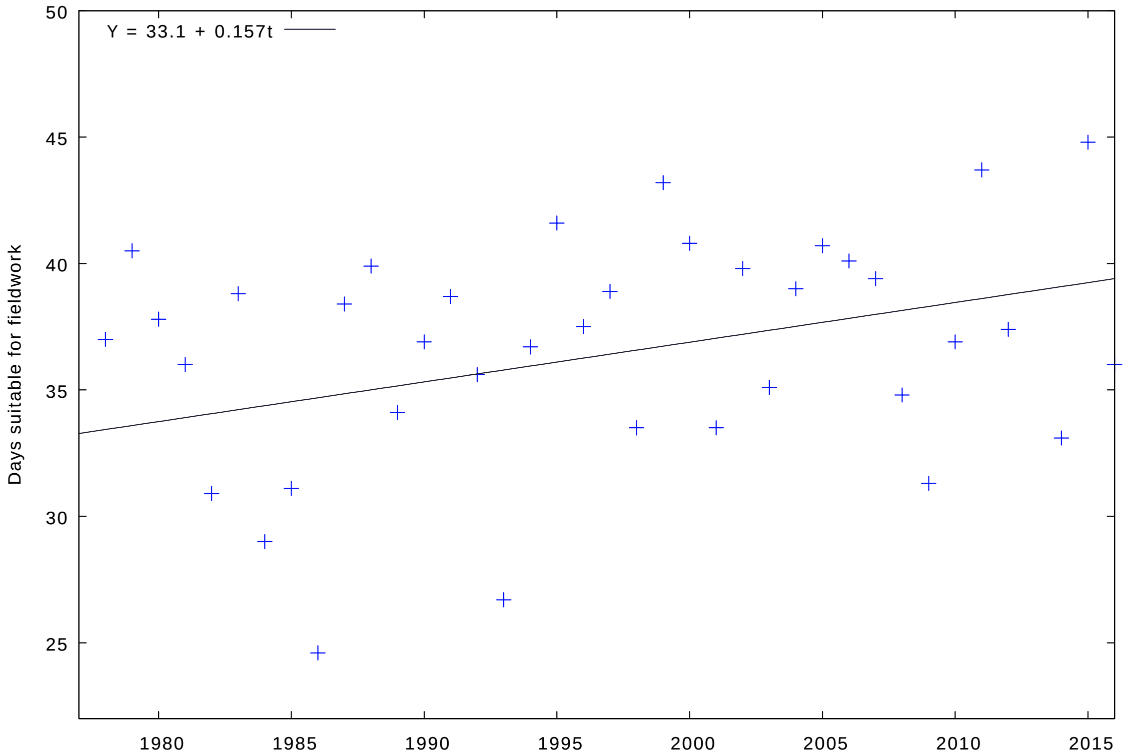
The slope was estimated using ordinary least squares (OLS) regression over the 1977 to 2016 time period (excluding 1982, 1983, 1984, and 1991 for lack of data). The number of days suitable in Missouri during the 'most active' corn planting weeks had a slope of 0.001, but it was not statistically significant.

Figure 4.17: Trend in Missouri DSFW during most active planting dates



The slope was estimated using ordinary least squares (OLS) regression over the 1977 to 2016 time period (excluding 2013 for lack of data). While the number of DSFW for planting corn in Missouri was not statistically different from zero, in the fall the number of DSFW for harvest were statistically significant with a p-value of 0.03. The slope indicates an increase of 0.157 days for each additional year. Farmers should be monitoring their combine capacity if they purchase new equipment as the number of DSFW increases to ensure they are not over-equipped.

Figure 4.18: Trend in Missouri DSFW during most active harvest dates



4.3 Farm Management Implications of DSFW

Variability in the number of DSFW impact crop production and whole-farm profitability, analogous to how knowledge of the number of DSFW impacts the farm decisions when allocating crop mixes and equipping the farm. As an example, a 12-row planter traveling 5.5 mph with a field efficiency of 65% has an effective field capacity of 13 acres per hour (Hanna 2016, 2). A maximum of 3,640 acres could be planted during the four 'most active' weeks in the spring in Iowa assuming 10-hour work days. At the 50th percentile of DSFW, the farmer would only expect 15.25 days suitable out of the four most active weeks and 1,982 acres planted in that timeframe, but in half of the years the farmer equipped at the 50th percentile would not be able to complete planting. Therefore, it is not realistic to plan for median days suitable. Calculating capacity at the 20th percentile of 12 days suitable would only allow for 1,560 acres to be planted during the most active weeks with the abovementioned equipment, a potentially excessive machinery expense.

As discussed, the amount of combine capacity should be monitored in Missouri as the number of DSFW during the 'most active' weeks for corn harvest increase. However, in the case of Iowa, planter capacity should be analyzed to ensure that all of the corn acres can be planted within the declining window of days suitable to plant in the spring. Being over-equipped or under-equipped can have negative financial implications on a farm operation. Therefore, long-term decisions such as equipping a farm with a planter should consider both the machinery expense and the yield penalty for delayed planting in a benefit-cost analysis.

4.4 Machinery Management Benefit-Cost Analysis

One machinery management question that eludes many farm decision makers asks how poor of a year to plan for when equipping a farm. Addressing this question requires knowledge of the number of days suitable for fieldwork during specific times of the year and the price ratios between crops and equipment. Using corn yield adjustment set parameters for planting and harvest dates (Doster, et al. 2006, 43), the yield penalties were estimated under a range of corn prices and equipment costs.

Table 4.5: Corn Yield Adjustment in Percent by Planting and Harvest Periods

Planting Periods	*Harvest Periods*				
	Sept 20 - Sept 26	Sept 27 – Oct 10	Oct 11 – Oct 31	Nov 1 – Nov 14	Nov 15 - Dec 5
April 22-25	90	96	**94**	90	85
April 26-May 2	0	100	**98**	94	89
May 3-9	0	95	**98**	94	89
May 10-16	0	92	**94**	90	85
May 17-23	0	0	**84**	84	79
May 24-30	0	0	**74**	74	69
May 31-June 6	0	0	0	0	56

Adapted from (Doster, et al. 2006, 43)

Parameters for planting periods from the October 11 to October 31 harvest period were chosen (bolded in Table 4.5) based on yield adjustment for six different time periods rather than the four time periods during the 100% yield potential, which was assumed to be 200 bushels per acre for this analysis. This vector of parameters were rescaled such that the highest values were 100% so corn planted in both April 26 to May 2 and May 3 to 9 time periods yielded at the maximum potential yield level. The weeks after and week before were rescaled to relative values but were all less than the 200 bushel per acre potential yield. The farm planted as many acres as possible during the time period with highest yield potential and when capacity were exhausted the farmer would begin planting corn in the next best time period until all corn acreage were planted. Therefore, yield penalties were observed from planting corn in time periods that had less than 100% yield potential.

A benefit-cost analysis was conducted to determine the optimal DSFW percentile to plan for when equipping a farm. For each state, the number of DSFW were estimated for the most active planting dates at each probability level. The number of expected days were assumed follow the relative distribution of DSFW reported by Rosburg (2017) in Table 4.6. The yield adjustment set or penalty matrix reported by Doster et al (2006) for the eastern corn belt was used for Iowa. The eastern corn belt yield adjustment sets were only appropriate to apply to Iowa, but not Kansas or Missouri. When those data become available, this analysis can be created for Kansas and Missouri.

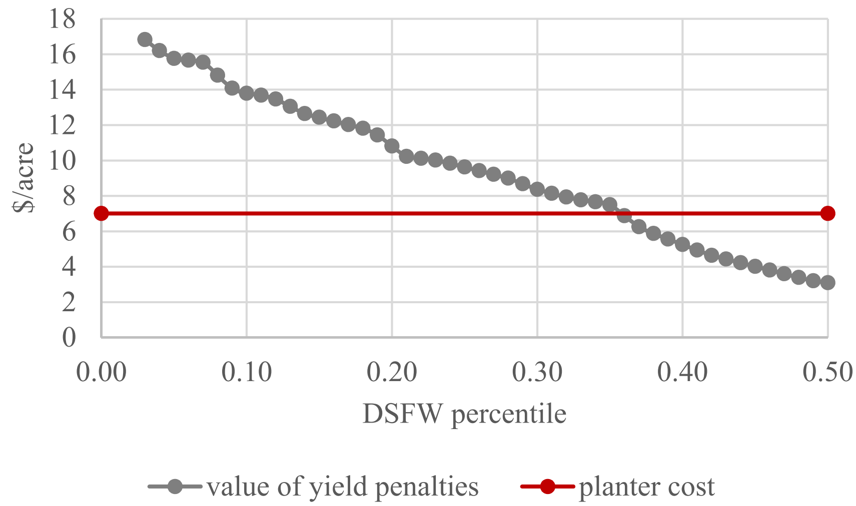
Table 4.6: Relative distribution of days suitable across the six most active planting periods for Iowa

	Proportion of Available DSFW
April 19 - 22	0.07
April 23 - 29	0.17
April 30 - May 6	0.17
May 7 - May 13	0.18
May 14 - May 20	0.21
May 21 - May 27	0.21

Source: Adapted from (Rosburg 2017)

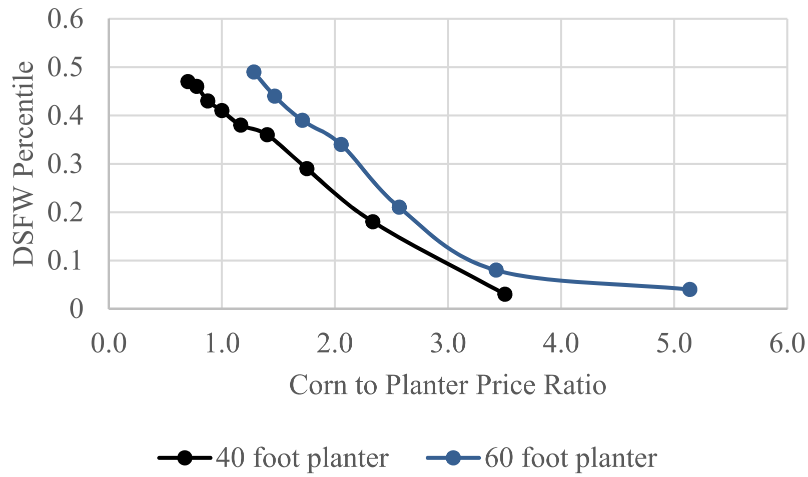
Dollar per acre yield penalties were calculated based on the number of acres planted during the weeks with less than 100% yield potential. This was then compared to a planter cost per acre to determine the optimal DSFW percentile to plan for. See Figure 4.19 for graphical representation showing the 35^{th}-36^{th} percentile. However, the optimal percentile changes based on each producer's location, planter size, working rate, corn yield, and corn prices.

Figure 4.19: Iowa DSFW percentiles versus per acre planter expenses



A range of corn prices were assumed for each planter custom rate. Corn prices were iterated from $2 to $10 per bushel in $1 increments. Rather than report the actual prices, the price ratio between per acre planter cost and per bushel corn price was used to make results representative over a wider range of possibilities. When corn to planter price ratios were 2 to 3, the risk neutral farmer would plan for the 10th to 20th percentile DSFW (Figure 4.20). As ratio of corn to planter prices reduces, the farmer would opt for smaller capacity planters and/or plan for a better year. Under expected price ratios, farmers would plan for 30th to 35th percentile DSFW, consistent with Doster et al (2005).

Figure 4.20: Iowa DSFW percentile versus corn to planter price ratio



A limitation of this analysis is that it assumes the farmer is risk neutral, so additional analyses could be performed on various levels of risk the farmer is willing to take on. Further research could also evaluate the benefit-cost analysis based on per row planter costs instead of per acre costs to provide more precise estimates.

CHAPTER V: CONCLUSIONS

With tighter profit margins for crop producers across the Corn Belt, farmers are closely analyzing all of their farm management decisions. Profit maximizing producers must manage machinery such that they are not over-equipped, but have adequate equipment capacity to plant and harvest all acreage within the available days suitable for fieldwork. The farm management implications were examined in relation to the results of the DSFW analysis. As demonstrated, the estimated DSFW percentile to plan for in Iowa would be around the 35th percentile. As discussed, farmers in Iowa are responsible for planting a large number of acres of corn in a shrinking timeframe, so farm operators need to be aware of this diminishing number of DSFW as they manage their machinery capacity. However, in Missouri the increasing days suitable for fieldwork during fall harvest suggests farmers should carefully consider their combine capacity if they purchase new equipment. The optimal percentile of days suitable for fieldwork to plan for varies depending on every specific farm operation so there are many possible ways to build on this topic including:

1. Expanding the yield penalty versus planter cost analyses to crop reporting districts or farm level. More specific yield adjustment sets for the benefit-cost analysis are likely to provide more precise results however those agronomic data were not available.
2. Expand the days suitable for fieldwork regression analyses to the crop-reporting district level.
3. Analyze the influential years in the regression analysis and potentially correct the trend based on the outliers.

Results of the DSFW and machinery utilization analyses are directly of interest to farmers desiring to optimally equip their farms, agricultural lenders providing farmers with financing of equipment, and equipment manufacturers.

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APPENDIX A

Total DSFW during most active weeks

Year	*Iowa planting*	*Iowa harvest*	*Kansas planting*	*Kansas harvest*	*Missouri planting*	*Missouri harvest*
1974	15.5					
1975	15.2	33.5				
1976	15.3	29.8				
1977	21.5	22.5			21.5	20.8
1978	16.5	29.0			7.5	37.0
1979	17.7	28.5			9.0	40.5
1980	26.8	29.6		50.5	20.6	37.8
1981	18.4	24.9	21.5	41.0	21.3	36.0
1982	16.2	22.9	23.5	44.5		30.9
1983	14.3	23.5		45.5		38.8
1984	12.8	19.6		39.0		29.0
1985	17.8	18.4		30.0	18.1	31.1
1986	14.0	18.8	25.0	31.0	22.5	24.6
1987	22.9	32.7	20.0	45.5	20.6	38.4
1988	21.9	30.5	25.0	46.0	26.0	39.9
1989	19.0		28.5	39.5	27.0	34.1
1990	15.8		16.5	46.0	10.6	36.9
1991	9.4		19.0	51.5		38.7
1992			25.0	47.5	19.4	35.6
1993	11.3	29.2	12.5	37.0	5.1	26.7
1994	20.0	28.3	13.5	44.5	11.8	36.7
1995	10.8	20.7	9.4	40.2	6.8	41.6
1996	11.5	26.7	21.4	34.8	18.9	37.5
1997	19.4	24.6	22.4	41.1	14.5	38.9
1998	16.6	24.0	20.8	40.2	11.5	33.5
1999	10.1	32.9	12.1	46.5	11.2	43.2
2000	21.2	29.0	27.3	50.8	29.3	40.8
2001	14.6	28.3	26.6	45.2	21.8	33.5
2002	13.3	21.0	24.1	42.2	14.0	39.8
2003	10.0	31.9	18.5	42.2	15.1	35.1
2004	17.3	25.6	23.3	41.8	22.6	39.0
2005	15.0	28.5	25.9	44.0	21.6	40.7
2006	15.8	27.1	23.1	42.8	21.5	40.1
2007	14.8	21.8	18.3	44.6	15.3	39.4
2008	12.3	23.7	21.2	34.0	9.7	34.8
2009	12.4	11.5	13.8	31.8	10.4	31.3
2010	13.1	32.0	21.7	46.9	20.6	36.9
2011	12.6	32.1	26.1	47.8	13.0	43.7
2012	17.5	27.1	32.1	49.0	22.2	37.4
2013	10.9		22.8		8.2	
2014	15.6	24.1	26.7	46.2	21.2	33.1
2015	13.4	29.0	11.9	47.4	17.9	44.8
2016	11.7	26.3	19.7	49.0	21.6	36.0