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ECONOMICS AND MARKETING

Available Time to Plant and Harvest Cotton across the Cotton Belt

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ABSTRACT

Field efficiency and machinery capacity have improved overtime, however optimal decisions for acreage allocation remain heavily dependent upon weather uncertainty. We evaluated days suitable for fieldwork (DSFW) during key cotton production times and report historic trends that farmers face for 13 cotton-producing states. The objective of this study was to report the number of days suitable for fieldwork during typical planting and harvesting time periods for each cotton-producing state. Weekly DSFW data reported by United States Department of Agriculture National Agricultural Statistics Service (USDA NASS) from 1995 to 2016 were analyzed to develop a probability distribution and estimate long-term trends. These results are usable to farmers, practitioners, and researchers for decision making including determining the number of acres that can be planted and/or harvested in a given year. These results are important for farm decision makers to make machinery selection and acreage allocation decisions.

Weather is a significant contributor to farmers' ability to plant, harvest, and conduct other field operations in a timely manner. One factor commonly reported for most cotton producing areas of the United States (US) is the number of days suitable for fieldwork (DSFW). Daily and weekly weather forecasts attract substantial attention from producers, researchers, policy makers and other stakeholders. From the producer's perspective, knowledge of precipitation events is important for production; however, knowledge of DSFW probabilities may assist in planting, harvesting, and other machinery management decisions. Conducting field operations such as tillage, planting, spraying and harvesting in a timely manner are important to obtain profit maximizing yields. Machinery management decisions such as choosing machine sizes relative to farm acreage should be made considering equipment efficiency and the likelihood of having sufficient DSFW to operate the machinery in the field. Knowledge of these probabilities on DSFW and planting or harvest progress, along with yield potential by planting and harvest date is important for machinery management, acreage allocation and financing decisions; and ultimately how many acres can realistically be managed with a given set of equipment. An understanding of these distributions also allows producers to better anticipate bottlenecks that may be experienced throughout the growing season.

Agricultural scientists have been using DSFW metrics for several decades. Long term DSFW trends have been reported for Arkansas (Griffin, 2009), Indiana (Parsons and Doster, 1980), Iowa (Hannah and Edwards, 2014), Kansas (Buller, 1992; Griffin 2016; Llewelyn and Williams, 2013), Mississippi (Spurlock et al., 1995), Missouri (Massey, 2007) and across the Corn Belt (Gramig and Yun, 2016).

Research and Extension publications have presented how farmers and their advisors utilize DSFW for sizing machinery complements and allocating cropping acreage. Schrock (1976) presented the concepts of understanding DSFW in the effort to size machinery to avoid bottlenecks by providing necessary equations. These were built upon with information specific to Kansas (Kastens, 1997), Missouri (Carpenter et al., 2012), and Iowa (Hannah, 2001). This study builds upon Griffin et al. (2015a, 2015b), who evaluated days suitable for fieldwork specific to sizing planters and cotton pickers across cotton producing states (see Table 1 for cotton production by state), by updating the DSFW database to include up to 2015 harvest and 2016 planting and presenting the results.

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The objective of this research was to present DSFW data for each state during cotton planting and harvest times that are useful to practitioners. Weather conditions and the number of DSFW in a given time period vary over time and across the cotton belt. Knowing how many DSFW are available to conduct fieldwork for planting and harvesting operations affects machinery investment, adaptation strategies, and cropping systems decisions. Specifically, we present the number of observed days to conduct planting and harvesting operations over a 22 year period; and test for changes in the number of DSFW over time.

Table 1. Harvested acreage and national rank of cotton producing states 2015

State	Acres harvested	U.S. Rank	Percent of U.S. Total (%)
Alabama	307,000	5	3.8
Arizona	105,000	13	1.3
Arkansas	207,000	6	2.6
California	162,000	9	2.0
Florida	83,000	15	1.0
Georgia	1,120,000	2	13.9
Kansas	16,000	17	0.2
Louisiana	112,000	12	1.4
Mississippi	315,000	4	3.9
Missouri	175,000	8	2.2
New Mexico	37,900	16	0.5
North Carolina	355,000	3	4.4
Oklahoma	205,000	7	2.5
South Carolina	136,000	11	1.7
Tennessee	140,000	10	1.7
Texas	4,515,000	1	55.9
Virginia	84,000	14	1.0

Source: USDA NASS

MATERIALS AND METHODS

Using the "most active" dates to plant and harvest cotton as reported by USDA NASS (2010) (Table 2 and Table 3), the number of DSFW for planting and harvesting cotton each year were graphed for thirteen cotton producing states. It should be noted that these dates are not necessarily the best timing for highest yields, but are simply when farmers are most actively conducting these field operations. It should also be noted that farmers conduct field operations before and after the 'most active' times.

The relevant planting and harvest dates for each state were assigned based on the 'most active' dates for the cotton producing states (USDA NASS, 2010). Days suitable for fieldwork (DSFW) data from 1995 to 2016 were collected for 13 of the 17 states (see Table 1 for cotton production and US ranking of states). Days suitable for fieldwork is determined by weather conditions such as rainfall and temperature that influence the condition of the soil surface, thereby affecting the ability of machinery to conduct the needed fieldwork during that time period. Historical DSFW was not available for Arizona, California, Florida, and Texas prior to 2014, therefore these states were excluded from this study. Most states report a single DSFW number for the whole state although a few (i.e. Kansas and Missouri) report by Crop Reporting District. Given that cotton is only produced in relatively small areas of Kansas and Missouri, DSFW for only southeastern Missouri and south central Kansas were considered for this study rather than using state-level data.

United States Department of Agriculture Crop Progress and Condition Reports are released on Monday during the growing season, reporting data for the previous week. Since it is a week-to-week measure, the exact month and day differ from year to year. To align data across time so that comparisons can be made, the week of year was defined such that week number 2 begins on Sunday following January 1. The total number of DSFW during the 'most active' planting and harvesting time periods were summed for each year; then the distribution of the number of DSFW were calculated. Table 2 and Table 3 present the most active planting and harvesting dates, respectively, for each state along with the number of total calendar days, expected number of DSFW in 20th percentile year and median year. The minimum number of DSFW are the least number of DSFW observed in the USDA NASS databank.

Table 2. DSFW summary statistics for planting time (1995-2016)[z]

State	Begin planting	End planting	Calendar days	Adjusted Days	Minimum DSFW	20th DSFW	Median DSFW
AL	24-Apr	24-May	31	28	11.7	19.8	22.0
AR	30-Apr	23-May	24	28	12.1	16.2	19.0
GA	2-May	31-May	30	28	16.9	21.7	23.5
KS[Y]	20-May	15-Jun	27	28	7.9	14.9	18.6
LA	24-Apr	17-May	24	21	11.0	13.9	16.2
MO[Y]	29-Apr	23-May	25	28	6.6	10.0	13.3
MS	27-Apr	19-May	23	21	8.9	11.9	14.2
NC	1-May	20-May	20	21	12.8	13.3	14.5
NM	20-Apr	10-May	21	21	22.19	24.4	26.1
OK	11-May	10-Jun	31	28	9.0	17.3	19.8
SC	1-May	20-May	20	21	12.9	16.5	17.1
TN	1-May	25-May	25	21	6.0	11.3	13.3
VA	25-Apr	11-May	17	14	6.4	7.24	9.4

[Z] Beginning and end planting dates are 'most active' dates reported by USDA NASS (2010)
[Y] Kansas and Missouri DSFW is reported for the South Central and Southeastern CRDs, respectively.

Table 3. DSFW summary statistics for harvest time (1995-2015)[Z]

State	Begin harvest	End harvest	Calendar days	Adjusted Days	Minimum DSFW	20th DSFW	Median DSFW
AL	20-Sep	20-Oct	31	28	10.8	19.8	23.2
AR	29-Sep	6-Nov	39	42	19.7	29.1	34.6
GA	10-Oct	2-Dec	54	49	29.4	33.8	39.4
KS[Y]	25-Oct	15-Dec	52	49	13.3	16.6	26.8
LA	23-Sep	23-Oct	31	35	15.3	25.7	29.4
MO[Y]	27-Sep	9-Nov	44	42	23.8	28.5	35.4
MS	27-Sep	29-Oct	33	28	8.6	19.2	22.5
NC	10-Oct	15-Nov	37	35	14.4	21.6	27.0
NM	25-Oct	30-Nov	37	35	22.4	26.9	32.0
OK	15-Oct	9-Dec	56	56	19.1	26.0	33.2
SC	15-Oct	13-Nov	30	35	21.7	23.2	29.9
TN	30-Sep	10-Nov	42	42	21.0	26.9	32.0
VA	8-Oct	20-Nov	44	49	25.9	31.5	37.2

[Z] Beginning and end harvest dates are 'most active' dates reported by USDA NASS (2010)
[Y] For Kansas and Missouri DSFW is reported for the South Central and Southeastern CRDs, respectively.

As an example, the number of observed DSFW at the 20^{th}, 50^{th} (median), and 80^{th} percentiles for Mississippi from 1995 to 2016 are presented in Figure 1. The 20^{th} percentile can be interpreted as 20 out of 100 years have fewer DSFW. Likewise, the 80^{th} percentile has 80 out of 100 years with fewer DSFW. In the 50^{th} percentile or median year, half of the years have fewer and half the years would have more DSFW. It should be noted that Figure 1 was developed such that each week of year is independent of the adjacent weeks of year.

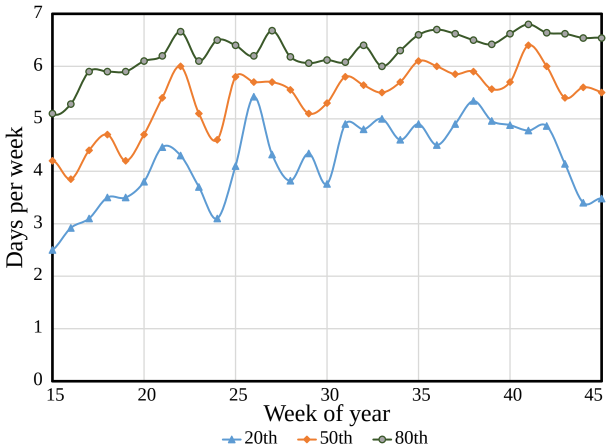

Figure 1. Historic days suitable for fieldwork trends in Mississippi (1995-2016).

RESULTS AND DISCUSSION

Historic DSFW are presented in Figures 2 through 4. Detail of Arkansas is presented in Figure 2 as an example. The number of DSFW for planting cotton in Arkansas ranged from 12 to 28 with the most common number of days between 18 and 19 (Figure 2). In half of the years Arkansas farmers had fewer than 19 days (Table 2 under median DSFW) while the lowest observed number was 12.1 (Table 2 under minimum DSFW). Still using the example for Arkansas, there were between 17 and 40 DSFW to harvest cotton, although the 2009 observation of 19 days seems to be an outlier (Table 3 and Figure 2). Half of the time, Arkansas cotton farmers had less than 35 days. The most active cotton planting dates in Arkansas were April 30 to May 23 (Table 2). There were 24 calendar days during this period but adjusted to 28 possible days given four full seven-day weeks to query the database. The number of calendar days between beginning and ending dates were converted to adjusted days to be multiples of seven, the number of days in a week, to fit weekly data. During this 28 day-planting period, the fewest number of DSFW observed between 1995 and 2015 was 12.1. The 20th percentile had 16 days while the median year had 19 days (Table 2 and Figure 2). Arkansas cotton harvest is most active September 29 to November 6 (Table 3). The 39 calendar days were adjusted to 42 days for six full seven-day weeks. The minimum number of days observed was 19.7 while the 20th percentile and median were 29.1 and 34.6, respectively. Again, the rational farm manager will attempt to size harvest equipment to cover all cotton acreage, more than 29.1 days but less than 34.6 days; additional analyses are needed to arrive at optimum.

The range between the minimum and 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

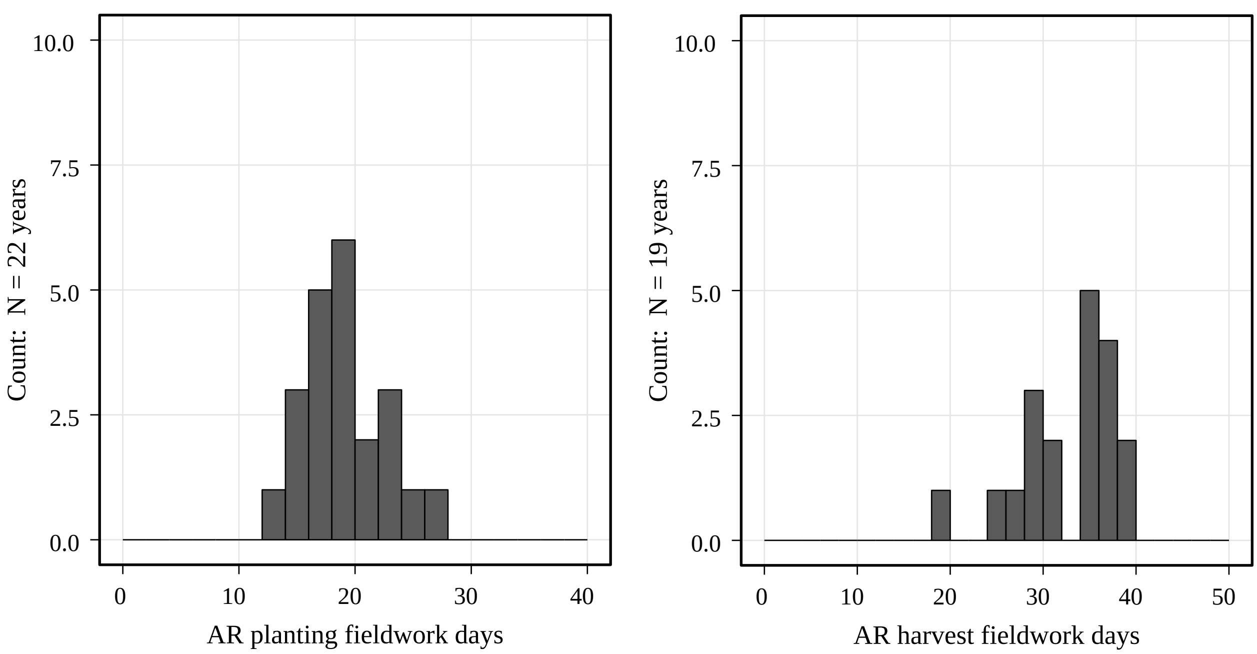

Figure 2. Histogram of DSFW for cotton planting (left) and cotton harvest (right) in Arkansas.

between 1st and 50th percentile is optimum. The distribution of summation of DSFW during the 'most active' planting and harvesting dates, respectively, for the remaining 12 cotton producing states are presented in Figure 3 and 4. Figure 3 and Figure 4 indicate how the number of DSFW for planting and harvesting, respectively, varied across the cotton belt. Figure 3 presents DSFW for the remaining 12 cotton producing states for their respective 'most active' planting periods. New Mexico had the least variability in the total number of DSFW while Missouri had the most variability (Figure 3). Figure 4 presents the range of DSFW for the 'most active' harvest period for 12 cotton producing states. Unlike planting periods, New Mexico has considerable harvest time variability, similar to the other states. Of the 21 years of data collection, only 12 and 15 years of observed data were collected for Oklahoma and Kansas, respectively, for the entire most active harvest date (Figure 4). Other states had additional years but typically less than possible 21 years of data. Only North Carolina had all possible 21 years of data on DSFW during harvest.

The estimated number of DSFW during most active planting and harvesting dates was converted to number of hours available to complete field operations. The total number of hours was calculated by multiplying DSFW by the expected number of hours per day that fieldwork could be conducted. For planting and harvesting, a ten-hour workday and a nine-hour workday was assumed, respectively, however it should be noted that planting workdays can be extended into the nighttime given current GPS-enabled guidance technology (Griffin et al., 2005). The median number of hours to plant during this time period ranged from 94 (Virginia) to 261 (New Mexico) (Table 4). The number of hours for harvest ranged from 202 (Mississippi) to 354 (Georgia) (Table 5). This is consistent with previous calculations of Willcutt et al. (2010). Georgia has more hours to plant and harvest cotton than other states partially due to higher heat unit accumulation and the result of farm management decisions being made specific to other crops (i.e. peanuts) such that cotton is planted and harvested during a wider window. The farm decision maker would use this information similar to the above example of number of days to plant or harvest. A Louisiana farmer would size harvest equipment to harvest all cotton acreage in less than 264 hours but more than 120 hours.

Change in DSFW over time. The number of DSFW over the most active planting and harvest times were summed for each state. Although the most active dates may change over time, the most recent USDA NASS estimates were used for all years (USDA NASS, 2010). The trend from 1995 to 2016 were evaluated by ordinary least squares (OLS) regression to determine if a significant change in DSFW were observed over the 22-year period (see Figure 5 for example graph of Missouri harvest). Specifically, the slope of the line was examined to determine if it was statistically different from zero.

Results of the trend in harvest DSFW are presented in Table 7. No state had a slope statistically different from zero (prob=0.05). In addition to examining if trend were significant, a Chow test (Chow, 1960) for structural change in linear regression models were conducted using strucchange (Zeileis et al., 2002) contributed package to R (R Core Team, 2016). The null hypothesis of no structural changes were failed to be rejected (prob=0.05) for all states in both planting and harvest time periods. Therefore, no substantial trend or structural breaks in DSFW were observed over the 22-year time period.

Farm Management Implications of DSFW. Borrowing a planter example from Griffin et al. (2015) of a 24-row center fill planter can plant 28 acres per hour. A farmer in South Carolina may expect to have less than 171 hours on average to harvest cotton (see Table 4 under median DSFW). If the farmer planned for the median year, they would expect to be able to plant 4,788 acres in half of years, but unable to finishing planting in the other half of years. If the minimum number of hours observed in South Carolina occurred given this planter, then 3,612 acres could be planted.

Again, borrowing a harvest example from Griffin et al. (2015) of a six-row modulating picker can harvest eight acres per hour. A farmer in Alabama is likely to base machinery and acreage decisions on the number of hours observed from the minimum to the median (Table 5). If the minimum number of hours for harvest in Alabama occurred again, 776 acres could be harvested with the example six-row picker. On average, the Alabama farmer would be able to harvest 1,672 acres. However, if the farmer sized cotton acreage to be 1,672 acres with only one six-row picker then the farm would be unable to harvest all acreage in half of the years.

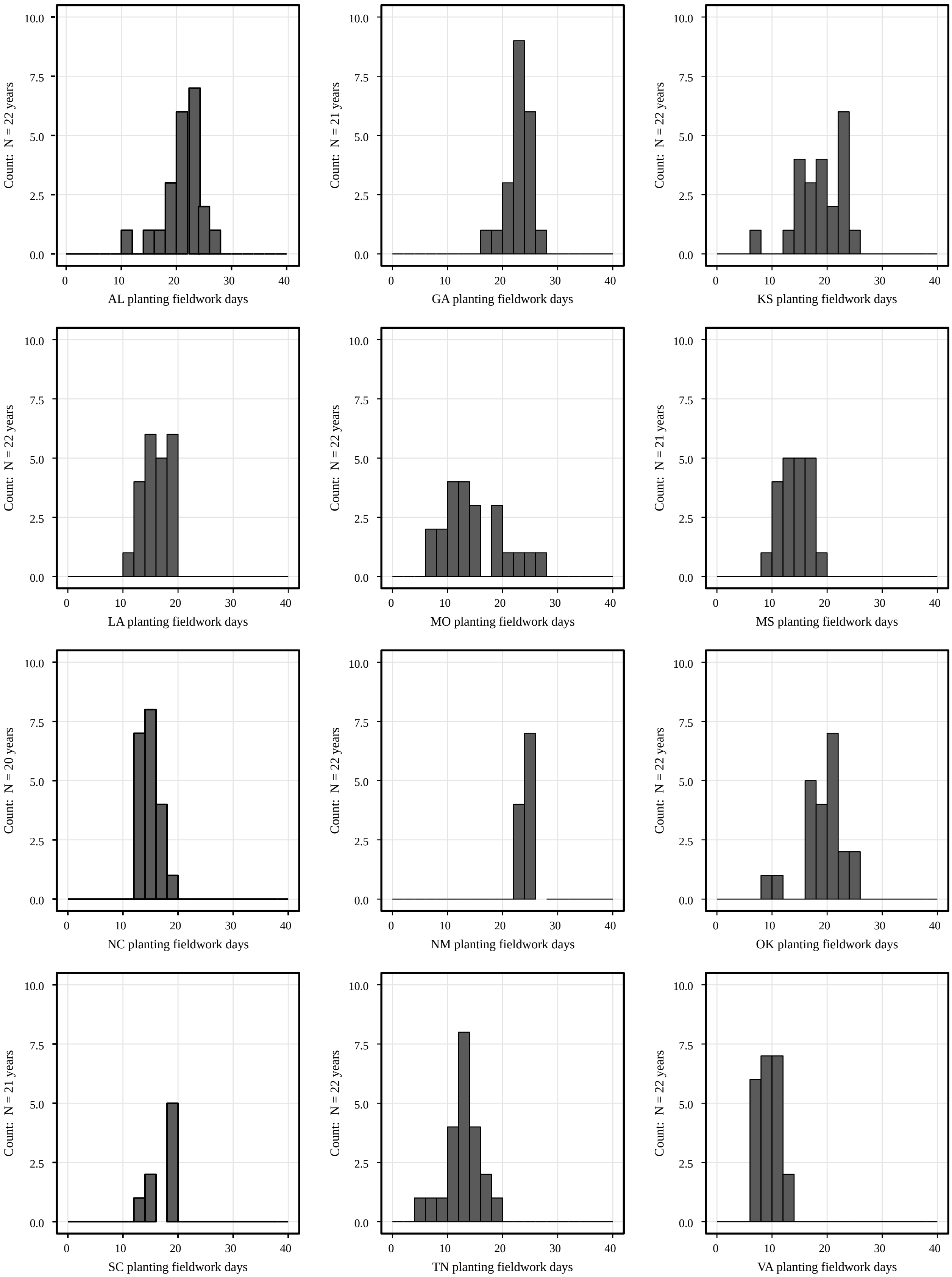

Figure 3. Distribution of DSFW for cotton planting by state. USDA NASS data 1995-2016.

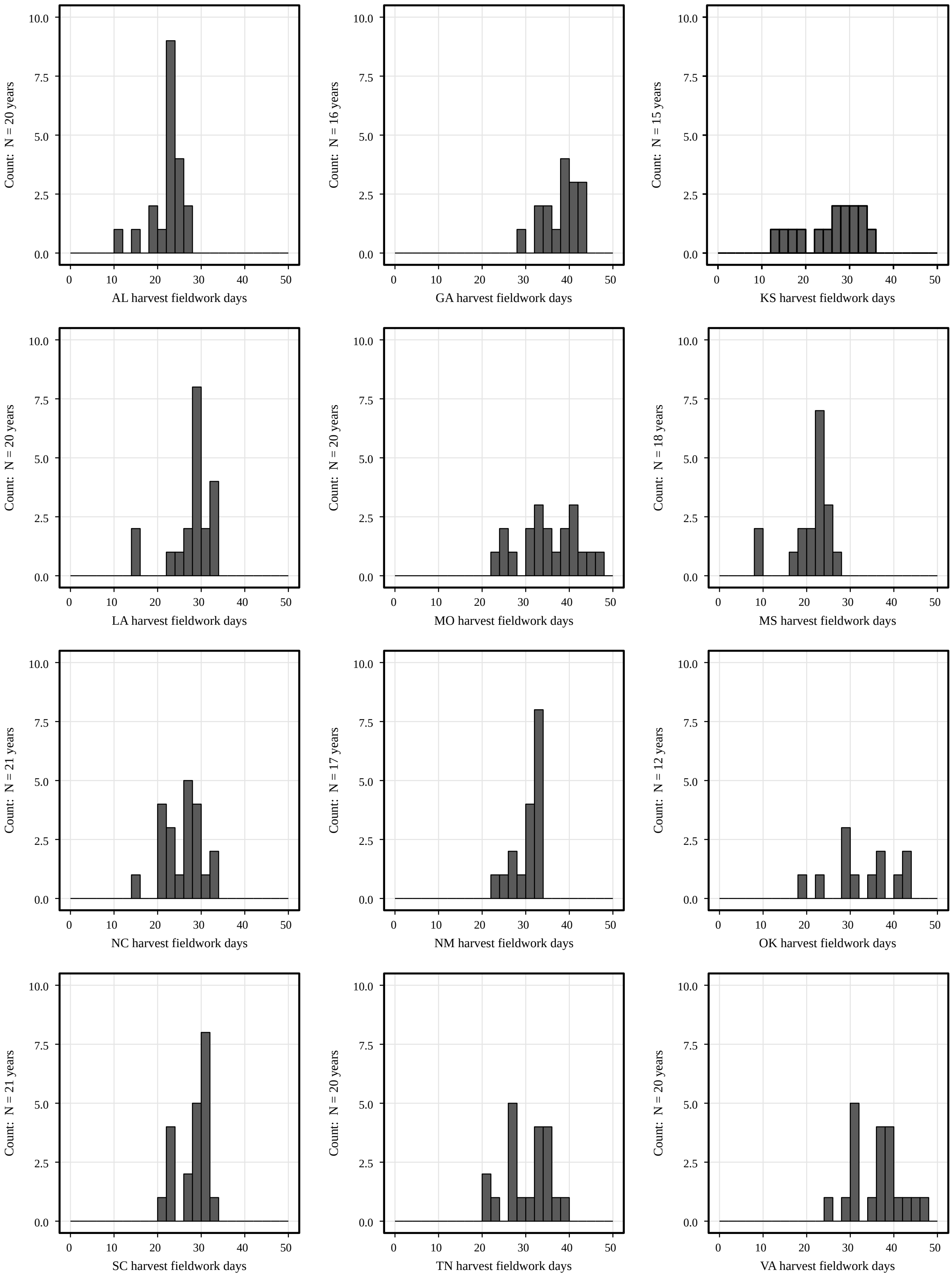

Figure 4. Distribution of DSFW for cotton harvest by state. USDA NASS data 1995-2015.

Table 4. Number of hours available for planting

State	Minimum hours	20th hours	median hours
AL	117	198	220
AR	121	162	190
GA	169	217	235
KS	79	149	186
LA	110	139	162
MO	66	100	133
MS	89	119	142
NC	128	133	145
NM	222	244	261
OK	90	173	198
SC	129	165	171
TN	60	113	133
VA	64	72	94

Assumes 10 hours per day

Table 5. Number of hours harvesting available

State	Minimum hours	20th hours	median hours
AL	97	178	209
AR	177	261	311
GA	265	304	354
KS	120	149	241
LA	138	231	264
MO	214	257	318
MS	77	173	202
NC	130	194	243
NM	202	242	288
OK	172	234	298
SC	195	209	269
TN	189	242	288
VA	233	284	335

Assumes 9 hours per day

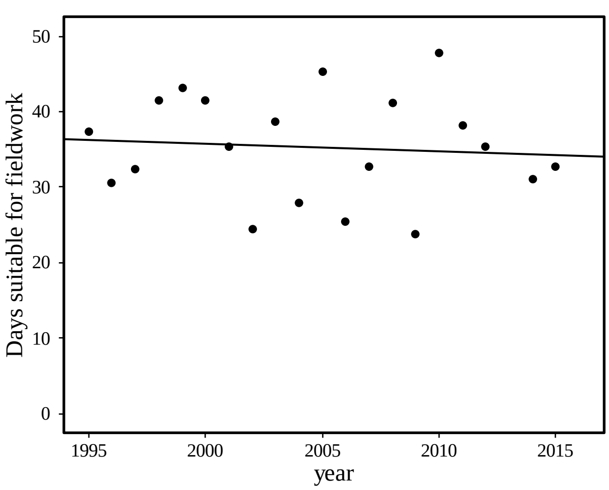

Figure 5 Trend in Missouri DSFW for cotton harvest.

Table 6. Slope and significance of trends in DSFW during most active planting dates over time

State	Slope	SE	t-value
AL	-0.10	0.11	-0.88
AR	-0.14	0.12	-1.22
GA	0.02	0.08	0.24
KS	0.09	0.15	0.63
LA	-0.02	0.08	-0.27
MO	-0.03	0.20	-0.17
MS	-0.10	0.09	-1.07
NC	-0.01	0.07	-0.12
NM	0.05	0.05	0.92
OK	-0.07	0.13	-0.54
SC	0.06	0.05	1.19
TN	0.02	0.10	0.18
VA	0.05	0.06	0.72

Table 7. Slope and significance of trends in DSFW during most active harvest dates over time

State	Slope	SE	t-value
AL	0.07	0.14	0.47
AR	-0.09	0.20	-0.44
GA	0.02	0.18	0.12
KS	0.44	0.33	1.30
LA	0.11	0.19	0.57
MO	-0.10	0.27	-0.37
MS	0.02	0.20	0.09
NC	0.00	0.16	0.02
NM	0.19	0.14	1.33
OK	0.32	0.39	0.81
SC	0.09	0.13	0.66
TN	-0.06	0.21	-0.29
VA	0.06	0.21	0.26

CONCLUSIONS

Weather variability is of concern to cotton farmers attempting to properly size acreage with planting and harvest equipment. In addition to year-to-year variability, the number of DSFW vary across cotton producing states. Although there were year to year variability in DSFW for each state, only New Mexico had significant changes in the number of DSFW over the 22-year period for harvest season. In addition, cotton planting season is typically less of a bottleneck to production than harvest season. The days suitable for cotton harvest are relatively fewer than for planting time, thus increasing the importance of properly sizing harvest machinery to cotton acreage. Knowledge of weather probabilities improves the farmer's ability to make optimal decisions. It has been shown that there is usually more available time to plant cotton than to harvest cotton for single equipment set farms; therefore, the majority of cotton equipment efficiency focuses on harvest rather than planting equipment.

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