Risk Analysis in Growing Season Length for Kansas, USA

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Introduction

In Kansas, agriculture continues to be a significant contributor to the state's economic well-being with rainfed production (e.g. sorghum and wheat crops) contributing its share. Agricultural production system is inherently a risky activity in rainfed areas where uncertainty in agroclimatic conditions affects production and profits. Understanding the role of risk and risk aversion in these systems, by reliable prediction of the uncertain variables is needed to develop technological and policy interventions that help reduce risk. Adaptation strategies such as synchronization of dates of cultivation practices and developing crop varieties with the changing climate have been used to reduce risk. Although the importance of risk has been widely recognized by researchers and policymakers, there is a dearth of quantitative information on risk.

Objective

To provide quantitative information on uncertain agro-meteorological indicators (AMI) such as growing season length (GSL), last spring freeze (LSF) and first fall freeze (FFF) used in many adaptation strategies to reduce risk.

Data Used

LSF, FFF, and GSL calculated from 23 centennial stations spread across Kansas (Figures 1 & 2).

Definitions of indices

Frost or freeze days is defined as a day with a minimum temperature (Tmin) Tmin < 0 ºC.
Number of frost days (nFDs) is the number of days with frost.
Last spring freeze (LSF) is the last day in March through May with Tmin < 0ºC for the last time until fall.
First fall freeze (FFF) is the day in September through November with Tmin < 0 ºC for the first time since spring.
Growing season length (GSL) is based on the onset of spring and fall. The number of days between the LSF and the FFF of the same year is used to determine GSL.

Methodology

Risk Analysis is based on probability distribution function (PDF's). The cumulative PDF (CDF) helps to identify and quantify the uncertainties associated with LSF, FFF & GSL. It gives the proportion less than X.

Steps in estimating empirical CDF:

1. Sort the observation into ascending order $X_{(1)}$ to $X_{(N)}$
2. Calculate CDF [F(x)]:

$$\mathbf{F(X)} = \begin{cases} 0 & -\infty < x < x_1 \\ \dfrac{i}{N} & x_i \leq x < x_{(i+1)} \\ 1 & x_n \leq x < \infty \end{cases}$$

3. Exceedence probability is calculated as 1 – F(X)
4. CDF is used for LSF & GSL; Exceedence probability is used for FFF.

Acknowledgements

This material is based upon work supported by the NSF under Award No. EPS-0903806 and matching support from the State of Kansas through Kansas Technology Enterprise Corporation.

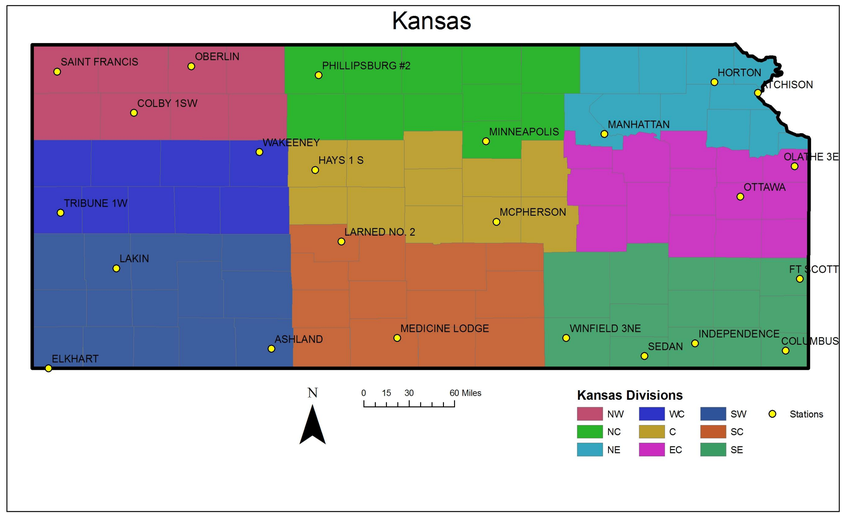

Fig. 1. Kansas is divided into 9 climate regions with gradients running from north to south and east to west. Long-term weather stations used for analysis are denoted within each climate division.

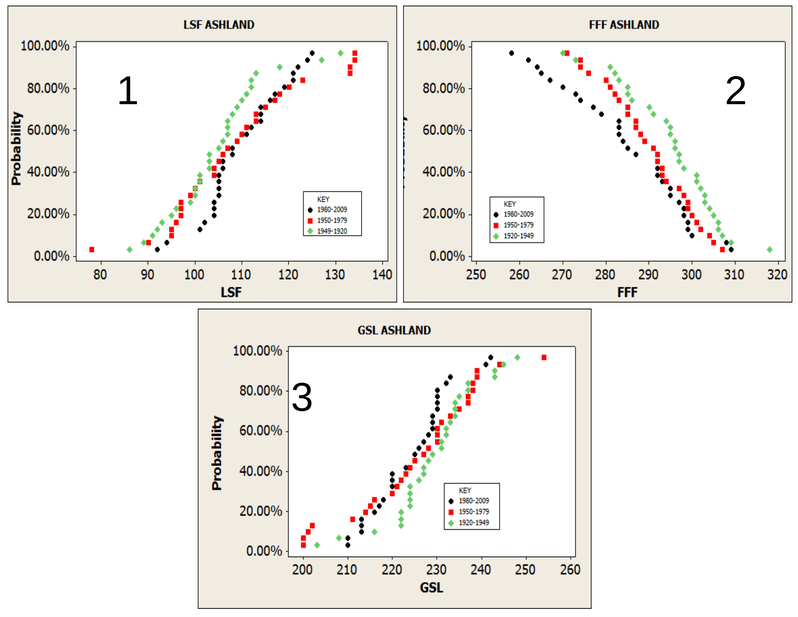

Fig. 2: Probability plots for one of the 23 centennial station results (Ashland). Cumulative probability plot of LSF & GSL (1 & 3). Exceedance probability plot of FFF(2). For each Individual plot the black dots correspond to the years from 1980-2009 the red squares correspond to the years from 1950-1979 and the green diamonds correspond to the years form 1920-1949.

50% probability level					
LSF:May 1	LSF: May 2	LSF:May 1	LSF:April 25	LSF:April 17	LSF:April 11
FFF:Oct 9	FFF:Oct 10	FFF:Oct 7	FFF:Oct 11	FFF:Oct 17	FFF:Oct 24
GSL 213	GSL:212	GSL 213	GSL:220	GSL:226	GSL:232
LSF: April 1	LSF:April 22	LSF:April 26	LSF:April 17	LSF:April 19	LSF:April 13
FFF:Oct 8	FFF:Oct 17	FFF:Oct 13	FFF:Oct 21	FFF:Oct 15	FFF:Oct 21
GSL:213	GSL:222	GSL:218	GSL:227	GSL:224	GSL:230
LSF:April 23	LSF:April 17	LSF:April 16	LSF:April 16	LSF: April 5	LSF:April 10
FFF:Oct 17	FFF:Oct 25	FFF:Oct 24	FFF:Oct 22	FFF:Oct 29	FFF:Oct 26
GSL:221	GSL:227	GSL:227	GSL:228	GSL:237	GSL:234
LSF:April 20		LSF:April 13	LSF:April 10	LSF:April 10	LSF:April 9
FFF:Oct 20		FFF:Oct 25	FFF:Oct 25	FFF:Oct 25	FFF:Oct 25
GSL:223		GSL:231	GSL:233	GSL:234	GSL:235

75% probability level					
LSF:May 9	LSF: May 12	LSF:May 11	LSF:May 3	LSF: April24	LSF:April 19
FFF:Oct 1	FFF:Sept 29	FFF:Sep 27	FFF:Oct 5	FFF:Oct 9	FFF:Oct 14
GSL: 222	GSL:221	GSL: 221	GSL: 228	GSL:234	GSL:248
LSF: May 11	LSF: April30	LSF:May 5	LSF::April26	LSF:April 29	LSF:April 20
FFF:Sep 28	FFF:Oct 9	FFF:Oct 6	FFF:Oct 14	FFF:Oct 6	FFF:Oct 13
GSL:220	GSL:229	GSL:227	GSL:234	GSL:232	GSL:238
LSF:May 1	LSF:April 24	LSF:April 27	LSF:April 27	LSF:April 12	LSF:April 16
FFF:Oct 9	FFF:Oct 16	FFF:Oct 15	FFF:Oct 13	FFF:Oct 21	FFF:Oct 17
GSL:229	GSL:232	GSL:236	GSL:234	GSL:245	GSL:242
LSF:April 27		LSF:April 19	LSF:April 16	LSF:April 18	LSF:April 16
FFF:Oct 10		FFF:Oct 14	FFF:Oct 17	FFF:Oct 18	FFF:Oct 18
GSL:231		GSL:239	GSL:243	GSL:243	GSL:243

90% probability level					
LSF:May 16	LSF:May 17	LSF:May 16	LSF:May 12	LSF:May 2	LSF:April 28
FFF:Sep 27	FFF:Sep 23	FFF:Sep 20	FFF:Sep 26	FFF:Sep 30	FFF:Oct 6
GSL:230	GSL:229	GSL:228	GSL:233	GSL:239	GSL:245
LSF: May 16	LSF:May 7	LSF:May 14	LSf:May 3	LSF:May 9	LSF:May 1
FFF:Sep 21	FFF:Sep 29	FFF:Sep 26	FFF:Oct 1	FFF:Sept 29	FFF:Oct 6
GSL:226	GSL:237	GSL:232	GSL:242	GSL:239	GSL:244
LSF:May 11	LSF:May 3	LSF: May 3	LSF:May 7	LSF:April 21	LSF:April 26
FFF:Sep 29	FFF:Oct 10	FFF:Oct 6	FFF:Oct 3	FFF:Oct 12	FFF:Oct 8
GSL:236	GSL:241	GSL:243	GSL:241	GSL:252	GSL:249
LSF:May 4		LSF:May 1	LSF:April 24	LSF:April 28	LSF:April 23
FFF:Oct 3		FFF:Oct 8	FFF:Oct 9	FFF:Oct 7	FFF:Oct 8
GSL:240		GSL:244	GSL:248	GSL:248	GSL:248

Table 1. 50%;75%;90% probability levels of LSF, FFF and GSL for station. Each value also corresponded to the actual day of occurrence for LSF and FFF, whereas, for GSL the value represents the duration. The location of the box represents the approximate geographical location.

UID: 76447

LSF: 91(4/11)	LSF: 92(4/2)	LSF: 94(4/4)	91(4/11)	LSF: 81((3/22	LSF: 77(3/17)
FFF: 246(9/9)	FFF: 255(9/12)	FFF: 246(9/3)	FFF: 252(9/9)	FFF: 262(9/19)	FFF: 269(9/26)
GSL:185	GSL: 185	GSL : 184	GSL: 185	GSL: 199	GSL: 195
LSF: 95(4/5)	LSF: 88(2/29)	LSF: 89(3/30)	LSF: 69(3/10)	LSF: 82(3/23)	LSF: 80(3/21)
FFF: 246(9/3)	FFF: 259(9/16)	FFF: 258(9/15)	FFF: 263(9/20)	FFF: 256(9/13)	FFF: 256(9/13)
GSL: 186	GSL: 186	GSL: 245	GSL: 189	GSL: 187	GSL: 197
LSF:91(4/1)	LSF: 78(3/19)	LSF: 79(3/19)	LSF: 82(2/23)	LSF: 59(2/28)	LSF: 79(3/20)
FFF:246(9/3)	FFF: 260(9/15)	FFF: 263(9/20)	FFF: 260(9/17)	FFF: 270(9/26)	FFF: 270(9/26)
GSL: 184	GSL: 184	GSL: 187	GSL: 187	GSL: 201	GSL: 197
LSF: 83(3/24)		LSF: 77(3/18)	LSF: 69(3/10)	LSF: 71(3/12)	LSF: 92(4/2)
FFF: 255(9/12)		FFF: 264(9/21)	FFF: 264(9/21)	FFF: 271(9/27)	FFF: 270(9/27)
GSL: 186		GSL: 180	GSL: 206	GSL: 206	GSL: 206
Latest Day for LSF,FFF, Maximum GSL for all Years					
LSF: 149(5/29)	LSF: 147(5/26)	LSF: 151(5/30)	LSF: 149(5/29)	LSF: 135(5/15)	LSF: 135(5/15)
FFF: 246(9/9)	FFF: 309(11/2)	FFF: 306(11/2)	FFF: 312(11/8)	FFF: 315(11/11)	FFF: 326(11/21)
GSL:237	GSL: 246	GSL : 240	GSL: 243	GSL: 254	GSL: 260
LSF: 147(5/26)	LSF: 147(5/27)	LSF: 149(5/29)	LSF: 147(5/27)	LSF: 147(5/27)	LSF: 135(5/15)
FFF: 301(10/28)	FFF: 318(11/14)	FFF: 314(11/10)	FFF: 323(11/18)	FFF: 315(11/11)	FFF: 315(11/11)
GSL: 239	GSL: 246	GSL: 185	GSL: 265	GSL: 251	GSL: 252
LSF:150(5/30)	LSF: 147(5/27)	LSF: 147(5/27)	LSF: 147(5/27)	LSF: 129(5/9)	LSF: 130(5/10)
FFF:311(11/7)	FFF: 320(11/14)	FFF: 326(11/21)	FFF: 318(11/14)	FFF: 330(11/25)	FFF: 330(11/26)
GSL: 245	GSL: 260	GSL: 256	GSL: 254	GSL: 275	GSL: 257
LSF: 147(5/26)		LSF: 151(5/30)	LSF: 127(5/6)	LSF: 127(5/6)	LSF: 129(5/9)
FFF: 318(11/14)		FFF: 322(11/18)	FFF: 328(11/24)	FFF: 328(11/24)	FFF: 330(11/25)
GSL: 255		GSL: 257	GSL: 265	GSL: 263	GSL: 260

Table 2. Calculated values of latest/earliest date of Last Spring Freeze, First Fall Freeze, and maximum and minimum days Growing Season Length for each corresponding station . Each value also corresponded to the actual day of occurrence. The location of the box represents the approximate geographical location.

Results*

Index	Probability levels	Latest day	Earliest day
LSF	90%	on or before May 17 (Oberlin NW)	on or before April 15 (Sedan SE)
	75%	on or before May 12 (Tribune WC)	on or before April 11 (Sedan/Independence SE)
	50%	on or before May 05 (tribune WC)	on or before April 05 (Sedan/Independence SE)
FFF	90%	on or after Oct. 15 (Independence SE)	on or after Sept. 20 (Oberlin NW)
	75%	on or after Oct. 23 (Sedan/Columbus SE)	on or after Sept 27 (Oberlin NW)
	50%	on or after Nov 01 (Columbus SE)	on or after Oct 06 (Tribune EC)

Index	Probability levels	Shortest	Longest
GSL	90%	224 days (Tribune WC)	254 days (Sedan SE)
	75%	218 days (Tribune WC)	245 days (Sedan/Independence SE)
	50%	210 days (Tribune WC)	238 days (Independence SE)

*summary of Tables 1 & 2 is calculated for 100+ years.

Conclusion

- There is one month difference in LSF, FFF and GSL across the state.
- LSF is occurring earlier in the season, FFF is occurring later in the season and GSL is longer for most stations in the state.
- The NW (Oberlin) or WC (Tribune) has the latest LSF, earliest FFF and shortest GSL.
- In general SE (Sedan, Independence, Columbus) having the earliest LSF, latest FFF and longest GSL.