Soybean frost risk at planting across Minnesota

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Summary:
The timing of soybean planting plays a critical role in determining yield outcomes. Early planting can enhance yields through better resource utilization, but it also introduces risks, particularly from adverse conditions such as late frosts that can impair crop establishment and potentially necessitate replanting. **Frost Risk Analysis:** This project assessed the risk of frost at a county scale using 15 years of weather data from the Daymet database, which provides high-resolution daily weather estimates.

Key Findings:

-Frost Timing and Distribution: The last frost date varies significantly across Minnesota, primarily influenced by latitude, but are also affected by altitude, landscape position, and moisture levels among other factors. A conservative estimate using a 30°F threshold indicated that in 9 out of 10 years, the last frost occurs before the dates shown in Figure 1.

-Planting before the last frost: Soybean seeds require approximately 200 growing degrees day (base temperature of 50°F) to emerge, during this phase the crop is protected by the soil. Figure 2 shows the earliest planting dates that ensure emergence after the last frost.

-Extended plant-to-emerge stage duration: Even avoiding frost, early planting dates typically result in a prolonged planting-to-emergence stage, leading to uneven crop establishment and increasing exposure to pests and diseases. Figure 3 highlights dates ensuring emergence within 15 days, therefore minimizing disease and insect risks.

-Seed Quality and Protection: High-quality seeds and protective technologies like fungicides and insecticides are essential to mitigate risks associated with early planting.

Conclusion: Early soybean planting can potentially increase yields, but managing the risks related to frost and prolonged emergence periods is crucial. This project generated information at a county level for the last frost date, the first day to plant to avoid frost after emergence and the first date to plant to avoid plant emergence periods above 15 days. These are useful tools to help in understanding the dynamics of frost risk and emergence duration along the state that could be incorporated to the planting date analysis to optimize planting strategies for better yield outcomes.

Introduction:
Research consistently indicates that the timing of soybean planting significantly impacts soybean yield. Early planting could offer an advantage, resulting in higher yield potentials compared to normal planting. This advantage stems from improved resource capture and utilization. However, while early planting presents potential yield benefits, it's crucial to evaluate risks due to adverse conditions affecting crop establishment, that could depress yield potential, and which may even lead to replanting.
A key consideration when adjusting planting dates earlier is the likelihood of late frosts occurring after crop emergence. The frost risk distribution for different planting dates will be dependent on the location (latitude, position in the landscape, etc.). In this project we used weather data from

Daymet to estimate frost risk (Thornton et al., 2021). The Daymet products provide estimates of daily weather parameters at 1 km resolution for North America. We retrieved minimum temperatures on a daily basis for the last 15 years at a county level across the state (average of at least ten fields per county).

Outputs:

A conservative prediction for the last frost dates at the county level can be observed in Figure 1 (in nine of ten years the last day with low temperature lower than 30ºF should be before the indicated date). As expected, the timing of the last frost and its risk distribution across Minnesota is heavily dependent on latitude. Moreover, other factors such as altitude, position in the landscape, and moisture levels also contribute to the observed patterns among counties and would contribute to the variability we should find within counties. Additionally, it's worth noting that while our estimates are conservative, using 30°F as a frost limit, in many situations, crops can withstand lower temperatures without significant damage. However, it's essential to recognize that the objective of the report is not to provide recommended localized planting dates but to generate a discussion about the different risks associated with early plantings that can be adapted to local situations and levels of risk tolerance.

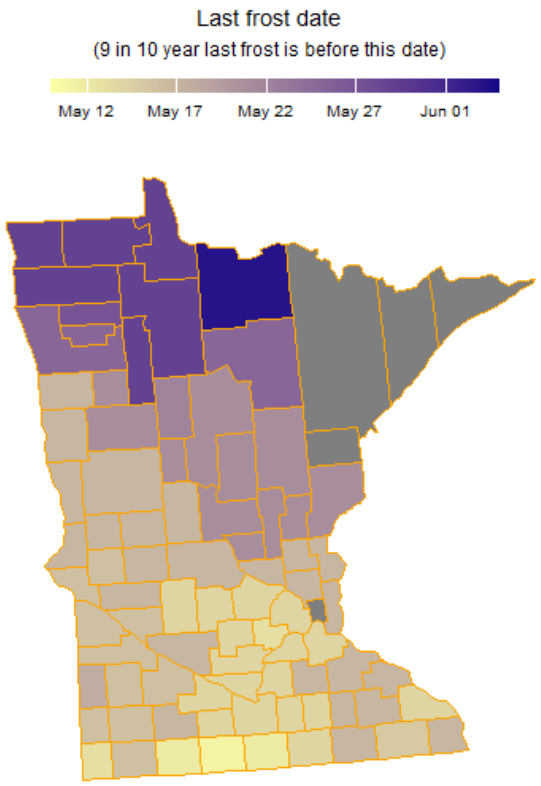

Figure 1: Conservative last frost date (daily minimum temperature below 30°F) at a county level (90th quantile). Nine out of ten years the last frost should be earlier than the indicated date. Estimated using DAYMET database for the last 21 years.

To inflict damage on soybean tissue, temperatures typically need to reach or fall below 28°F for an extended period (Meyer and Badaruddin, 2001). In addition, prior to emergence, the soil

serves as a protective barrier against freezing temperatures. Thus, it seems that a precise tool to assist planting decisions based on frost risk in early stages should incorporate time to emergence into the model. The duration from planting to the emergence stage varies based on the average soil temperature. Considering that soil temperature is influenced by ambient conditions, soybeans typically require approximately 200 growing degree days (with a base temperature of 50°F) after planting until emerging above the surface. We incorporated this plant-to-emergence period into the equation and considering both the spatial data on frost dates and the duration of this stage based on daily average temperature (also retrieved from DAYMET), we determine an indicative earliest planting date that will prevent soybeans from emerging before the last frost across the state (Figure 2). Figure 2. displays the map of the first planting date that would allow the emergence to occur after the last frost in 9 out of 10 years (shown in Figure 1), with an imposed earliest planting limit of 20 days before that date.

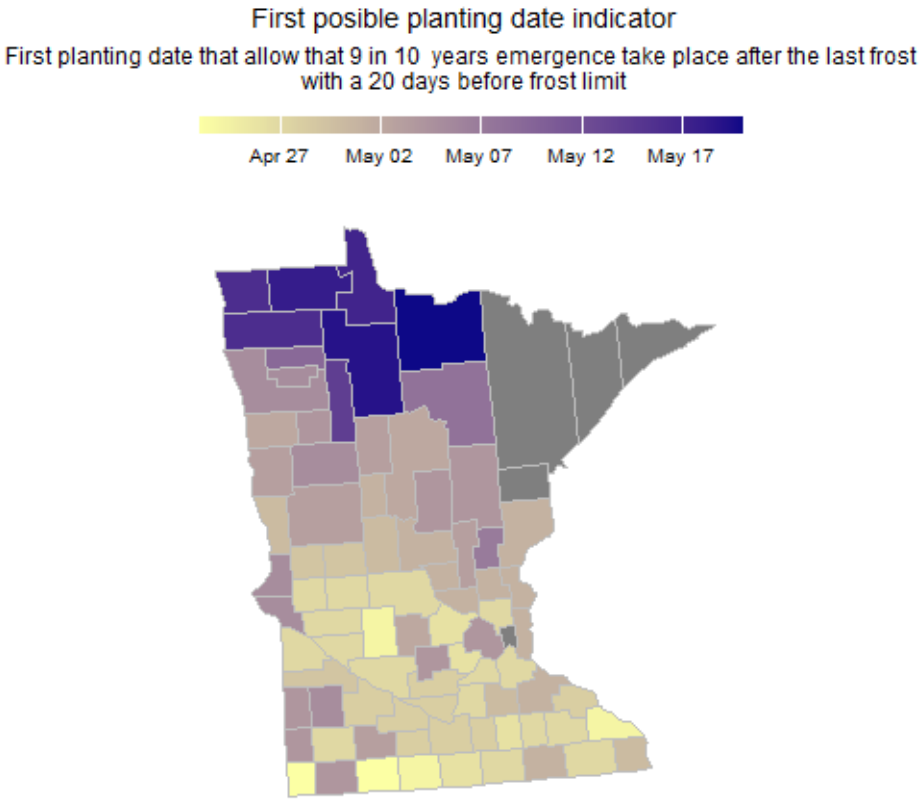

Figure 2: First possible planting date for an emergence after the last frost at a county level (90th quantile). If planting soybeans on these dates, nine out of ten years the crops should emerge after the last frost. Estimated using DAYMET database for the last 21 years considering the duration of the planting-to-emergence to be 200 growing degree days above a base temperature of 50°F.

As anticipated, the potential earliest planting date far precedes the last frost date. A key point to consider is that after planting there is a period of rapid water uptake by the seed (the imbibitional phase typically is no longer than 24 hours). Chilling during the first phase can cause problems because cold temperatures (conservatively, less than 50°F) interfere with proper

hydration of seed membranes. Thus, receiving a cold snap 0-24 hours after planting can lead to chilling injury in soybean. Chilling injury is likely to be lower if soil temperatures become cold 24 or more hours after sowing. Checking the average soil temperatures and the temperature forecast are useful tools to manage chilling injuries during germination. However, beyond the seed chilling damage, we emphasize here the long duration for the plant-to-emergence stage under these earlier planting date strategies. By comparing Figure 2 and Figure 1, we can deduce that for these early planting dates, the plant-to-emergence stage would extend well over two weeks (the difference in between planting date (Figure 2) and the frost date (Figure 1). In fact, the average estimated difference between the last frost and the earliest possible planting date along the state was greater than 17 days.

The duration of the planting-to-emergence stage is relevant for germination, seedling emergence and crop establishment. In general, the longer this stage lasts, the greater the chances of encountering disease and insect related issues, and the more uneven the crop is likely to be. A different approach to analyze the same issue is to assess the first planting date that would allow the crop to emerge in a determined period of time. Accordingly, Figure 3 illustrates the first planting that would allow the crop to emerge in less than 15 days in 9 out of 10 years. If we compare this with Figure 2, we will appreciate that these dates are later compared to the earliest planting date targeted to avoiding frost. Therefore, the length of the planting-to-emergence stage is a significant consideration for early soybean plantings and may be more relevant than the first possible planting date itself.

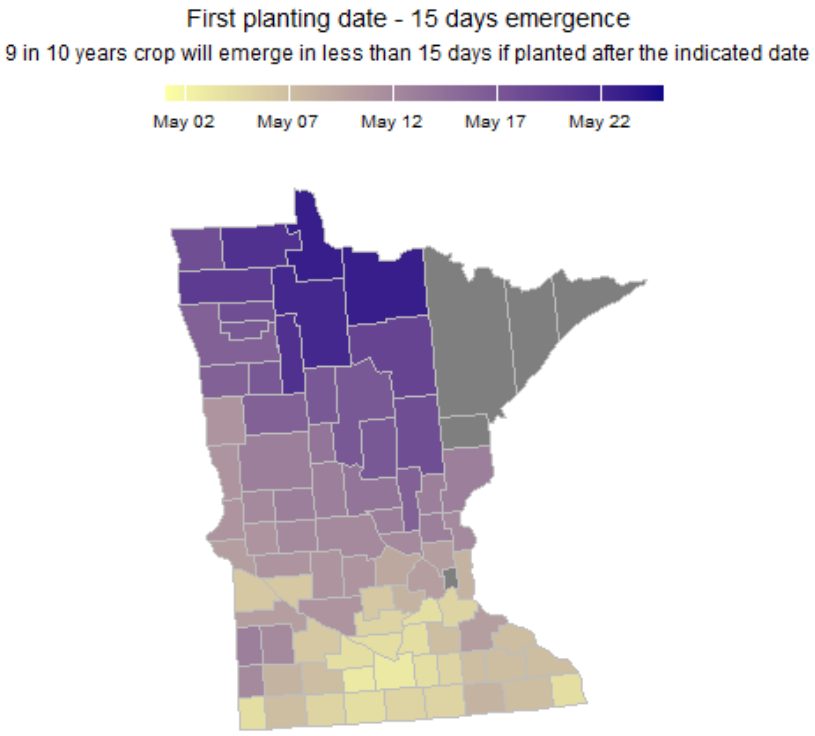

Figure 3: First planting date that allows the crop to emerge in less than 15 days at a county level (90th quantile). Nine out of ten years the crop would emerge in 15 days or less if planted on the indicated date. Estimated using DAYMET database for the last 21 years.

The noteworthy aspect here is that while we can set an early planting target that includes a low frost risk (the idea behind Figure 2), it is difficult to escape from a prolonged duration of the plant-to-emergence stage for early plantings in Minnesota. Let's take the data for Le Sueur as an example. For this county, the earliest possible planting data to avoid frost was Apr 28th, which means that if we plant after this date, we should expect a low risk of frost damage for our crops (1 out of 10 years). However, for Le Sueur, the first planting date that allows the crop to emerge within 15 days is May 4th. Therefore, there is a low frost risk for plantings at the beginning of May, but it is highly probable that for these earlier planting dates will have planting-to-emergence period that will exceed 15 days. Consequently, while the last frost generally raises major concerns, the prolonged plant-to-emergence period consistently impacts early planted crops.

Fortunately, there are tools at our disposal to address delayed emergence. Seed quality, such as vigor, is crucial. A pertinent recommendation for such cases is also to evaluate and leverage technologies that aid in seed protection, such as fungicides and occasionally insecticides.

Conclusions:

Early soybean planting offers the potential for higher yields due to improved resource utilization. However, it's essential to carefully manage the associated risks, particularly regarding adverse environmental conditions that may affect crop establishment. Understanding the relationship between planting timing, frost occurrence, and the duration of the plant-to-emergence stage is crucial for attaining yield potential while mitigating risks. By leveraging available data and technologies, farmers can make informed decisions oriented to reduce frost risk, protect seed quality, and enhance crop resilience against environmental challenges presented in early plantings.