Relationship between Environmental Factors and Flowering Time in E. angustifolia

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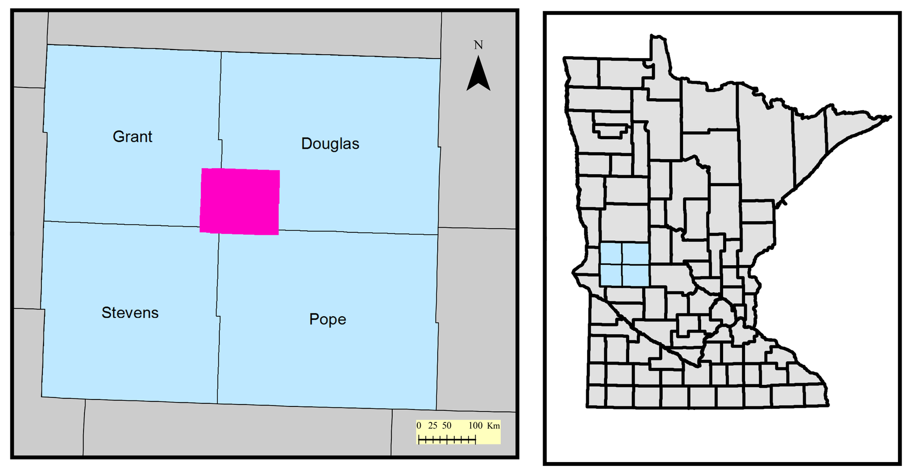
Abstract

The survival of plant populations in remnant prairies is dependent on their ability to flower and reproduce at similar times, or their phenology. However, many plants within a population flower at different times, leading to reproductive isolation of individuals Among plants affected by this phenological isolation is the model plant Echinacea angustifolia, a long-lived species that is self-incompatible.

Therefore, five environmental variables were tested for their relationship to E. angustifolia flowering time to determine what factors contribute to phenological difference. Distance from roads, isolation from nearest neighbor, slope, aspect, and topographic wetness were tested for a relationship with flowering time relative to the population peak through Ordinary Least Square regression and exploratory regression. No significant relationships were found between the variables (individually or in combination) and flowering time. This suggests other variables, such as genetics or conditions at the time of plant establishment in the spring should be explored for their relationship to phenology, or at least that the tested variables should be explored further over a greater number of seasons.

Figure 9: Study Area



Coordinate System: NAD_1983_StatePlane_Minnesota_Central_FIPS_2202
Central Meridian: -94.25

Introduction

Echinacea angustifolia is a long-lived prairie plant that has been selected as a model organism for the study of prairie plant reproduction, particularly the reproductive challenges facing plants in remnant prairies. Remnant prairies, defined as prairies that have never been farmed, are in effect the only true prairies that exist and are the ideal that restored prairies try to imitate. These remnant prairies are primarily small, isolated patches, typically located in areas where agricultural technology can't reach. As such, the plants that exist in remnant prairies are frequently isolated by small population sizes that are widely dispersed. Additionally, prairie plants (including angustifolia) are further isolated as individual plants flower at different points in the season. This variation in flowering time is called phenology. Previous research on this plant has found that while both population and temporal isolation affect the plants' abilities to reproduce, temporal isolation from differences in phenology are most important (Ison, 2014). Therefore, understanding what leads to differences in phenology among prairie plant populations is crucial to conserving such species. Our goal was to determine if various environmental factors (slope, aspect, estimated topographic wetness, distance from roads, and distance to neighbors) affected the phenology of E. angustifolia.

Methods

The E. angustifolia data we received were all plants in remnant prairie populations in a 25 sq mi study area in Western Minnesota (Figure 9), and were collected in the summer of 2015. We classified these flowers based on the median day of their flowering period relative to the peak flowering date of 7/13/15 (the median date of the period in which the largest number of plants in the area were flowering). Plants whose median flowering date was before the peak date received a negative value of the days different from the peak, while plants whose median flowering date was after the peak date received a positive value of the days different from the peak. This phenological distribution is visualised in Figures 5 and 8.

Once flowering times were standardized for all plants in the study area, we performed regression on these values against the variables of topographic wetness index, slope, distance to roads, aspect, and distance from 4th, 15th, and 30th neighbors. Ordinary Least Squares regression was applied to each individual variable to determine individual effects of any variable (Figures 1-6). Additionally, an exploratory regression including all variables was also performed to account for combined effects, with no significant result.

Topographic Wetness Index: Calculated from 1 Meter DEM data from (Minnesota DNR, 2014) (Figure 1)
Slope: Calculated from 1 Meter DEM data from (Minnesota DNR, 2014) (Figure 2)
Roads: The complete map of roads was created by merging TIGER/line Shapefile road networks from the four counties, then clipping them to the study area. We then created a raster of Euclidean distance from this road network (Figure 3).
Aspect: Calculated from 1 Meter DEM data from (Minnesota DNR, 2014) (Figure 4)
Distance from Neighbors: (Wagenius, 2006)
The 4th nearest neighbor has been shown to have the highest relation to other aspects of angustifolia reproduction- namely, style persistence, seed set, and fecundity. As such, we included the 4th nearest neighbor in our analysis. Floret production was not found to be related to isolation, and instead was based principally on resource availability. 15th nearest neighbor and 30th nearest neighbor were also shown to be thresholds of relationship between groups of plants (but to a lesser extent) (Ison, 2014). (Figure 6)

Figure 1: Topographic Wetness Index

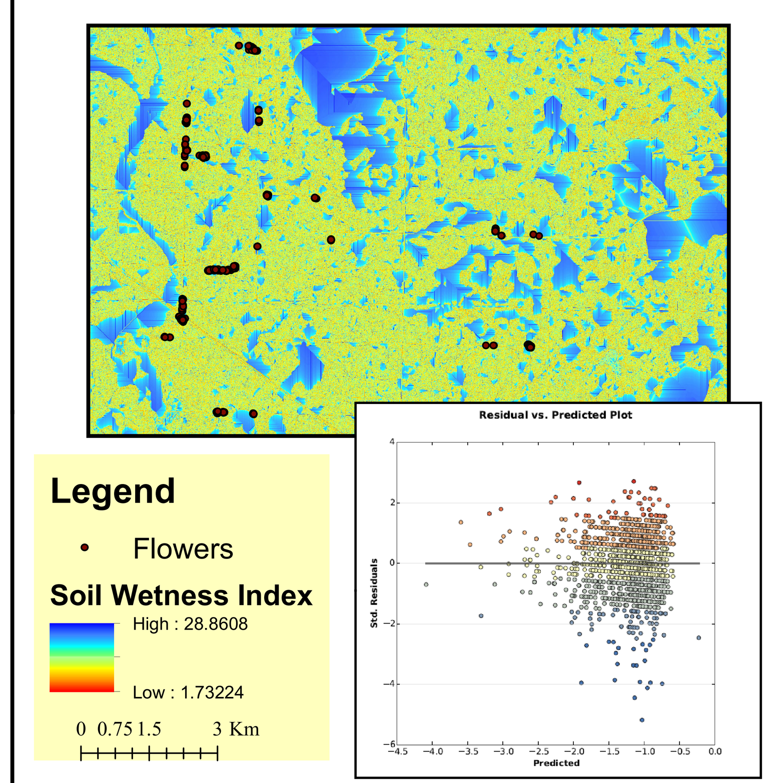


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Figure 2: Slope

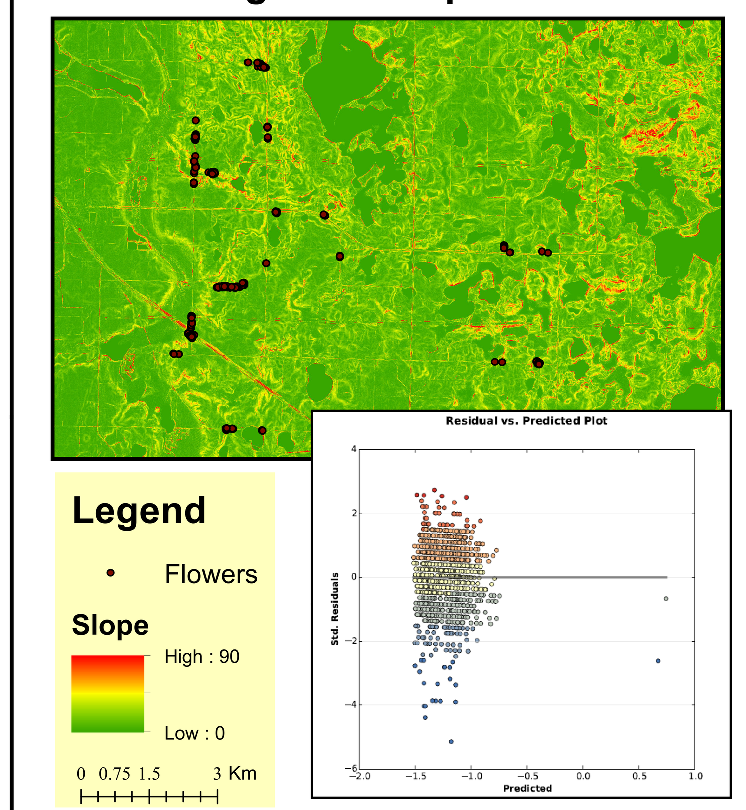

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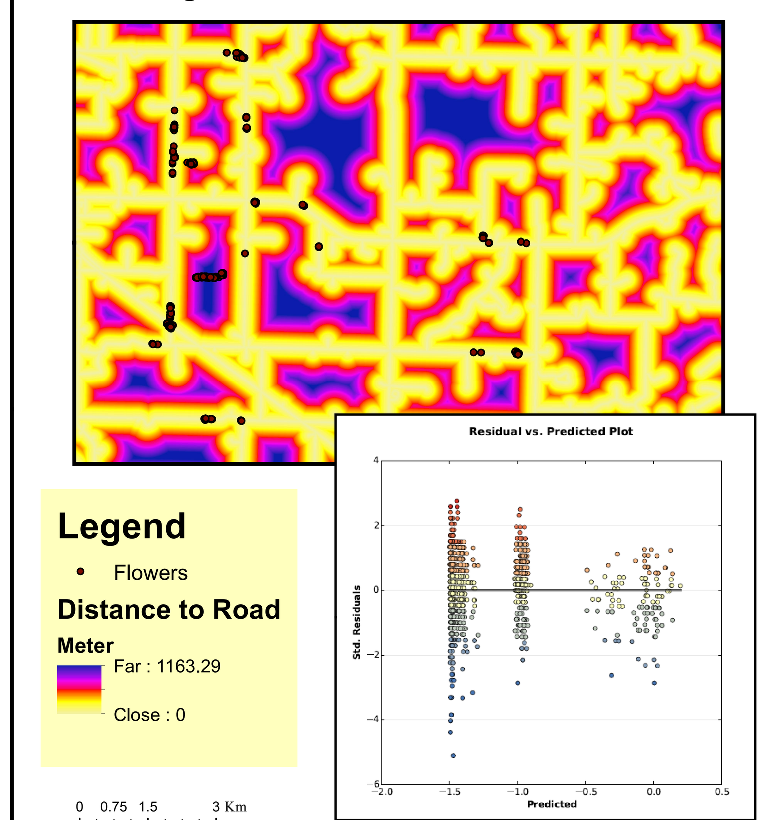
Figure 3: Distance to Road



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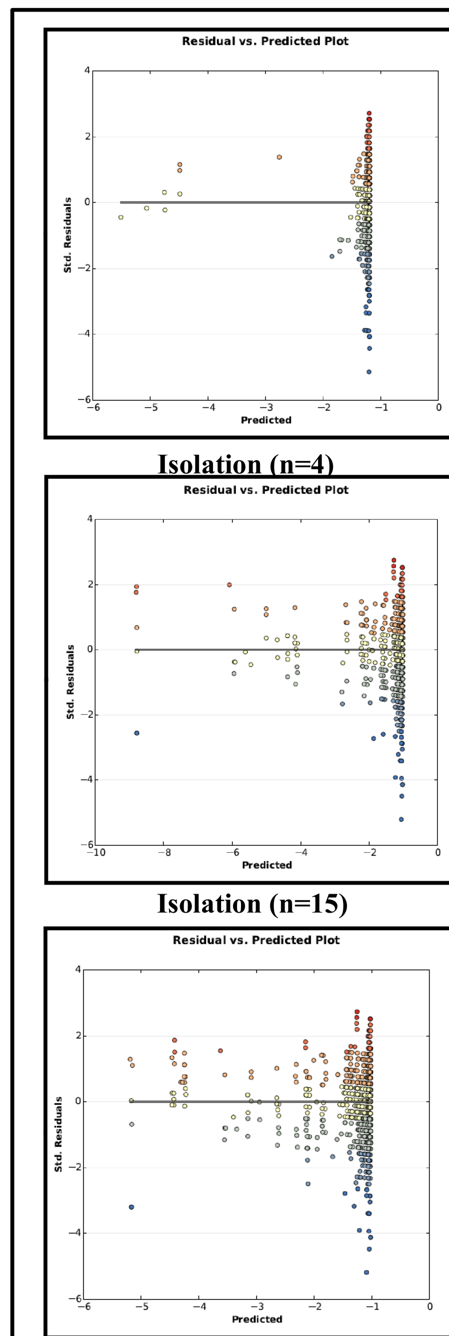

Figure 6: Ordinary Least Square for nth Nearest Neighbor

Figure 4: Aspect

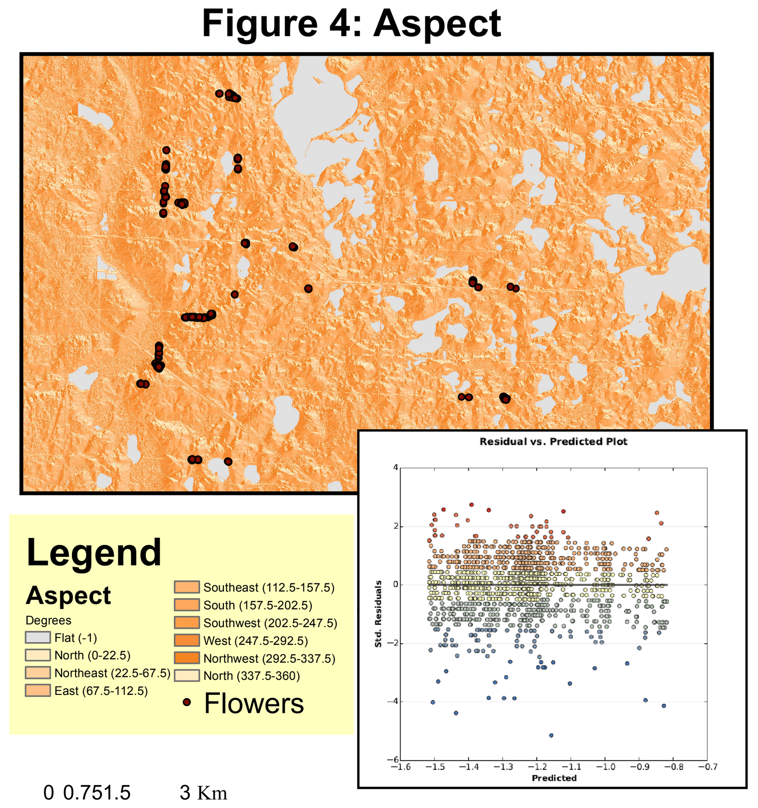

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Figure 5: Outliers

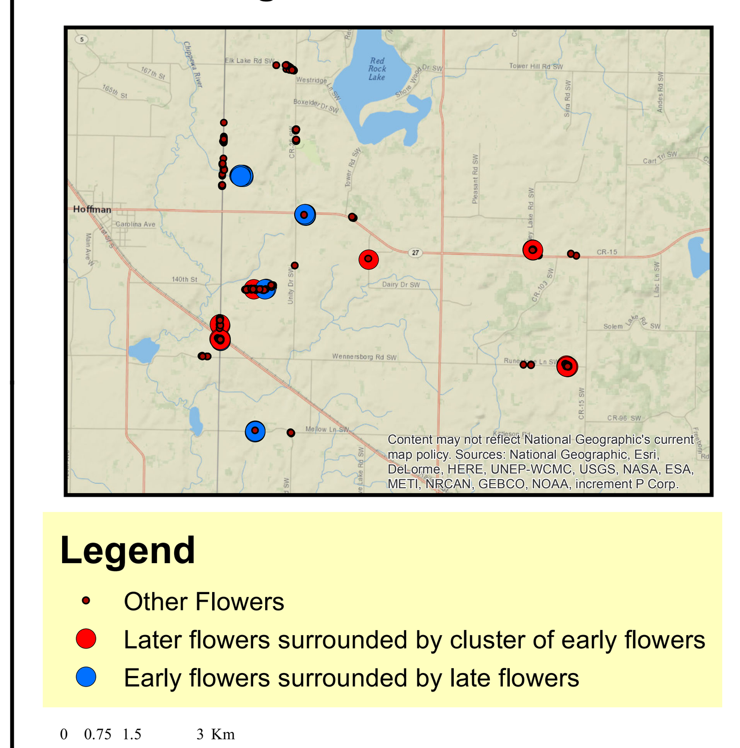

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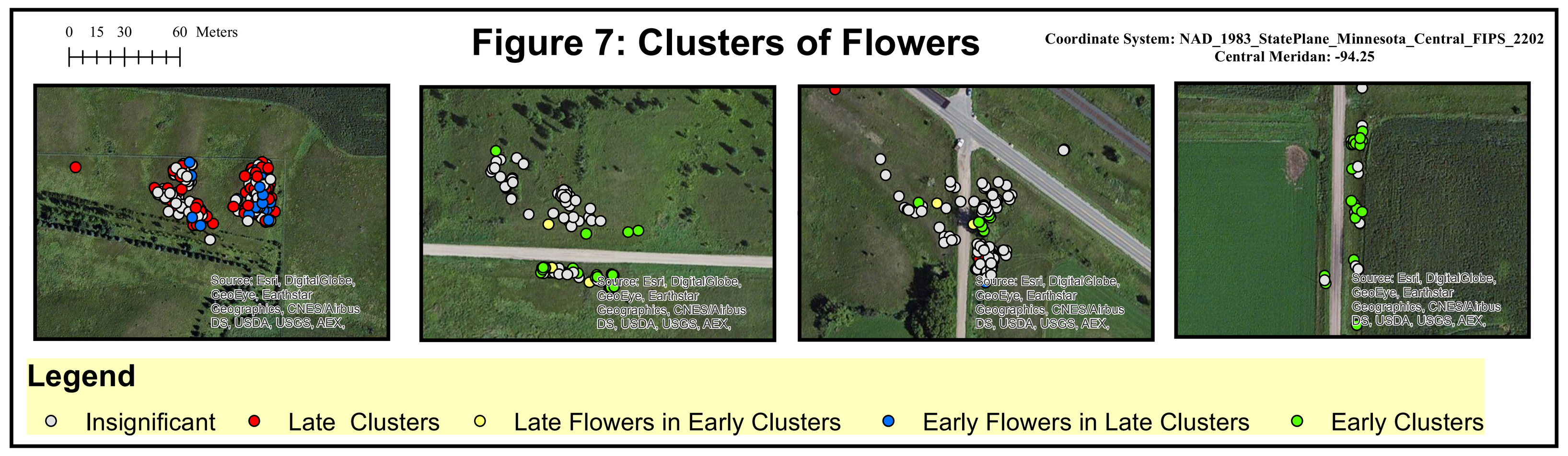
Figure 7: Clusters of Flowers



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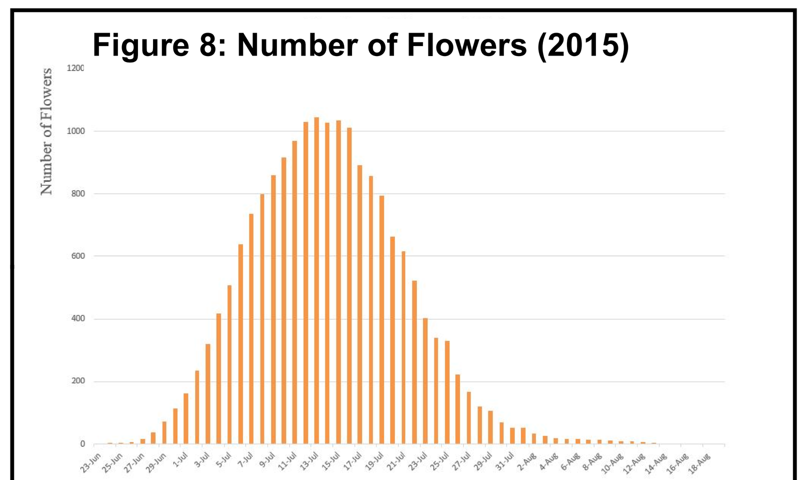
Results

No significant relationship was found between any of the variables of we studied and the phenology of E. Angustifolia. Both individually and combined, no individual variables or combinations produced a significant correlation.

Adjusted R2 values for each environmental factor and variation from peak flowering date:

Environmental Factor	Adjusted R^2 Value
Slope	0.000183
Aspect	0.000201
Distance from Roads	0.004736
Wetness Index	0.005237
Distance to 4th Nearest Neighbor	0.001474
Distance to 15th Nearest Neighbor	0.017618
Distance to 30th Nearest Neighbor	0.009866

Figure 8: Number of Flowers (2015)



Discussion & Conclusion

Since we found that the environmental factors we tested were not related to flowering time, this suggests phenology is principally determined by other factors. These factors may also be environmental, such as snow depth when plants are establishing themselves in the spring or nutrient availability in the soil. Additionally, the literature suggests that phenology may be principally genetically determined (Wagenius et al., 2014, below).

However, the extent to which genetics play a role are difficult to determine. Because the plant's ability to produce seed is dependent on the range of its pollinators (~3km) and seed dispersion is relatively close around the seed head, one would expect that plants that are closer to one another would be similar phenologically. To a certain extent, this is appears to be true. Different groups of individuals, clustered temporally, can be seen within populations, as seen in Figure 7.

Furthermore, the strength of our conclusions and relationships explored would likely be stronger if we had more than one season's worth of phenology to analyze. The dataset used had flowering dates only for the 2015 season. As a plant is unlikely to flower at exactly the same time each season, understanding a plant's phenological distribution over its lifetime in a particular environment would lead to more robust conclusions about the effect of the environment on when a plant flowers.

Future Study

If we were to continue studying the phenology of E. angustifolia, we would be interested in assessing the similarity of phenology based on proximity within population. Additionally, if we could compare this data with genetic similarity, we might have a stronger conception of the genetic effect on phenology.We would also have liked to run our analysis on a population level, instead of just at an individual level, since relationships between flower aspects have been known to change based on the scale of analysis. (Wagenius, 2006). Finally, phenology data that spans multiple years would give a more accurate picture of how a plant's location affects its flowering time.

References

ArcGIS Desktop Help
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