Nitrogen Fertilizer Recommendation Zones

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Introduction

Nitrogen fertilizer recommendations for stubble-seeded crops have been related to soil and climate geography for decades. Laboratories in western Canada recognized the importance of moisture and introduced soil test based recommendations that varied according to moisture conditions. However, there was no definition of dry, medium, wet, average or excellent. In 1990 Henry introduced a new system of recommendations that calculated potential yields based on specific moisture contents at seeding and on the 75, 50 and 25 percent probability of rainfall for May, June and July. Potential crop yields were based on moisture use efficiency equations developed for various Soil Climatic Zones (SCZ). SCZ were based on a climatic index derived from annual precipitation and temperature. Each SCZ was characterized by a unique water use efficiency coefficient for each crop and crop yield potentials and the corresponding nitrogen requirements were determined based on soil moisture at seeding time and growing season precipitation.

The concept of the Nitrogen Fertilizer Recommendation Zones (NFRZ) is introduced here. NFRZ are a function of Soil Zones that reflect soil genetic characteristics and the Growing Season Climatic Index (GSCI) that reflects growing season environmental conditions. Crop yield potentials and, hence, fertilizer recommendations are determined by the soil moisture at seeding time and growing season precipitation.

Climate Classifications for Crop Production

Climate Index (CI)

Mitchell et al. (1944) first attempted to classify climate for crop production. They developed a climate index (CI) based on mean annual precipitation and mean annual temperature as follows:

$$CI = 1895 \times \frac{\text{Precipitation}}{\text{Temperature} \times (1.38 \times \text{Temperature} - 27.4)}$$

The mean annual precipitation was expressed in inches and the mean annual temperature in °F. The CI is meant to provide a relative value of the sufficiency of moisture supply for crop production, with precipitation being an indicator of supply and temperature of demand. It resulted in numerical values ranging from 20 to 130.

Soil Climatic Zones (SCZ)

The Soil Climatic Zones (SCZ) developed by Henry 1990 were defined by dividing the CI into classes, e.g. Moist Dark Brown soils were defined as those for which CI ranged from 36 to 41.4. Henry and Harder (1991) first derived a map of SCZ of Southern Saskatchewan and Meyers and Karamanos (1997) later expanded the concept to the derivation of SCZ of the Canadian Prairies.

One of the important assets of this index was that weather data was available from a sufficient number of weather stations on the Prairies – more than 300 – so that geographical boundaries of the classes could be defined with confidence. The major disadvantage of the CI was that it utilized mean annual climate characteristics. Thus, it did not necessarily represent growing season conditions; rather it reflected long-term climatic conditions. Growing season for cereals and oilseeds is generally recognized as only slightly exceeding three months (May, June and July).

Water Stress at Soft Dough Stage of Wheat

Ash (1991) estimated soil water stress at the soft dough stage of wheat for southern Manitoba and southeastern Saskatchewan. He simulated daily crop water demand based on the stage of crop development and potential evapotranspiration data from some 150 weather stations with at least 15 years of daily temperature and precipitation data. After assigning an appropriate soil water-holding capacity to each weather station, water stress (mm of equivalent rainfall) was defined as the difference between demand and supply – stored soil moisture in spring and growing season precipitation. Calculations were made for every year for which data was available and were then averaged. This calculation considers both soils and daily weather and, therefore, is considered a fairly realistic estimate. However, it is not practical to do this for 400 weather stations across the Prairies.

Basis for Current Classification

The basic philosophy behind the current classification is that fertilizer recommendation should be based on yield potential. Research shows that growing season precipitation is the most important source of water for crops. Although the season may extend from planting in May to as late as late September or early October, most of the crop growth occurs during May, June and July.

Analyzing the entire length of record, i.e. daily data, which in some cases could be 100 years, for some 350 weather stations on the Prairies was deemed an impossible task. As a compromise, it was decided to use the 30-year "normal" data. The 1951-80 normal period was used in this analysis because it included a greater number of weather records.
With regard to supply of water, it is recognized that effectiveness of supply depends upon time in the growing season in which precipitation occurs. For example, 25 mm of rain in July is much more likely to affect yield than that same amount in May. Several methods of weighting average monthly precipitation were investigated. Finally, it was decided to estimate "effective" supply by:

May precipitation + 2 x June precipitation + 4 x July precipitation
Crop water demand depends upon a number of factors, e.g., solar radiation, temperature, relative humidity, wind, as well as the degree to which the crop covers the ground. The only one of these variables for which data is available for a significant number of weather stations on the Prairies is temperature. It was assumed that crop water demand was proportional to the average temperature during the months of May, June and July.

The index designed to be an indicator of the degree to which crop water demand is met. It was calculated by dividing the estimate of supply (mm) by the estimate of demand, as follows:

$$GSCI = \frac{\text{May precipitation} + 2 \times \text{June precipitation} + 4 \times \text{July precipitation}}{\text{Average May, June, July Temperature}}$$

The index was calculated for 373 weather stations in the Prairies. Numerical values of the index ranged from <20 to > 40. Initially, it was decided that the map be limited to 5 classes: <21, 21-27, 27.1-31.5, 31.6 – 39.9 and >40. However, it became apparent that three separate classes had to be identified for the Peace River Region of Alberta (<33, 33.1-40,>40) and a unique GSCI for the Red River valley of Manitoba (27.1-31.5).

Comparison of Current Classification to Previous Work

The GSCI was compared to the CI (Figure 1) and to water stress at soft dough of wheat (Figure 2) for those weather stations for which data was available.

It has already been demonstrated that the CI is a useful guide in making fertilizer recommendations. The relationship between GSCI and CI was quite good at low values of the indices, i.e. “dry” areas (Figure 1). However, at higher values, the indices were not as closely related. This was to be expected since the CI was developed to primarily suit the drier parts of the Canadian prairies (Saskatchewan). On the contrary, the water stress at dough (Ash, 1991) that has been developed utilizing data from wetter parts of the Canadian prairies (Manitoba). The relationship of the GSCI to the water stress at soft dough (Figure 2) was not as close as that to the CI. There are several reasons for this. The GSCI does not consider the effect of soil type and winter precipitation on spring soil moisture status. Stress at soft dough was calculated at an estimated calendar date for the soft dough stage, which varies from year to year. The GSCI assumes that only the weather conditions in May, June and July affect crop growth. Hence, a close relationship is not to be expected in the first place. It was encouraging, however, to see a well-defined general trend.

The GSCI does not provide an ultimate solution to deriving an appropriate climatic index to describe growing season conditions. However, it provides a reasonable characterization of the growing season.

Geographical Distribution of Growing Season Climatic Index Zones

The driest areas, i.e. growing season climatic index values < 21, as expected, occur in southeastern Alberta, including locations like Medicine Hat, Taber, Suffield, etc. The next driest area, 21 – 27, surrounds the first area, and extends through east-central Alberta to Saskatoon and Regina. The moderate area, index values 27-31.5, again surrounds the second area and includes Hanna and Strathmore in Alberta, North Battleford, Prince Albert, Yorkton in Saskatchewan, Melita, Carberry, Ninette, Deerwood, Elm Creek in Manitoba. The humid area, 31.5 – 40, takes in the area of the Peace River and that near Edmonton and east in Alberta, northern Saskatchewan, the Duck and Riding Mountain, and most of the eastern half of southern

Manitoba. The extremely humid areas are restricted to the Mountainous areas west of Calgary and Edmonton. There are also “pockets” which are different from the surrounding areas; e.g. due to its higher elevation, the Cypress Hills region of Saskatchewan is “wetter” than the surrounding area.

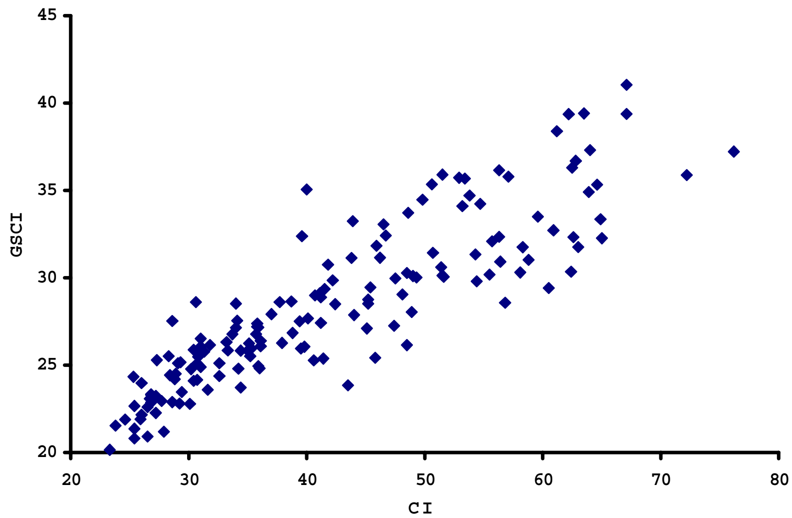

Figure 1. Relationship between the GSCI and CI.

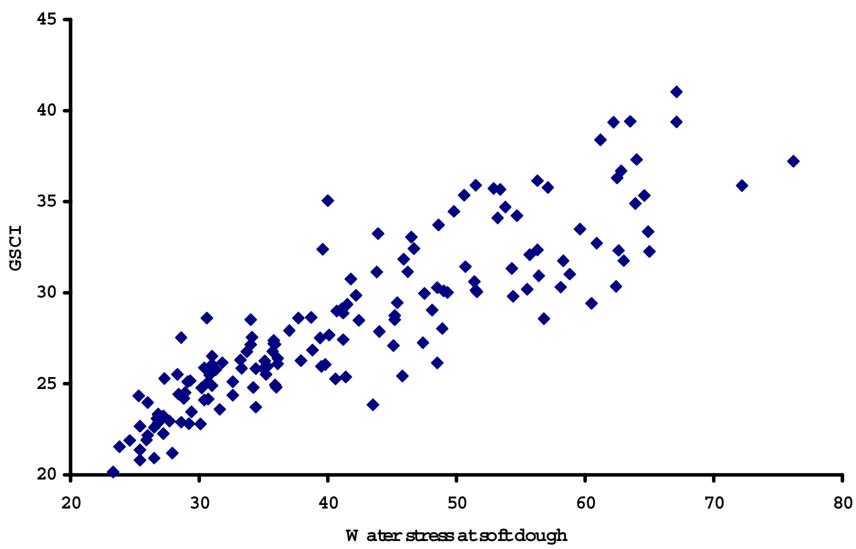

Figure 2. Relationship between GSCI and water stress at soft dough as calculated by Ash (1991).

Nitrogen Fertilizer Recommendations

Derivation of nitrogen fertilizer recommendations using GSCI Zones will be based on a principle similar to that utilized by Henry (1990) when he introduced the SCZ.

A map has been developed by Henry et al. (2000) that combines the traditional Soil Zones with the Growing Season Climatic Index Zones. The resulting combinations represent “Nitrogen Fertilizer Recommendation Zones” with unique GSCI and soil characteristics, especially pertaining to soil nitrogen mineralization. An example of the moisture use efficiency coefficients utilized in the new system of nitrogen fertilizer recommendations is presented in Table 1.

Table 1. Moisture use efficiency coefficients for wheat barley and canola for the GSCI of Saskatchewan.

	Wheat CWRS					Feed Barley					Canola				
		Probability of precipitation, %					Probability of precipitation, %					Probability of precipitation, %			
GSCI Zones	Intercept	75	50	25	10	Intercept	75	50	25	10	Intercept	75	50	25	10
Palliser Dry Plain	2.50	3.00	3.50	4.00	4.00	2.50	5.00	5.25	5.75	5.75	2.50	2.00	2.25	2.50	2.50
Palliser Moist Plain	2.25	3.50	4.00	4.50	4.50	2.25	5.50	6.00	6.50	6.50	2.25	2.25	2.50	2.75	2.75
Parkland and Cypress Highlands	1.75	3.75	4.25	4.75	4.75	1.75	6.25	6.75	7.00	7.00	1.75	2.75	3.00	3.25	3.25
Moist Parkland	1.50	4.00	4.50	5.00	5.00	1.50	6.75	7.25	7.50	7.50	1.50	3.25	3.50	3.75	3.75

Work is currently underway to define soil nitrogen mineralization parameters for all GSCI Zones.

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