SECTION 4

The Effects on Spring Wheat Production

In this section the impacts on a specific crop, spring wheat, are discussed. As noted previously (Section 1), spring wheat production is the major crop production activity in Saskatchewan and, therefore, is a logical choice for study in impact analyses related to the agricultural industry.

In this study a crop growth model is used to estimate the changes in spring wheat yields that could be expected to accompany the changes in climate outlined in *Tables 1.3* and *1.4*. In the following subsections details of the crop growth model and its sensitivity to changes in various climatic parameters are outlined. The impact of the different climatic scenarios on spring wheat yields and production are then discussed. Finally, the derived yield changes are incorporated into farm and provincial level input–output models to examine the possible impacts on the economy of Saskatchewan. The results of this application are presented in Section 5.

4.1. Methodology

4.1.1. The yield and phenological models

The procedures used to estimate spring wheat phenology and yields are briefly described in the following; a detailed discussion of the yield model is provided by Stewart (1981), while Robertson (1968) and Williams (1974) provide a more detailed discussion of the phenological model. Calculation of spring wheat yields is based on the methodology developed by the FAO (1978) and utilizes tabulated results from the de Wit (1965) photosynthesis model to compute "constraint-free" yields. Yield estimates assume a sigmoidal cumulative growth curve with development incremented up to the number of days required to mature the crop. Net biomass production (B_n) is calculated as a function of the gross biomass

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production (B_{gm}) capacity of the crop, determined by its photosynthetic response to temperature and radiation, a maintenance respiration coefficient (C_T) and the number of days required to reach maturity (N). This relationship is expressed as:

$$B_n = 0.36B_{gm}/(1/N + 0.25C_T) \tag{4.1}$$

To estimate N, a phenological model developed by Robertson (1968) is used. Robertson's model describes the phenological development of spring wheat as a function of temperature and photoperiod in the form:

$$\sum_{i=S_1}^{S_2} \left[a_1(L_i - a_0) + a_2(L_i - a_0)^2\right]\left[b_1(T\max_i - b_0) + b_2(T\max_i - b_0)^2 + b_3(T\min_i - b_0) + b_4(T\min_i - b_0)^2\right] = 1 \tag{4.2}$$

where: L_i is the photoperiod (duration of daylight in hours) on day i, $T\max_i$ is the maximum air temperature on day i, $T\min_i$ is the minimum air temperature on day i, S_1 is the date of a phenological stage in the development of wheat toward maturity and S_2 is the next stage, and a_0–a_2 and b_1–b_4 are coefficients.

In the model, five phenological phases are considered: planting to emergence, emergence to jointing, jointing to heading, heading to soft dough and soft dough to ripe. For each stage a different set of a and b coefficients are used. The reader is referred to Robertson (1968) for a detailed description of the model and for a more precise definition of each of the crop phenological stages.

If the commencement date for a phase is known, then by using equation (4.2) with the appropriate set of coefficients, the date this phase ends and the next begins can be estimated. This is accomplished by summing the value calculated by equation (4.2) from day to day until a value of 1 is reached. The date the crop ripens or matures is derived by continuing the summation from the planting date through all five phases. N is then derived as: N = IEND − ISTART + 1, where ISTART and IEND are the Julian dates that the crop is planted and reaches maturity, respectively.

The planting date is calculated as the date the smoothed mean minimum air temperature first exceeds 5 °C in the spring. This represents, with a 50% probability, the average date for the last spring and first autumn "killing frosts" (−2.2 °C) when using averaged 30-year climatic normals data (Sly and Coligado, 1974). In determining this date, the monthly temperature data are first converted to daily values using the Brooks (1943) sine-curve technique. The planting date is then derived by computer interpolation of the first day the minimum air temperature reaches 5 °C. Similar criteria are used to determine the end of the growing season in the autumn. If an estimated autumn frost occurs before the crop reaches maturity, the crop is assumed killed and the yield component set equal to zero.

Crop dry matter yield (B_y) is then derived as: