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Regional Land Use Data Requirements

data requirements and
sources of agricultural
land use and management
practices for selected
soil degradation models



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REGIONAL LAND USE DATA REQUIREMENTS:

**data requirements and sources of agricultural
land use and management practices for selected
soil degradation models**

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Summary

Over the past 10 years, complex, process-based models that simulate several soil degradation processes have been developed and tested on small-scale farm or plot data. The application of these models has helped to describe how changes in agricultural land use and management practices may affect the natural processes that influence soil quality over limited areas (Acton 1993). There is an ever increasing need, however, to address issues of soil quality and environmental sustainability at a regional level (i.e. on one or more landscapes). Studies conducted at this level will need to obtain and generalize broad-scale information representing the major patterns of agricultural production within a given agricultural area. Thus, for regional analysis, the manner in which data is gathered, organized and presented differs from the collection of site (or farm) specific information (Dumanski et al., 1993). The objective of this study was to examine the land use and management modules of selected soil degradation models, construct an inventory of the land use requirements of those models and subsequently determine the structure, content and data sources for a regional land use database.

The land use data requirements were assessed for 5 models: EPIC (erosion productivity impact calculator), WEPP (water erosion prediction project), WERM (wind erosion prediction system), Century, RUSLE (revised universal soil loss equation) and WEQ (wind erosion equation). The inventory identified over 200 different variables. This variable list was then summarized into 118 common variables in 9 general categories. This summarized list of requirements essentially forms the contents and structure of the database.

For the purposes of regional analysis, the extent to which the required data for each of the land use variables was expected to vary, both in terms of space (biophysical land units) and time was assessed. This characterization accomplished two things: (1) it identified the need for grouping, categorizing and generalizing the highly variable, detailed data for regional representation, and (2) allowed for a direct comparison of the information required for regional analysis with what is available.

Available sources of regional information for the land use variables were identified, characterized by type, scale or reporting unit and the time period of the source. This characterization enabled a comparison of the data characteristics with source characteristics. In general, it was found that considerable gaps exist between what is required for regional analysis and what is available, both on a spatial and temporal basis. Few studies exist that provide the kinds of land use data that will allow these models to run on a landscape basis. As a result, expert opinion was identified as one of the most important sources of regional land use information available.

While expert opinion is a valid source of regional data, inconsistencies in reporting of the land use data in a given region can occur. Further, it follows that if every analyst or user were to proceed on their own, there would be both a great deal of duplication of effort and the development of databases which, while not likely very different, would nonetheless not be identical. Consistent data input, in the form of a standard land use database for all regions, would enable consistent reporting of and direct comparisons amongst model output on soil quality, regardless of the users or nature of the studies involved. The database would also function as a means for integrating various model outputs to obtain an overall assessment of soil quality within a given agricultural region, at a given time. The identification of the need for a regional land use database provides a point of reference for further discussion and considerations relevant to regional analysis.

A number of recommendations are suggested:

1. A standard, regional land use database should be developed as a basis for regional assessments of soil quality and environmental sustainability.
2. Since much of the land use data must be obtained from expert sources, a major coordinated survey should be conducted.
3. Since many different agencies are identified as both sources and users of information, multi-agency collaboration and coordination should be pursued for considerations of efficiency and duplication.
4. The national ecological stratification should be considered as a standard natural resource base for spatial integration.

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1.0 Introduction

Research on sustainable development in Canada has led to a closer examination of the quality of soils used in agricultural production. Policy makers consider sustainable agricultural development to be based, in part, on economically efficient production systems that maintain or enhance soil quality (Dumanski and Smyth 1994). Agronomists, soil scientists and geographers use soil degradation models to assess the impact of production systems on the current status of, and future changes to, soil quality (Acton and Padbury 1994). These models, which use detailed, site-specific data, help to describe how changes in agricultural land use and management practices (referred to as 'land use' for the remainder of the paper) may affect the natural processes that influence soil quality over small areas (Acton 1994). Recent attempts to use these models to assess soil quality over broader areas (i.e., one or more landscapes) have found that regional land use databases are required for successful model simulation (Hiley and Huffman 1994). At present, these databases are not available for agricultural regions of Canada. The term "regional" as used in this paper refers to any area larger than an immediate site or field that requires extrapolation or scaling of data from the site to a larger landscape area.

The development of regional agricultural land use and management databases would be beneficial to regional assessments of soil quality for at least 4 reasons. First, land use databases would provide consistent representation of agricultural production in a region at a given time. Second, consistent land use databases would ensure that the output from different soil degradation models are not biased by different representations of regional agricultural production. Third, consistent land use information and model outputs would improve the consistency of reporting on the status of soil quality. These reports would allow researchers to integrate the output from various soil degradation models to assess the current status of, and future changes to, soil quality. Fourth, regional land use databases could be updated on a regular basis to describe and monitor the effects of changing land use and management practices on regional soil quality. Given that a regional land use database would have several potential benefits to regional assessments, a research project was devised to determine the content of, and sources for, a land use database.

1.1 Objectives

The objective of this research is to recommend sources of land use data in support of the development of regional databases. In order to achieve this objective, several assumptions must be made concerning how the land use data will be used by soil degradation model users. This research follows the assumption that the land use information requirements for detailed assessments are set in the architecture of the soil degradation models, as described in the supporting model documentation. Examination of this documentation will identify a complete list of land use variables that represent the land use information requirements of each model. The complete list of land use variables would then be separated into those variables whose values can not be altered, termed 'model-supplied' land use variables, and those variables that can be manipulated, termed 'user-specified' land use variables. Model users would change the value of these 'user-specified' land use variables to represent agricultural production in a region. Thus, the 'user-specified' land use variables would form the structure of a regional database and reliable sources of data are required for these variables.

1.2 Study Method

The study method is a 3 step process:

1. prepare an inventory of 'user-specified' land use variables for selected soil degradation models (Section 2);
2. reduce duplication in the inventory by constructing a summary list of 'user-specified' land use variables and organizing those variables into a limited number of categories (Section 3); and,
3. compare the data characteristics of "user-specified" land use variables to available data sources (Section 4) for each category of variables in the regional Land use database.

The final 2 sections of the study discuss the findings of the above process and interpret the relevance of the findings within a regional context (Section 5). Recommendations for future work are presented in Section 6.

Given the diversity of agricultural regions and data sources of land use information in Canada, the study will be initially limited to a review of information sources for Alberta.

2.0 Model Descriptions

This section identifies the 'user-specified' land use variables required for each soil degradation model. The list is refined from a complete inventory of the land use variables supplied for each model (Appendices 1-6). The 'user-specified' land use variable list (Tables 1-6, end of this section) is compiled from soil degradation models that are either process-based (Section 2.1) or empirically derived (Section 2.2).

2.1 Process-Based Models

Five process-based models are under consideration for use in regional soil quality assessments. They include: the Erosion Productivity Impact Calculator (EPIC); the Water Erosion Prediction Project (WEPP) model; the Wind Erosion Research Model (WERM); the Century soil organic model; and, the SEEP/W and CTRANS/W models that are used to simulate the movement of water through porous materials (soil salinization). The 'user-specified' land use variables associated with these models are presented under the appropriate submodels and routines.

2.1.1 Erosion Productivity Impact Calculator (EPIC)

The Erosion-Productivity Impact Calculator (EPIC; Tech. Bull. No. 1768; Sept. 1990) is a process-based model that was designed to study the relationship between soil erosion and productivity. The model is comprised of physically-based components which simulate, on a daily time-step: wind and water erosion; plant growth, soil nutrient status (N and P) and other related processes, as well as economically-based components which assess the cost of that erosion and aid the user in developing management strategies that will minimize erosion in the system under study (Sharpley and Williams 1990). The watershed area EPIC considers is usually small (≈ 1 ha) because soils and management effects are assumed to be spatially homogenous. The model can be used to simulate the effect of various types of management on the soil erosion/productivity relationship: drainage, irrigation, water yield, erosion control, fertilizer/lime applications, pest control, crop rotations, planting dates, tillage, crop residue management and furrow dike systems. EPIC is composed of the following submodels: hydrology, weather, erosion, nutrients, crop growth, soil temperature, tillage, economics, plant environment control and pesticide fate. The crop growth, tillage, plant environment control and pesticide fate submodels have land use variables.

2.1.1.1 Crop Growth Submodel

The crop growth submodel simulates the growth and yield of 22 common annual and perennial crops and can run 11 crops at a time within a crop rotation schedule. It is based on a daily heat unit accumulation concept. Annual crops grow from planting date to harvest or until accumulated heat units (HU) equal the potential heat units (PHU) for a given crop. Perennial crops maintain their root systems throughout the year, and start growing when the mean daily air temperature exceeds the base temperature of the crop (the crop may become dormant after a frost).

Crop yield is estimated via the harvest index concept: economic yield/above ground biomass. Optimal yields are reduced by various stress factors including water and pests (insects, weeds and plant diseases). EPIC has no real rangeland option as of yet; grasses are the only plant considered (trees and shrubs excluded). Grazing, however, can be approximated by adjusting the harvest index (i.e. 12 mm above ground) to simulate livestock ingestion. The primary use of EPIC under rangeland conditions, at this point in time, is to predict the long-term impacts of annual forage removal by livestock and the influence of range fertilization on soil erosion (Cooley et al., 1990).

The inputs needed for growth and yield simulation are from two sources: 'model-supplied' and 'user-specified'. The types of variables supplied by EPIC generally consist of specific crop physiological parameters, whose values are based on field experiments or data reported in the literature (Appendix 1). These crop datasets allow EPIC to operate with readily available inputs and make the model quite flexible with regard to input requirements.

The 'user-specified' land use variables for the crop growth submodel are: crop type, crop rotation, planting dates, seeding rates, crop category, PHU for the crop/region, price for yield, pest factor and seed cost (Table 1).

The user has the option to add new crops/crop varieties with different crop performance characteristics; however, this requires adjusting parameter values of the EPIC-supplied variables. The model developers strongly caution against crop parameter adjustment, except for research purposes. If adjustments have to be made, crop parameters can either be evaluated through field experiments, data reported in the literature or by interpolation between data for similar crops in the EPIC-supplied datasets (Williams et al., 1990).

2.1.1.2 Tillage Submodel

EPIC uses subroutines of the tillage submodel and its associated datafiles to simulate all management operations; for example, operations such as harvesting, grazing, burning, green manuring, harvesting for silage, swathing and others are simulated by adjusting two parameters in the tillage datasets called harvest index (HI; portion of above ground biomass removed from the crop) and harvest efficiency (HE; portion of harvested material removed from the field). As an example, if a crop like barley was harvested for grain, the HI is set to 0.4, but if barley was to be harvested for silage then the HI could be adjusted to 0.95. Similarly, the override option for the HI allows single crops to be harvested in two ways: oats could be harvested for grain with HI=0.4, and then the straw baled by using the appropriate HI override value (0.5-0.95). Grazing can be simulated by adjusting the HE to ≈ 0.1 , while an HE value of 0.0 would simulate the plowing under of cover crops or green manuring. The EPIC tillage submodel also functions in mixing nutrients and crop residues within the plow layer, simulating changes in bulk density; converting standing residue to flat residue; and simulating ridge height, ridge interval and surface roughness after each tillage operation.

Land use and management inputs for the tillage submodel are both model-supplied and 'user-specified'. EPIC-supplied tillage/machinery parameter datafiles contain legitimate values for all the major operations and types of equipment supported by EPIC (Appendix 1).

The 'user-specified' land use variables consist of the type of tillage operation (ID number -- informs EPIC of the type of operation), operation code (i.e. type of planting, type of harvesting,

etc.) and the date of each tillage operation (Table 1). The user must enter all operations associated with every crop in the rotation.

2.1.1.3 Plant Environment Control Submodel

Potential crop growth or yield is reduced by stressors: water, temperature, nutrient (N&P), aeration, root stress factors, aluminum (Al) toxicity and pest factors. The plant environment control submodel accounts for some of these as it incorporates irrigation, fertilization, liming and drainage subroutines (Appendix 1).

Both irrigation and N/P fertilization operate on either a manual or automatic basis. In terms of manual operations, the 'user-specified' land use variables for irrigation are: application rates, dates and cost of irrigation water (Table 1). Manual N and P fertilizer application require application rates, dates, costs, depth of placement and the fraction of fertilizer potentially applied at planting (if the management scheme involves fertilization at planting) (Table 1).

For automatic operations, irrigation is initiated when a certain moisture stress threshold for a plant is reached. 'User-specified' land use variables for automatic irrigation include plant physiological trigger levels, upper/lower limits of application, maximum volume applied per growing season, minimum time interval between applications, the cost of irrigation water and annual limits of application (Table 1). When automatic fertilization is selected, EPIC will fertilize when the plants encounter a certain level of nutrient stress. The user must specify the plant stress level to trigger fertilization, maximum annual N application for a crop, costs of N and P fertilizer, and the minimum number of days between applications (Table 1).

Liming occurs automatically to either neutralize Al toxicity or raise soil pH to normal levels. The user must input only the lime cost as the pH model can access most of the input data from other submodels (Table 1).

Simulation of drainage by subsurface drainage systems is achieved through a modification of the normal lateral underground flow of the site. The user must specify the following land use variables: the drainage area, the soil layer containing the drainage system and the time required for the drainage system to eliminate plant stress (Table 1).

2.1.1.4 Pesticide Fate Submodel

Subroutines from the Groundwater Loading Effects of Agricultural Systems (GLEAM) model, which account for the pesticide fate in soil and groundwater, have been incorporated into EPIC (Leonard et al., 1987; Sabbagh et al., 1991). An EPIC-supplied database contains chemical properties for numerous commercially available pesticides.

The "user-specified" land use variables for the pesticide submodel are: tillage implement that carries a pesticide operation code, application date, application rate, pest control factor and pesticide identification number (Table 1).

Table 1. "User-specified" land use variables for the EPIC model

Table 1. "User-specified" land use variables for the EPIC model. EPIC VARIABLE DESCRIPTION	VARIABLE NAME
CROP GROWTH SUBMODEL	
Crop name (up to 4 characters-EPIC)	CPNM
Crop category number (1-WSAL; 2-CSAL; 3-PL; 4-WSA; 5-CSA; 6-P; 7-T ^a)	IDC
Crop rotation duration (yr)	NRO
Seeding rate (kg ha-1)	SDW
Crop residue (t ha- 3)	RSD
Seed cost (\$ kg-1)	COSD
Price for yield (\$ t-l)	PRY
Potential heat units/GDD for growing season (crop/region specific)	PHU1
Pest factor (insects, weeds and disease; fraction of yield remaining after damage)	PST
TILLAGE SUBMODEL	
Tillage operation ID No.	LT
Month of tillage operation	MT
Day of month of tillage	IT
Crop ID No. (used only at planting)	KDC
Operation/Implement effect code (planter, drill cultivator etc.)	IHC
PLANT ENVIRONMENTAL CONTROL SUBMODEL - IRRIGATION	
Irrigation code	IRR
Minimum application interval for auto. irrigation (days)	IRI
Water stress factor to trigger automatic irrigation	BIR
Min. single application vol. allowed for auto.(mm)	ARMN1
Max. single application vol. allowed for auto. (mm)	ARMX1
Irrigation runoff ratio	EFI
Maximum annual irrigation volume allowed for each crop (mm)	VIMX1
Month of irrigation application	MO
Day of month of irrigation application	IDA
Irrigation water cost (\$ m-3)	COIR
Irrigation volume (mm)	VIRR
PLANT ENVIRONMENTAL CONTROL SUBMODEL - FERTILIZERS/AMENDMENTS	
Liming code --(0 applies lime automatically; 1 applies no lime)	LM
N stress factor to trigger automatic fertilizer	BFT
Fraction of maximum N fertilizer potentially applied at planting	FNP1
Maximum annual N fertilizer application for a crop (kg ha-1)	FMX1
Month of fertilizer application	MO
Day of month of fertilizer application	IDA
Nitrogen fertilizer applied	FN (kg ha-1)
Phosphorus fertilizer applied	FP (kg ha-1)
Depth of fertilizer placement (mm)	FDP
Nitrogen fertilizer cost (\$ kg-1)	CON
Phosphorus fertilizer cost (\$ kg-1)	COP
Lime cost (\$ t-1)	COL

Table 1. “User-specified” land use variables for the EPIC model.	VARIABLE NAME
EPIC VARIABLE DESCRIPTION	
PLANT ENVIRONMENTAL CONTROL SUBMODEL - DRAINAGE	
Drainage area (ha)	DA
Drainage code (0- no drainage; 1-10 for soil layer with drainage system)	IDR
Time required for drainage system to eliminate plant stress	DRT
Pesticide Fate Submodel	
Pesticide cost (\$ ha-1)	COPC
Herbicide cost (\$ ha-1)	COHC
Tillage implement that carries a pesticide operation code	*
Pesticide application date	*
Pesticide application rate (kg ha-1)	*
Pesticide ID number	*
SUPPORT PRACTICES (P factor)	
PEC Value (erosion control practice factor)	PEC

a - WSAL (warm season annual legume); CSAL (cold season annual legume); PL (perennial legume); WSA (warm season annual); CSA (cold season annual); P (perennial); T (trees).

* - The presence of an asterisk in the variable name column means the exact name of the variable was not clearly identified in the model documentation.

2.1.2 Water Erosion Prediction Project (WEPP)

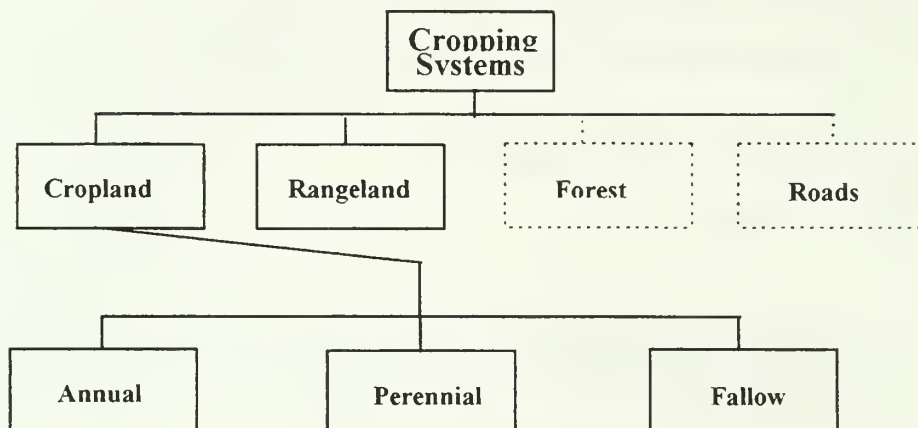
The USDA’s Water Erosion Prediction Project (WEPP) has produced a process-based model to continuously simulate erosion and deposition on both simple and complex hillslopes (Flanagan et al., 1994; Version 94.3). As in EPIC, the continuous simulation (daily time step) of critical parameters such as canopy height, soil cover factors, soil roughness, soil moisture and other related variables, eliminates the need for the user to estimate the distribution of these crucial variables over time. The crop residue decomposition submodel accompanying WEPP is based on the RESMAN (RESidue MANagement) model (Stott and Rogers 1990). As 'user-specified' land use variables for RESMAN are obtained from other submodels in WEPP, it is not discussed in this paper.

Five data input files must be constructed prior to simulation: climate, slope, soil, cropping systems/management and irrigation. The latter 2 input files are associated with the crop growth submodel and management submodel and are presented accordingly. The 'user-specified' land use variables for these input files and the irrigation input file are discussed below.

2.1.2.1 Crop Growth Submodel

The WEPP crop growth submodel simulates the growth of plants on 2 broad types of land use, those being cropland and rangeland. Future model developments will include forests and roads as land use options (Figure 1). It is based on the same principles as in the EPIC crop growth model (Williams et al., 1989), where accumulated heat units (HU) and the harvest index (HI) are used to account for biomass production and harvested yield, respectively. Of the models studied in this paper, WEPP explicitly models rangeland conditions (grass, trees and shrubs are considered).

Figure 1. Cropping system options in WEPP.



Like EPIC, input variables are from two sources: those stored in WEPP-supplied crop and rangeland databases (for major crops grown in the U.S.) and those specified by the user at the time of simulation (Appendix 2). The model-supplied variables generally consist of specific crop physiological parameters derived from the literature and research. The 'user-specified' land use variables are organized by cropland and rangeland land use types.

The cropland land use type is subdivided into annual, perennial and fallow cropping types (Figure 1). Prior to the selection of the cropping type, the user must decide on the length of rotation and the number of crops grown annually (Table 2). The following 'user-specified' land use variables are entered for each cropping type: crop name, planting date/start of fallow period, row width, number of rows, in-row plant spacing, crop grown and amount of residue left prior to the start of simulation, growing degree days for the specific crop and/or region, date for perennial crop to reach senescence/end of a fallow period, cutting height, optimal yield under no stress conditions and harvest units.

In the rangeland land use type, the user must specify the following variables: frost-free period for the region; average number of herbaceous plants, shrubs and trees along a 100 m transect; average shrub, tree and herbaceous plant height; initial fraction of live/dead roots; initial standing woody biomass (trees) and above-ground biomass; fraction of biomass produced and date of peak standing crop during 1st and 2nd growing season; and the maximum potential standing live above ground biomass (Table 2).

2.1.2.2 Management Submodel

This submodel contains input files for management operations such as tillage, drainage, plant management and residue management options. The types of management operations available differ for the various cropping types (i.e., annual, perennial and fallow). With the annual cropping type, management options include tillage, drainage, plant and residue management. The perennial

cropping type uses the tillage, drainage and plant management, with no residue management option. For the fallow cropping type, options include tillage, drainage, plant management (herbicide variables), residue management and a previous crop function (to account for residual cropping effects). The rangeland land use type supports grazing, burning and herbicide options. The 'user-specified' land use variables for each management operation follow.

2.1.2.2.1 Tillage Operations

Tillage operations contain either 'model-supplied' or 'user-specified' land use variables. Parameters for over 80 different implements are stored in the model-supplied databases (Appendix 2). The 'user-specified' land use variables are tillage type (primary or secondary); tillage date(s); operation code (planter, drill, cultivator, etc.) and cultivator position (Table 2).

2.1.2.2.2 Drainage Operations

Drainage of the soil profile through subsurface tiling can be simulated. The user first selects the drainage option and then enters the following "user-specified" land use variables: depth to tile drain, drainage coefficient, drain tile diameter and drain tile spacing (Table 2).

2.1.2.2.3 Plant Management

Options under this management operation include grazing, cutting/harvesting, herbicide and silage. Model-supplied databases are not available for these options, therefore the user must select the option and then define how it will proceed.

The grazing option has variables common to both the perennial cropping type and the rangeland land use type. These 'user-specified' land use variables are pasture size, number of grazing sequences per year; start and finish grazing dates; number of grazing animals and average body weight of a grazing animal (Table 2). For the perennial cropping type, the user must enter digestibility of a perennial crop. With the rangeland land use type, the user must enter fraction of forage available for consumption, maximum and minimum digestibility of forage, mean amount of supplemental feed, supplemental feed start and finish dates.

Within the cutting/harvest operation, variables common to both the annual and perennial cropping type are: harvest dates, fraction of standing residue mass cut, fraction of vegetative biomass converted to standing residue mass at harvest, fraction of vegetative or flat residue mass removed from the field and dates of silage removal (Table 2). 'User-specified' land use variables specific to the perennial cropping type are vegetative dry matter of a perennial crop not harvested or grazed, first cutting of a perennial crop, and number of cuttings of a perennial.

Variables for the herbicide operations differ according to land use type. For the cropland land use type, the user must specify the date of herbicide application (Table 2). The rangeland land use type requires the user to specify: type of herbicide (soil or foliar); date of herbicide application; fraction decrease in live aboveground biomass; fraction change in evergreen biomass; fraction change in the ratio of above ground to below ground biomass; change in forage accessibility and decomposition of woody biomass due to herbicides.

The silage operation requires the user to input: the fraction of standing residue mass mechanically cut and the date of silage removal (Table 2).

2.1.2.2.4 Residue Management

Model-supplied databases are not available for residue operations so the user must describe how the operation proceeds. The options for residue operations include shredding, residue harvesting and burning. The shredding option requires the user to specify the dates of shredding and the fraction of standing residue mass mechanically shredded (Table 2). The residue harvesting option requires the user to input the fraction of residue cut; fraction of residue removed from the field and the dates of those operations.

Variables for the burning option differ according to land use type. For the cropland land use type, the 'user-specified' land use variables are: the fraction of standing residue mass lost by burning and the date of burning (Table 2). For the rangeland land use type the user specifies fractional increase in forage accessibility after burning, fractional change in standing dead biomass, fractional increase in AG biomass production, fractional change in evergreen biomass, date of burning residue date of burning and the fractional decrease in litter and organic residue from burning.

2.1.2.3 Irrigation Submodel

In the hillslope profile application of WEPP, both stationary sprinkler and furrow irrigation are available. This paper will confine the documentation of land use and management variables to stationary sprinkler irrigation, because furrow irrigation is not widely used in Canada. Model-supplied databases for irrigation are unavailable so the user must define all irrigation periods. 'User-specified' land use variables are associated with the type of scheduling option, either depletion level or fixed date. Shared variables are application rate of the system; the sprinkler nozzle impact energy factor and the minimum and maximum irrigation depths (Table 2).

For the depletion level option, the variables are the ratio of application depth to application water needed to fill the profile to field capacity (for maximum rooting depth); the depletion ratio at which irrigation will occur and the approximate dates for the beginning and end of an irrigation period.

Fixed-date scheduling requires the user to specify the dates of irrigation and the depth of application of irrigation water.

Table 2. “User-specified” land use variables for the WEPP model.

WEPP VARIABLE DESCRIPTION	VARIABLE NAME
CROP GROWTH SUBMODEL	
Cropland	
Land type use	IPLANT
Cropping type (1-annual crop, 2-perennial or 3-fallow)	IMNGMT
Number of years in the rotation	NYEARS
Number of crops grown annually	NYCROP
Crop name	*
Crop ID No.	RESMAN
Date of planting/start of fallow period	JDPLT
Row width (m)	RW
Number of rows	NUMOF
In-row plant spacing (m)	PLTSP
Crop residue (t ha-3)	RESMAN
Crop grown prior to the start of the simulation	IRES
Potential heat units/GDD for growing season (crop/region specific)	GDDMAX
Approx. date to reach senescence (perennial crop)/end of a fallow period	JDHARV
Perennial crop growth stops (Date)	JDSTOP
Post cutting harvest height (m)	CUTHGT
Optimal yield under no-stress conditions (kg m-2)	YLD
Pounds of grain per bushel of grain	Y4
Harvest units (bu a-1, kg ha-1, t a-1, etc.)	CRUNIT
RANGELAND (Native Range)	
Frost free period	FFP
Average no. of herbaceous plants along a 100 m transect	GPOP
Proportion of biomass produced during 1st growing season	CF1
Proportion of biomass produced during 2nd growing season	CF2
Max. herbaceous plant height (m)	HMAX
Average shrub height (m)	SHGT
Average no. of shrubs along a 100m transect	SPOP
Average tree height (m)	THGT
Average no. of trees along a 100 m transect	TPOP
Initial standing non-decomposable woody biomass (trees)	WOOD
Initial standing AG biomass (kg m-2)	OLDPLT
Max. potential standing live AG biomass (kg m-2)	PLIVE
Date of peak standing crop(1st growing season)	PSCDAY
Date of peak standing crop(2nd growing season)	SCDAY2
Initial fraction of live and dead roots	ROOTF
DECOMPOSITION (Crop specific parameters)	
Fragile /nonfragile operation MFO values (RESMAN-residue management model)	MFOCOD
Residue mgmt. option (1-herbicide, 2-burn, 3-silage, 4-shred/cut, 5-removal, 6-none)	RESMGT
MANAGEMENT SUBMODEL	
TILLAGE OPERATIONS	
Tillage type (primary or secondary)	TYPTIL
Date of tillage	MDATE

Table 2. “User-specified” land use variables for the WEPP model.	VARIABLE
WEPP VARIABLE DESCRIPTION	NAME
Operation/Implement effect code (planter, drill cultivator etc.)	PCODE
Cultivator position	CLTPOS
Contouring - ridge height (m)	RDGHGT
Contouring - slope steepness (m/m)	CNTSIP
Contouring - row length (m)	ROWLEN
Contouring - row spacing (m)	ROWSPC
DRAINAGE OPERATIONS	
Depth to tile drain (m)	DDRAIN
Drainage coefficient (m/day)	DRAINC
Drain tile diameter (m)	DRDIAM
Drain tile spacing (m)	SDRAIN
PLANT MANAGEMENT	
GRAZING	
Grazing pasture size (m2; annual, perennial and native range)	AREA
Fraction of forage available for consumption (native range)	ACCESS
No. of grazing sequences per year (annual, perennial and native range)	JGRAZ
Date that grazing begins (annual, perennial and native range)	GDAY
Date that grazing ends (annual, perennial and native range)	GEND
No. of grazing animals (annual, perennial and native range)	ANIMAL
Digestibility of a perennial crop	DIGEST
Maximum digestibility of forage (native range)	DIGMAX
Minimum digestibility of forage (native range)	DIGMIN
Date supplemental feed starts (native range)	SEND
Date supplemental feed ends (native range)	SSDAY
Average amount of supplement feed per day (kg animal-1;native range)	SUPPMT
Average body weight of a grazing animal (annual, perennial and native range)	BODYWT
CUTTING/HARVESTING	
Harvest date	JDHARV
Date cutting/harvest for perennial crop	CUTDAY
Number of cuttings of a perennial crop	NCUT
First cutting of perennial crop	ISTART
Date of silage removal	JDSLGE
Vegetative D.M. of a perennial crop not harvested/grazed (kg m-2)	TOTHAV
HERBICIDE	
Soil/foliar herbicide (native range)	ACTIVE
Fraction of change in evergreen biomass after herbicide (native range)	HERB
Date of herbicide applications (native range)	IHDATE
Date of herbicide application (annual,perennial, fallow)	JDHERB
Fraction decrease in live AG biomass from herbicide (native range)	DLEAF
Fraction change in AG/BG biomass (native range)	REGROW
Change in forage accessibility (native range)	UPDATE
Decomposition of woody biomass due to herbicides (native range)	WOODY
RESIDUE MANAGEMENT	
SHREDDING	
Fraction of standing residue mass mechanically shredded/cut	FRCUT
Date of residue shredding/cutting	JDCUT
RESIDUE HARVESTING	
Fraction of veg./flat residue mass removed from the field	FRMOVE

WEPP VARIABLE DESCRIPTION	VARIABLE NAME
Conversion of veg. biomass to standing res. mass at harvest	PARTCF
Date of residue removal	JDMOVE
BURNING	
Fractional increase in forage accessibility after burning (native range)	ALTER
Fraction of change in standing dead biomass from burning (native range)	BURNED
Change in potential AG biomass production from burning (native range)	CHANGE
Fraction of standing residue mass lost by burning (annual, perennial, fallow)	FBRNAG
Fraction of flat residue mass lost by burning (annual, perennial, fallow)	FBRNOG
Fraction of change in evergreen biomass after burning (native range)	HURT
Date of burning residue (annual, perennial, fallow)	JDBURN
Date of burning rangeland (native range)	JFDATE
Fraction of reduction in litter and organic residue form burning (native range)	REDUCE
IRRIGATION SUBMODEL	
Irrigation code	IRSYST
Irrigation scheduling option	IRTYPE
Minimum irrigation depth (m)	IRDMIN
Maximum irrigation depth (m)	IRDMAX
Sprinkler nozzle impact energy factor	NOZZLE
Depletion Level Irrigation	
Flag identifying the OFE's for which the remaining elements of the line apply	OFEFLG
Application rate of the irrigation system (m sec-1)	IRRATE
Ratio of appln. depth to water needed to fill profile to FC	APRATI
Date at beginning of period for which irrigation might occur	IRBEG
Year of beginning of period during which irrigation might occur (year)	YRBEG
Date at end of period during which irrigation might occur	IREND
Year of end of period during which irrigation might occur (year)	YREND
Depletion ratio at which irrigation will occur	DEPLEV
Fixed Date Irrigation	
Flag identifying the OFE for which the remaining elements of the line apply	OFEFLG
Application rate of the system (m sec-1)	IRRATE
Irrigation depth (m)	IRAMT
Date of an irrigation event (Julian date)	IRDAY
Year of the irrigation event (Year)	IRYR

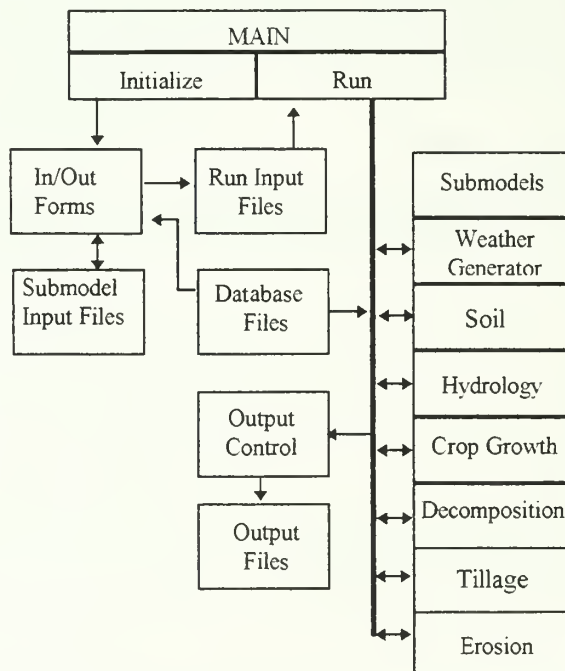
* - The presence of an asterix in the variable name column indicates that the exact variable name was not clearly identified in the model documentation.

2.1.3 Wind Erosion Research Model (WERM) and Wind Erosion Prediction (WEPS)

Development of the new wind erosion prediction technology involves two steps: (i) the development of a wind erosion research model (WERM; Version 92.10) which will be validated and used as a reference standard for wind erosion prediction and (ii) reorganize subroutines, expand databases and install a user-friendly interface to produce the final wind erosion prediction system package (WEPS) for the average user (Hagen 1991). The end result will be a process-based, continuous, daily time-step model which will simulate erosion based on fundamental wind erosion mechanics processes.

The WERM model is organized in a modular fashion and consists of: a main coordinating program; a user-interface input system; 7 submodels (with their associated databases); and an output control section (Figure 5). The WERM model operates in the following fashion. Run files, which contain either model-supplied or 'user-specified' variables, supply data to the 7 submodels. Five of these sub-models, the crop growth, decomposition, soil, hydrology and tillage, predict daily soil/vegetative cover variables. These submodels respond, in turn, to inputs generated by a weather submodel. The erosion submodel computes soil loss/deposition and revised estimates of soil/plant variable values if wind speeds exceed a threshold value. The submodels with 'user-specified' land use variables are crop growth and decomposition. The tillage submodel is under development and will not be discussed in this paper.

Figure 2. Module organization of WERM with associated files, databases and submodels (Hagen 1991).



2.1.3.1 Crop Growth Submodel

The crop growth submodel is fashioned after the EPIC crop growth model (Williams et al., 1989). Deviations from the EPIC model include modifications to the plant height function (WERM's Crop submodel uses a sigmoid function similar to the leaf area growth equation), stem area index (to assemble leaf and stem area distributions by height) and nitrogen uptake processes. These changes give a more accurate estimation of daily plant height, an essential variable to the calculation of the leaf and stem area distribution by height variables. These latter 2 variables are required for estimating wind speed profiles within plant canopies (Retta and Armbrust 1992).

Variables for growth simulation of each crop are from two sources: model-supplied and 'user-specified'. The model-supplied variables, with the exception of those variables related to nutrient uptake and stem/leaf area distribution by height, were borrowed from the EPIC database (Appendix 3). Thus, the WERM-supplied CROP database will contain specific crop parameters which include growth, leaf-stem relationships, decomposition and harvest information for common crops grown in the US.

The 'user-specified' land use variables are crop, crop seeding density, crop seeding location in relation to ridge, in-row plant spacing and the PHU for the specific crop/region (Table 3).

2.1.3.2 Decomposition Submodel

This sub-model is based on crop C:N ratios, temperature and moisture and follows first order rate kinetics (Steiner et al., 1992). The decomposition subroutines compute the decrease in biomass residues in the standing, flat, buried and root categories, due to microbial decomposition. WERM-supplied databases provide most of the inputs for specific crops (Appendix 1). The user specifies the age of residues on the field prior to simulation, the crop species of the most recent harvest and the species of the penultimate harvest (Table 3).

Table 3. "User-specified" land use variables for the WERM model.

Table 3. "User-specified" land use variables for the WERM model.	VARIABLE NAME
WERM VARIABLE DESCRIPTION	
CROP GROWTH SUBMODEL	
Crop name	NAM
Crop identification No.	ID
Crop seeding density (p m ⁻²)	POP
Crop seeding location in relation to ridge	RG
In-row plant spacing (m)	ROW
Plant population density (p m ⁻²)	PPD
Potential heat units/GDD* for growing season (crop/region specific)	PHU
DECOMPOSITION SUBMODEL	
Age of residue	IAGE
Species of most recent harvest	IDRES
Species of the penultimate harvest	IDRESO

* GDD - growing degree days

2.1.4 Century

Century (Version 4, 1993) is a process-based soil organic matter (SOM) model that simulates, on a monthly time step, the long-term cycling of C and N in both cropland and rangeland in response to climatic gradients. While the model's primary emphasis is on SOM transformations, it also simulates plant production, soil nutrient dynamics (N, P and S), and soil water dynamics (Parton et al., 1987). The model can be used to simulate the effects of management and soil/plant properties on SOM and productivity over periods of 50 years or more. Since the debut of the model in the Great Plains publication (Parton et al., 1987), Century has been used to model SOM dynamics in several long-term plot studies (Paustian et al., 1992; Monreal et al., 1992; Parton and Rasmussen 1994).

During a simulation run, the model calls on 9 data-input files that are coordinated by a scheduling file (Event 100). The user adjusts variables in the scheduling file to correspond to local agricultural conditions. The Site 100 input file contains the site-specific variables (climate, soil properties and initial amounts of soil organic matter, in specific C, N, P and S concentrations), values for which need to be assigned to adequately describe the location being modeled. If the scheduling and data input files do not contain the appropriate information, considerable resources are required to construct suitable data input files. The following discussion assumes that the 8 data input files, crop, cultivation, fertilization, harvest, organic amendments, burning, grazing and irrigation, have appropriate information.

2.1.4.1 Crop Input File

The crop.100 file contains variables that are used to simulate the monthly dynamics of C, N, P and S in the live and dead above and below ground plant biomass, and structural and metabolic surface/soil residue fractions. This file contains model-supplied variables that represent the physiological and plant nutrient partitioning functions associated with each general class of crop (Appendix 4).

The variables the user must specify, if the crops are in the Century-supplied input files, are crop type(s) and the number of years in the rotation (Table 4). Some model-supplied variables can become user-specified variables in the cases where crops are not included in the Century-supplied database (i.e. the user will have to supply new values for required crop parameters (see Appendix 4) or modify pre-existing crop.100 files to fit the crop being modeled. Variables on planting operations are included in the cult.100 (cultivation input) file.

2.1.4.2 Cultivation Input File

The cult.100 file contains both model-supplied and 'user-specified' land use variables to represent 7 cultivation options: plowing, sweep, cultivator, rodweeder, drill, no-till drill and an herbicide application (Appendix 4). Model-supplied variables have been developed for some Canadian conditions (Monreal et al., 1992). If these preset options apply, the user specifies the type of operation (operation effect code), the month of the cultivation option and the number of cultivations (Table 4).

2.1.4.3 Fertilization Input File

The fert.100 file has both model-supplied and 'user-specified' land use variables for automatic and manual fertilization of N, P and S. For the automatic fertilization option, there are 6 model-supplied options varying in the amount of fertilizer required to sustain some fraction of maximum C production or level of plant nutrient concentration (Appendix 4). The user specifies the code for the type of automatic fertilization and the month the fertilizer application will take place (Table 4). The manual fertilization mode requires the user to select the code (fertilizer effect code) for the type/amount of N, P and S applied and the month of application. If the model-supplied data-input files do not represent the user's fertilization scheme, then the user can alter values of variables in pre-existing fert.100 files to adjust the amounts of N, P and S added to better reflect the system being simulated.

2.1.4.4 Harvest Input File

The model-supplied harv.100 files for harvest operations indicate what parts of the crop are to be removed from the field. The user must specify the effect code for the type of harvest operation and the month when it takes place (Table 4).

2.1.4.5 Organic Amendments Input File

The omad.100 file defines (to Century) the quality and quantity of organic C in an amendment. The model-supplied omad.100 files contain preset values for all the variables describing different types of OM additions (Appendix 4). The user needs to specify the appropriate OM amendment effect code that represents the type of amendment (straw, manure etc.) and the month of application (Table 4).

2.1.4.6 Burning Input File

The model-supplied burn.100 files for burn operations contain values for all the variables describing a fire event. The 'user-specified' land use variables are the fire effect code (representing the appropriate burn.100 file) and the month of the fire event (Table 4).

2.1.4.7 Grazing Input File

The graz.100 input files contain variables that define a grazing event. The user must specify the code for the type of grazing effect (a particular graz.100 file) and the month in which grazing occurred (Table 4).

2.1.4.8 Irrigation Input File

Both automatic and manual irrigation are available in the irrig.100 file. The model-supplied variables describing automatic irrigation vary the timing of an application: i.e., the fraction of AWHC below which irrigation will occur. Irrigation will continue until a specified amount of

water is applied or field capacity is reached. The user must specify the automatic type code (particular irrig.100 file) and the month in which irrigation is likely to occur (Table 4).

The manual mode requires the user to specify the code for the proper amount of water applied and the month in which the user would like irrigation to occur. If the user has to construct a unique parameter file (irrig.100 file) for manual irrigation, altering the amounts of water applied in pre-existing files would suffice.

Table 4. "User-specified" land use variables for the Century model.

Table 4. "User-specified" land use variables for the Century model.	VARIABLE NAME
CENTURY VARIABLE DESCRIPTION	
CROP INPUT FILE	
Number of years in the rotation	*
Crop name	*
Most recently harvested crop type	*
CULTIVATION INPUT FILE	
Month of tillage operation	*
List of months when cultivation takes place (number of cultivations)	CULTMO
Operation/Implement effect code (planter, drill cultivator etc.)	*
FERTILIZER INPUT FILE	
Fertilization effect code	*
Month of fertilizer application	*
HARVEST INPUT FILE	
Month of harvest operation	*
Fraction of veg./flat residue mass removed from the field	RMVSTR
Harvest effect code	*
ORGANIC AMENDMENTS INPUT FILE	
Month of organic matter addition	*
OM addition effect code	*
BURNING INPUT FILE	
Month of fire event	*
Fire effect code	*
GRAZING INPUT FILE	
Month of grazing event	*
Grazing effect code	*
IRRIGATION INPUT FILE	
Month of irrigation application	*
Irrigation event code	*

* - An asterix indicates the exact variable name was unavailable.

2.1.5 SEEP/W and CTRANS/W (marketed by Geo-Slope, Inc. of Calgary, Alta)

Both SEEP/W (seepage model) and CTRANS/W (contaminant transport model) are finite element models (marketed by Geo-Slope Inc. of Calgary, AB). SEEPW simulates movement and pore water pressure distribution within porous materials such as soil and rock and can model both simple and highly complex seepage problems. CTRANS/W simulates the movement of contaminants through porous materials such as soil and rock. The two models were designed to work in conjunction, thus the seepage patterns determined by SEEP/W function as inputs for CTRANS/W. These models have been used to estimate salinization on agricultural land. However, there are no 'user-specified' land use variables and these models are not discussed further in this paper.

2.2 Equation-Based Models

Equation-based models are used in the study of water and wind erosion. The models considered in this subsection include the Revised Universal Soil Loss Equation (RUSLE; Version 1.02, May 1993) and the Wind Erosion Equation/Revised Wind Erosion Equation (WEQ/RWEQ). The 'user-specified' land use variables associated with these models are presented under the appropriate submodels and routines.

2.2.1 Revised Universal Soil Loss Equation (RUSLE)

RUSLE is a revision and update of the original USLE equation developed in the 1960's where,

$$A = R * K * L * S * C * P,$$

and A= average annual soil loss from sheet/rill erosion caused by rainfall and associated overland flow (tons $\text{ac}^{-1} \text{y}^{-1}$); R= factor for climatic erosivity; K= the factor for soil erodibility measured under standard conditions; L= the factor for slope length; S= the factor for slope steepness; C= factor for cover-management and P= the factor for support practices (Wischmeier and Smith, 1978). Unlike process- based models where erosion processes are considered individually, RUSLE has a "lumped-equation structure that does not explicitly consider runoff or the individual processes of detachment, transport and deposition" (Yoder et al., 1992). Each of the factor relationships has either been updated with recent data, or new ones derived based on modern erosion theory and data. The C and P factors have 'user-specified' land use variables.

2.2.1.1 C (Cover) Factor

The C factor represents the average soil loss under a given crop cover as a proportion of that on bare, unprotected soil (Tajek and Coote 1993). The C factor considers the effects of plants, soil cover, soil biomass, and soil disturbing activities on water erosion. The major influences on C, termed sub-factors, are: crop canopy, surface cover, surface roughness, prior land use and antecedent soil moisture. The numerical value of each of these sub-factors is the ratio of soil loss

with the sub-factor to the corresponding loss without it. The C factor is the product of all the major sub-factors.

To form a complete cover-management scenario for the run, the user accesses model-supplied crop and operations databases. The user can customize existing crops by altering certain parameters unique to the region of interest, or the user can build specific crop datasets by entering new values for all the variables separately. Further, the operations database contains information on operations which can affect soil and cover conditions; the user can also customize these files to suit his/her needs.

2.2.1.1.1 Crop Database

This file contains variables that describe the growth and residue characteristics of specific crops and other vegetation (Appendix 5). The values supplied in the model-supplied crop database are considered as typical values and should be used as guidelines for specific crop variables. In general, the user can alter the values so that the results reflect the specific situation. Data for specific crops/plant communities are sorted into database sets. The user must decide how many sets are needed to show differences caused by region, variety or crop stress. Knowledge of the sensitivity of the outputs to differing inputs is essential in this task. For each crop in the rotation all landuse/management inputs are entered at 15 day intervals after planting or by initiation of regrowth (rangelands), until the harvest date is reached.

The 'user-specified' land use variables, if the crop(s) exist in the crop database, are: crops in the rotation (cropping sequence); length of the rotation; number of crop database sets; crop ID; crop category-cultivated crops or permanent pasture/rangeland and whether the senescence option applies. Further, if residue additions occur at harvest, the user must enter the amounts. If any other residue additions occur the user must enter the amount and the percent cover they provide (Table 5).

2.2.1.1.2 Operations Database

This file contains variables that describe how field operations affect the soil, crop, residues and ultimately erosion rates for a given field (Appendix 5). Management operations disturb the soil, begin vegetative regrowth, kill the crop, add residue to the surface, or incorporate residue and may even affect the phenology of the crop. Once again, data are separated into database sets, each one representing a specific operation. The user must determine how many sets are required to adequately reflect all the differences in the type, speed and effect of implements used. Like EPIC, this section is used to mimic all field operations including planting, harvesting, baling, herbicide/fertilizer applications, burning, etc.

The 'user-specified' land use variables, if the operation exists in the operation database are: the operation type (planting, harvesting, etc.); the date of the operation; and the appropriate effect(s) of that operation (9 variables are used to describe the effect of every operation) (Table 5). Further, if residue removal operations like baling or burning are used, the user must input the fraction of residue removed. If any organic amendments are applied, the user must specify the % cover it provides as well as the decay rate constant for the type of amendment.

2.2.1.2 P (Support Practices) Factor

RUSLE uses the P factor value for conservation planning to compute soil loss, and also calculates a value for sediment yield P factor; this can be manually entered in the RUSLE spreadsheet to compute sediment yield. The P factor does not include management practices such as cropping rotations and conservation tillage that contribute to erosion control (these are included in C). Support practices that the user must consider are contour tillage; stripcropping on the contour, and terrace systems.

To compute P values for contouring and stripcropping, the user selects the cover-management condition that best reflects the runoff index value in a 3 month period when rainfall and runoff are most erosive and the soil is most susceptible to erosion (Yoder et al., 1992). The runoff index value applies to either cropland or rangeland (Table 5).

Contouring is the practice of using ridges and furrows left by a tillage operation to redirect runoff from going straight down hill to a path around the hillslope. The user must input the following variables to compute a P factor for contouring: ridge height; furrow grade; slope steepness and slope length.

Stripcropping involves alternating strips of clean/nearly clean-tilled crops with strips of close growing vegetation (legumes or grasses). The equation is based on the assumption that strips are of equal width and that the crops are rotated through each strip during the rotation schedule. The user must specify: the number of years to complete the rotation cycle; for each year, the location of the lower edge of each strip and the cover-management conditions for each strip (for the 3 month period when rainfall/runoff are most erosive and soil is most susceptible); strip width; slope steepness and maximum slope length.

Terraces affect sheet and rill erosion in two ways: by reducing slope length (represented in L factor) and by causing deposition in either the terrace channel (grades<1%) or in the impoundment associated with a tile outlet terrace. 'User-specified' land use variables include the terrace grade and the terrace spacing.

Table 5. "User-specified" land use variables for the RUSLE model.

Table 5. "User-specified" land use variables for the RUSLE model.	VARIABLE NAME
RUSLE VARIABLE DESCRIPTION	
CROP DATABASE	
Number of years in the rotation	*
Number of CROP database sets	*
Crop name	*
Crop category (cultivated vs. pasture/rangeland)	*
Supplementary residue additions (lb. ac-1)	*
Supplementary residue additions (% cover)	*
Residue added at harvest of a crop (lb.ac-1)	*
OPERATIONS DATABASE	
Operation type	*
Date of tillage	*
Fraction residue removed through a removal operation (burning, baling, etc.)	*

Table 5. "User-specified" land use variables for the RUSLE model.	VARIABLE
RUSLE VARIABLE DESCRIPTION	NAME
Operation effect:(7 numeric values are used to describe the tillage operation)	*
SUPPORT PRACTICES (P factor)	
Runoff index value	*
Contouring - ridge height	*
Contouring - furrow grade	*
Contouring - slope steepness	*
Contouring - slope length	*
Stripcropping - strip width as function of slope length	*
Stripcropping - slope steepness	*
Stripcropping - location of lower edge of each strip; cover-mgmt for each strip	*
Terracing - terrace grade	*
Terracing - spacing	*

* - the presence of an asterisk in the variable name column indicates the exact name of the variable was unavailable.

2.2.2 Wind Erosion Equation (WEQ) and Revised Wind Erosion Equation (RWEQ)

The WEQ (WEE) was designed for two purposes (1) to determine if a particular field is adequately protected from wind erosion and (2) to assess the effectiveness of various management strategies in erosion minimization (Woodruff and Siddoway, 1965). The RWEQ (version 4.02), was unavailable at the time of press, and therefore is not discussed here.

The WEQ equation consists of the following factors:

$$E = f(I', K', C', L', V)$$

where E = predicted soil loss (tons/acre/year); I' = soil erodibility factor (tons/acre/year) determined by amount of aggregates > 0.84 mm in diameter; K' = soil ridge roughness factor; expressed in terms of the height of standard ridge; C'=climatic factor; L' = field width (max. unsheltered distance across the field along the direction of the prevailing wind) and V = vegetative cover factor expressed in relation to an equivalent amount of flat small grain stubble.

The relationships between the factors are complicated because the factors have numerous subfactors and interactions with other factors. Thus it is not merely a matter of multiplying the derived factors together to arrive at an estimate of soil erosion; the user must consult considerable supporting materials such as charts, nomographs, slide rulers and computer programs. The number of land use and management variables required for simulations are relatively few and are used to derive the K and V factors.

2.2.2.1 K (Soil Ridge Roughness) Factor

Kr is subfactor of K and provides a measure of soil surface roughness other than that caused by clods or vegetation. It is modified by management schemes that alter ridge height and ridge spacing. Specialized tables are used to assess Kr in the field (Skidmore 1983). In order to derive Kr, the user needs to determine, in the downwind direction, the measured field ridge height and the ridge spacing (Table 6).

2.2.2.2 V (Vegetation) Factor

The protection offered by this factor is a function of the dry matter it contains, the texture of the residue/living matter, whether the vegetation is living or dead and whether the residue is standing or flat. The original work for the vegetation factor was done on flattened wheat straw (Woodruff and Siddoway, 1965), and that has now become the standard for the V factor determination.

The user must determine the dry weights and types of growing crops/residues (R') and the percent residue cover on a field to calculate V (Table 6). R' is then converted to the equivalent quantity of flat wheat straw (V) by specialized charts (Skidmore 1983).

Table 6. "User-specified" land use variables for the WEQ model.

WEQ VARIABLE DESCRIPTION	VARIABLE NAME
V FACTOR	
Crop name	*
Dry matter mass of crop	*
Type of crop residue	*
Supplementary residue additions (lb. ac-1)	*
Percent cover of residue	*
K FACTOR	
Ridge height	*
Ridge spacing	*

* - An asterisk in the variable name column indicates that variable names are unavailable.

3.0 Summary of “User-Specified” Land Use Variables

This section takes the individual model “user-specified” land use inventory, which was detailed for each degradation model in the previous section, and summarizes the variables into a limited number of categories. Categorizing and summarizing the land use variables reduces duplication in the inventory; encourages correlation or integration between the models, especially within a regional context; improves the consistency in reporting of results and aids in the development of a common regional land use database structure. The summary list will be the basis for a comparison of the data characteristics of variables in each category to available data sources (Section 4).

The approach used to construct the summary list began with an examination of each of the model’s inventory of “user-specified” land use variables. Where possible, a generic variable term which represented several variables common to one or more models was substituted for the original land use variables. For example, the variable “crop name” satisfied several of the individual models’ variable requirements relating to crop type, crop ID, crop ID no, crop category, crop, crops in the rotation, whether the crop was a warm or cool season crop, an annual or perennial, and so on. Once the list of common variables was condensed and duplication eliminated by following this procedure, the basic architecture or structure of the land use database emerged (Table 7).

Nine main categories of “user-specified” land use variables were identified from the summary list: crop-related parameters, tillage-related parameters, drainage, fertilizers/amendments, herbicides, irrigation, plant management, residue management and support practices. Variables under the plant management category were further divided into grazing and cutting/harvest/silage subcategories. Not every category of variables was represented by each of the models, however, categories usually applied to at least two, if not more, of the models studied.

An exception to the above list was the rangeland variable inventory of the WEPP model which was treated separately from the variables shown in Table 7. WEPP has a unique set of “user-specified” land use variables for the rangeland land use type. A sophisticated level of knowledge on the part of the user is required to adjust the values of these variables in order to simulate range conditions properly. The other models use the same variables regardless of the type of cropping system (i.e. pasture, range, perennial, annual or fallow) and to attempt to accommodate the unique set of range variables under WEPP proved cumbersome and not entirely warranted due to the complicated nature of the values required. Thus, the list for the rangeland land use type of the WEPP model is shown in Appendix 6 and will not be considered in further discussions.

3.1 Crop Related Parameters

Each of the soil degradation models had a crop growth subroutine of one form or another (with the exception of WEQ), which led to the designation of the first category called “crop-related parameters”. In addition to “user-specified” land use variables which are involved in the simulation of crop growth, this category also contains variables that represent cropping costs, crop-specific residue parameters, rotational information and yield conversion factors (Table 7).

3.2 Tillage Related Parameters

Tillage, or the effects thereof, was another common component to the models studied (WERM tillage subroutines are under development). This category contains variables that describe the type of tillage operation, the effect of that operation, dates of tillage operations, ridge heights and spacings and a few other variables unique to a particular model (Table 7). It should be noted that for the EPIC and RUSLE models, the variable “tillage operations” includes every operation associated with a particular crop. These operations would include planting, burning, grazing, herbicide applications and so on (see Section 2.1.1.2 for further explanation).

3.3 Drainage

The third category, designated as “drainage”, accommodates the drainage subroutines in both EPIC and WEPP models. The variables found in this category relate to drain tile dimensions, spacing, rates of drainage and vertical position in the landscape (Table 7).

3.4 Fertilizer/Amendments

The fertilizer/amendment category includes variables which aid in the simulation of fertilizer, lime or organic amendments. It was noted that fertilizer/amendment subroutines are common to Century and EPIC, but do not exist in WEPP, WERM (at this point in time), RUSLE or WEQ (Table 7). The variables found in this category are dates and rates of application; application limits for fertilizer N and P; fertilizer effect codes; fertilizer, lime and pesticide costs and organic matter addition dates and effect codes. (Note - fertilizer and lime application dates would fall under dates of tillage operations for EPIC: see Section 2.1.1.2 for further explanations).

3.5 Pesticides

The pesticide category contains those variables pertaining to pesticide/herbicide applications (Table 7). Of the models studied, only WEPP and EPIC simulate pesticide action or activities. The land use variables included in this category are application dates (see Section 2.1.1.2 for explanation as to why the date of herbicide application was not included here for the EPIC model) and rates, specific implement codes and costs of pesticide/herbicide application.

3.6 Irrigation

Irrigation was found to be a common component of the EPIC, WEPP and Century models. This category was designed to include variables for irrigation scheduling, application limits and depths, impact factors for sprinkler type irrigation, runoff ratios, volumes and costs, automatic irrigation trigger factors and dates of application (Table 7).

3.7 Plant Management

Several of the models studied supported a variety of plant management options. The subdivision into “grazing” and “cutting/harvest/silage” reflects the two major management subcategories. EPIC, WEPP and Century all simulate grazing, although the grazing operation under EPIC is described under the tillage category (see Section 2.1.1.2). Variables found in the grazing subcategory include pasture sizes, start and end dates, the number and weight of grazing animals, digestibility of forage and grazing effect codes (Table 7). The cutting/harvest/silage subcategory includes harvest dates and heights, effect codes, conversion factors and dates of silage removal (Table 7).

3.8 Residue Management

Residue management was placed in a separate category due to the importance of residue in the prevention of soil erosion and its repeated occurrence in the models studied. Residue management variables include the dry matter mass of a crop, codes for management options (baling, burning, etc.), fractions and dates of residue removed, total amounts of residues, the cover provided by pre-existing or any supplementary additions, amounts added at harvest of a crop, dates of shredding and the fraction of residue mass shredded, fraction of standing/flat residue mass lost by burning, dates of burning and fire effect codes (Table 7).

3.9 Support Practices

The final category, entitled “support practices”, includes variables from EPIC, WEPP and RUSLE which account for any practices which alleviate the effects of erosion. Generally, practices that are involved in the usual calculation of the P factor in RUSLE (Yoder et al., 1992) are included here: contouring, stripcropping and terracing (Table 7). The contouring variables describe factors on ridge, row and slope dimensions. Stripcropping variables describe strip widths, slope steepness and the location of the lower edge of each strip. Terracing variables include terrace grade and spacing (Table 7).

It is apparent from Table 7 that not all variables or categories may be required for any given simulation. Further, at a regional level certain variables are clearly more significant than others. These considerations lead to the next step in support of the research objective: to recommend sources of land use data for the categories of variables that define the land use regional database.

Table 7. Summary of "user-specified" land use variables for the various models.

Table 7. SUMMARIZED VARIABLE LIST	EPIC	WEPP	WERM	CENTURY	RUSLE	WEQ
Crop Related Parameters						
Crop name	X	X	X	X	X	X
Planting date (or start of fallow period)		X				
Seeding rate (kg ha-1)	X					
Crop seeding density (p m-2)			X			
Crop seeding location in relation to ridge			X			
Row width (m)		X				
Number of rows		X				
In-row plant spacing (m)		X	X			
Seed cost (\$ kg-1)	X					
Price for yield (\$ t-l)	X					
Potential heat units/GDD for growing season (crop/region specific)	X	X	X			
Approx. date to reach senescence (perennial crop)/end of a fallow period		X				
End date of perennial crop growth		X				
Optimal yield under no-stress conditions (kg m-2)		X				X
Dry matter mass of a specific crop						
Fragile or nonfragile operation MFO values (RESMAN)		X				
Age of residue			X			
Species ID of most recent harvest			X	X		
Species ID of the second last harvest			X			
Pounds of grain per bushel of grain		X				
Harvest units (bu a-1, kg ha-1, t a-1, etc.)		X				
Number of years in the rotation	X	X		X	X	
Number of crops grown annually		X				
Tillage Related Parameters (Harvest, Burn, Graze, Plant etc for EPIC/RUSLE)						
Tillage operation type	X	X			X	
Date of tillage	X	X		X	X	

Table 7. SUMMARIZED VARIABLE LIST						
	EPIC	WEPP	WERM	CENTURY	RUSLE	WEQ
Operation/Implement effect code(s)	X	X		X	X	
Ridge height						X
Ridge spacing						X
Cultivator position		X				
Number of months when cultivation takes place				X		
Drainage						
Depth to tile drain		X				
Drainage coefficient		X				
Drain tile diameter		X				
Drain tile spacing		X				
Drainage code	X					
Drainage area (ha)	X					
Time required for drainage system to eliminate plant stress	X					
Fertilizers/Amendments						
Date of Fertilizer Application	X			X		
Fertilization effect code				X		
N stress factor to trigger automatic fertilizer	X					
Fraction of maximum N fertilizer potentially applied at planting	X					
Maximum annual N fertilizer application for a crop (kg ha-1)	X					
Nitrogen fertilizer applied (kg ha-1)	X			X		
Phosphorus fertilizer applied (kg ha-1)	X			X		
Sulphur fertilizer applied (kg ha-1)	X			X		
Depth of fertilizer placement (mm)	X					
Nitrogen fertilizer cost (\$ kg-1)	X					
Phosphorus fertilizer cost (\$ kg-1)	X					
Liming code --(0 applies lime automatically; 1 applies no lime)	X					
Lime cost (\$ t-1)	X					
Date of organic matter addition				X		
OM addition effect code				X		

Table 7. SUMMARIZED VARIABLE LIST						
		EPIC	WEPP	WERM	CENTURY	RUSLE WEQ
Pesticides						
Date of herbicide/pesticide application		X	X			
Pesticide/herbicide application rates (kg ha-1)		X				
Herbicide/pesticide cost (\$ ha-1)		X				
Tillage implement that carries a pesticide operation code		X				
Irrigation						
Irrigation code		X	X			
Irrigation scheduling option			X			
Min. application interval for automatic irrigation (days)		X				
Water stress factor to trigger automatic irrigation		X				
Min. single application volume allowed for auto.(mm)		X	X			
Max. single application volume allowed for auto. (mm)		X	X			
Minimum irrigation depth (m)			X			
Maximum irrigation depth (m)			X			
Sprinkler nozzle impact energy factor			X			
Irrigation runoff ratio		X				
Maximum annual irrigation volume allowed for each crop (mm)		X				
Irrigation water cost (\$ m-3)		X				
Irrigation volume (mm)		X				
Irrigation event code				X		
Application rate (m sec-1)			X			
Ratio of appln. depth to water needed to fill profile to FC			X			
Irrigation date		X	X		X	
Date at end of period during which irrigation might occur			X			
Depletion ratio at which irrigation will occur			X			
Irrigation depth (m)			X			
Plant Management						
Grazing						
Grazing pasture size (m2)			X			
No. of grazing sequences per year			X			

Table 7. SUMMARIZED VARIABLE LIST						
	EPIC	WEPP	WERM	CENTURY	RUSLE	WEQ
Date that grazing begins		X		X		
Date that grazing ends		X				
No. of grazing animals		X				
Digestibility of a perennial crop		X				
Average body weight of a grazing animal		X				
Grazing effect code				X		
Cutting/Harvesting/Silage						
Harvest date		X		X		
Cutting/harvest height (m)		X				
Date cutting/harvest for perennial crop		X				
Number of cuttings of a perennial crop		X				
Harvest effect code				X		
Conversion of veg. biomass to standing residue mass at harvest		X				
Date of silage removal		X				
Residue Management						
Crop residue (t ha-1)	X	X				X
Percent cover of residue						X
Crop grown prior to the start of the simulation		X				
Supplementary residue additions (lb. ac-1)					X	
Supplementary residue additions (% cover)					X	
Residue added at harvest of a crop (lb.ac-1)					X	
Vegetative D.M. of a perennial crop not harvested/grazed (kg m-2)		X				X
Residue mgmt. option (1-herbicide, 2-burn, 3-silage etc)		X				
Date of residue removal		X				
Fraction residue removed through a removal operation				X		
Fraction of vegetative to flat residue mass removed from the field		X		X		
Date of residue shredding/cutting		X				
Fraction of residue mass mechanically shredded/cut		X				
Date of burning residue		X				
Fraction of standing residue mass lost by burning		X				

Table 7. SUMMARIZED VARIABLE LIST						
	EPIC	WEPP	WERM	CENTURY	RUSLE	WEQ
Fraction of flat residue mass lost by burning		X				
Fire effect code				X		
SUPPORT PRACTICES (P factor--RUSLE)						
Runoff index value						X
PEC value (erosion control practice factor)	X					
Contouring - ridge height (m)		X			X	
Contouring - furrow grade					X	
Contouring - slope steepness (m/m)		X			X	
Contouring - slope length					X	
Contouring - row length (m)		X				
Contouring - row spacing (m)		X				
Stripcropping - strip width as function of slope length						
Stripcropping - slope steepness					X	
Stripcropping - location of lower edge of each strip; cover-mgmt for each strip					X	
Terracing - terrace grade						
Terracing - spacing					X	

4.0 Data and Source Characteristics for a Regional Land Use Database

Recently, attention has been focused on the use of process-based models to assess the impact of agricultural land use and management practices at broad scales (Izaurrealde et al., 1992; Setia and Piper 1992; Agriculture Canada 1994; Mellerowicz et al., 1994). The use of degradation models at a regional scale requires new or different data to represent broad patterns of agricultural production. The key to adapting these detailed process or equation-based models for application to broader regions partially lies in carefully selecting or adjusting the scale of the database that will be used to run the models at the appropriate regional level (Dumanski et al., 1993).

In this section, the data requirements and availability were assessed from a regional perspective. Each of the "user-specified" land use variables was first characterized by the extent of variation, both temporally and spatially, that the data or values of the variable were expected to show. Next, a comparison of these expected data characteristics for each of the 'user-specified' land use variables with the documented sources of data for each variable was made to determine whether appropriate sources of land use data are currently available for broad-scale soil quality assessments.

Three data characteristics were considered and included (1) temporal variation, (2) spatial variation and (3) regional data type (Table 8):

(1) The three classes for temporal variation give an indication of the frequency with which the data or values of the 'user-specified' land use variables are expected to change (in a regional analysis):

- Yearly - varies from year to year (short-term)
- 1-5 yrs - varies within a 1 to 5 year period (mid-term)
- > 5 yrs - varies at intervals greater than 5 years (long-term).

(2) The descriptions for spatial variation indicate the spatial extent to which the data or value of the 'user-specified' land use variables are expected to vary (in a regional analysis):

- LRA - on a Land Resource Area basis (units about 100,000 ha in size)
- ECR - on an Ecoregion basis (broad vegetational zones; may contain several LRAs)
- PRO - constant for the entire province
- N/A - not applicable (derived from another variable).

(3) Regional data type indicates how the data for the variable could be assembled or compiled for regional assessments:

- 1 - physically collected or measured
- 2 - assigned, or constant for a given region
- 3 - theoretical or literature-based
- 4 - derived from the values of others
- 5 - not applicable to Canadian situations or regional analysis; a candidate for deletion.

The source characteristics for each 'user-specified' land use variable are described in terms of the type of source, the source itself, the reporting unit or scale of the data in a particular source and finally, the applicable time period of the source.

Table 8. Data and source characteristics of the “user-specified” land use variables for regional assessments.

TABLE 8. Data and Source Characteristics for Regional Assessments			DATA CHARACTERISTICS			SOURCE CHARACTERISTICS		
No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL ^a VARIATION	REGIONAL DATA TYPE	TYPE OF SOURCE ^b	SOURCE(s) ^c	REPORT-ING UNIT ^d	TIME PERIOD ^e
Crop Related Parameters								
1	Crop name	Yearly	LRA	1	Published	CRITICALE	LRA	1981
2	Long term planting date (or start of fallow period)	>5 yrs	LRA	2	Published	CENSUS	EA	5 yrs
3	Seeding rate (kg ha-1)	1-5 yrs	ECR	2	Published	ARA Database	LRA	1981, 1986
4	Crop seeding density (p m-2) (derived from 3)	-	N/A	4	E.O.	CS-DRO	AD	N/A
5	Crop seeding location in relation to ridge	>5 yrs	ECR	2	Published	EPIC-CRAM	CR	1991
6	Row width (m)	>5 yrs	ECR	2	Published	EPIC-CRAM	CR	1991
7	Number of rows	>5 yrs	ECR	2	E.O.	CS-DRO	AD	N/A
8	In-row plant spacing (m)	>5 yrs	ECR	2	E.O.	CS-DRO	AD	N/A
9	Seed cost (\$ kg-1)	Yearly	PRO	1	Industry	CSGA	-	N/A
10	Market price for crop (\$ t-1)	Yearly	PRO	1	Published	ASY-SB	CD	Yearly
11	Potential HU/GDD for growing season (region specific)	>5 yrs	LRA	2	E.O.	CS-DRO	AD	N/A
12	Approx. date to reach senescence (perennial)/end of fallow	1-5 yrs	LRA	2	Published	ARA Database	LRA	1981, 1987
13	End date of perennial crop growth (derived from variable 12)	-	N/A	4	E.O.	CS-DRO	AD	N/A
14	Optimal yield under no-stress cond. of a crop (kg m-2)	>5 yrs	ECR	2	-	-	-	N/A
15	Crop yield (kg ha-1)	Yearly	LRA	1	E.O.	UNIV	-	N/A
16	Dry matter mass of a specific crop (derived from 15)	-	N/A	4	E.O.	RS	-	N/A
17	Age of residue	1-5 yrs	ECR	3	Published	CS-DRO	AD	N/A
18	Crop species of last harvest	1-5 yrs	LRA	1	E.O.	ASY-SB	CD	Yearly
19	Crop species of the second last harvest	1-5 yrs	LRA	1	Published	-	-	N/A
					E.O.	CS-DRO	AD	N/A
					Published	AFS	Risk Area	Yearly
					E.O.	CS-DRO	AD	N/A

TABLE 8. Data and Source Characteristics for Regional Assessments			DATA CHARACTERISTICS			SOURCE CHARACTERISTICS		
No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL ^a VARIATION	REGIONAL DATA TYPE	TYPE OF SOURCE ^b	SOURCE(s) ^c	REPORT-ING UNIT ^d	TIME PERIOD ^e
20	Pounds of grain per bushel of grain	>5 yrs	PRO	3	Published	AFS	Risk Area	Yearly
21	Number of years in the rotation	1-5 yrs	LRA	1	E.O.	Literature	N/A	N/A
22	Number of crops grown annually	1-5 yrs	LRA	1	E.O.	CS-DRO	AD	N/A
						CS-DRO	AD	N/A
Tillage Related Parameters								
23	Tillage operation type	1-5 yrs	LRA	1	Published E.O.	EPIC-CRAM CS/SCS/CE-DRO	CR AD	1991 N/A
24	Operation/Implement effect code(s) (derived from variable 23)	-	N/A	4	Published	ACTS	Soil zone EA	1987, 1992
25	Date of tillage	1-5 yrs	LRA	1	Published E.O.	CENSUS -	-	5 yrs N/A
26	Ridge height (m)	1-5 yrs	LRA		Published	EPIC-CRAM CS/SCS/CE-DRO	CR AD	1991 N/A
27	Ridge spacing (m)	1-5 yrs	LRA	2	E.O.	ACTS	Soil zone AD	1987, 1992
28	Cultivator position (front or rear mounted)	>5 yrs	PRO	2	E.O.	SCS/CE-DRO	AD	N/A
29	No. of months when tillage takes place (derived from 23 and 25)	-	N/A	4	-	SCS/CE-DRO	AD	N/A
30	Fragile/nonfragile operation MFO values (derived from 1 and 23)	-	N/A	4	Published	-	-	N/A
Drainage								
31	Depth to tile drain (m)	>5 yrs	LRA	2	E.O.	WEPP MD	AD	N/A
32	Drainage coefficient	>5 yrs	LRA	2	E.O.	ES-DRO	AD	N/A
33	Drain tile diameter (m)	>5 yrs	LRA	2	E.O.	ES-DRO	AD	N/A
34	Drain tile spacing (m)	>5 yrs	LRA	2	E.O.	ES-DRO	AD	N/A
35	Drainage area (ha)	>5 yrs	LRA	2	E.O.	ES-DRO	AD	N/A
36	Time required for drainage system to eliminate plant stress (h)	>5 yrs	LRA	2	E.O.	ES-DRO	AD	N/A
Fertilizers/Amendments								
37	Date of fertilizer application	1-5 yrs	LRA	1	Published E.O.	EPIC-CRAM CS-DRO	CR AD	1991 N/A

TABLE 8. Data and Source Characteristics for Regional Assessments			DATA CHARACTERISTICS			SOURCE CHARACTERISTICS		
No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL VARIATION	REGIONAL DATA TYPE	TYPE OF SOURCE ^b	SOURCE(s) ^c	REPORT-ING UNIT ^d	TIME PERIOD ^e
38	N stress factor to trigger automatic fertilizer	-	PRO	5	-	N/A	-	N/A
39	Fraction of max. N fertilizer applied at planting	1-5 yrs	LRA	2	Published E.O.	EPIC-CRAM	CR	1991
40	Nitrogen fertilizer applied (kg ha-1)	Yearly	LRA	1	Published E.O.	CS-DRO EPIC-CRAM CS-DRO	AD CR AD	N/A 1991 N/A
41	Max. annual N fertilizer application for a crop (derived from 40)	-	N/A	4	Published	CRITICALE	LRA	1981
42	Phosphorus fertilizer applied(kg ha-1)	Yearly	LRA	1	Published E.O.	EPIC-CRAM	CR	1991
43	Sulphur fertilizer applied (kg ha-1)	Yearly	LRA	1	E.O.	CS-DRO	AD	N/A
44	Fertilization effect code (derived from variables 40, 42 and 43)	-	N/A	4	-	CS-DRO	AD	N/A
45	Depth of fertilizer placement (mm)	1-5 yrs	ECR	2	E.O.	-	-	N/A
46	Nitrogen fertilizer cost (\$ kg-1)	Yearly	PRO	1	E.O.	CS/ES-DRO CS-DRO	AD AD	N/A N/A
47	Phosphorus fertilizer cost (\$ kg-1)	Yearly	PRO	1	CCz	Industry	-	Yearly
48	Lime cost (\$ t-1)	Yearly	PRO	1	E.O.	CS-DRO	AD	N/A
49	Liming code -(0 applies lime ; 1 applies no lime)	1-5 yrs	LRA	2	CC	Industry	-	Yearly
50	Date of organic matter addition	Yearly	LRA	1	E.O.	CS-DRO	AD	N/A
51	OM addition type (effect code)	1-5 yrs	LRA	1	CC	CS-DRO	AD	Yearly
Pesticides								
52	Date of pesticide/herbicide application	1-5 yrs	LRA	2	Published E.O.	EPIC-CRAM	CR	1991
53	Pesticide/herbicide application rates (kg ha-1)	Yearly	LRA	1	E.O.	CS-DRO	AD	N/A
54	Pesticide/Herbicide cost (\$ ha-1)	Yearly	PRO	1	Published E.O.	ASY-SB CS-DRO	CD AD	Yearly N/A
55	Tillage implement that carries a pesticide operation code	1-5 yrs	-	3	Published	EPIC-UM	-	N/A
Irrigation								
56	Irrigation type	>5 yrs	ECR	2	E.O.	CS/IS-DRO	AD	N/A
57	Water stress factor to trigger automatic irrigation	> 5 yrs	PRO	5	E.O.	IS-DRO	AD	N/A

TABLE 8. Data and Source Characteristics for Regional Assessments			DATA CHARACTERISTICS			SOURCE CHARACTERISTICS		
No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL ^a VARIATION	REGIONAL DATA TYPE	TYPE OF SOURCE ^b	SOURCE(s) ^c	REPORT-ING UNIT ^d	TIME PERIOD ^e
58	Minimum single application volume allowed for automatic (mm)	1-5 yrs	PRO	5	E.O.	IS-DRO	AD	N/A
59	Maximum single application volume allowed for automatic (mm)	1-5 yrs	PRO	5	E.O.	IS-DRO	AD	N/A
60	Minimum irrigation depth (m)	1-5 yrs	ECR	5	E.O.	CS/IS-DRO	AD	N/A
61	Maximum irrigation depth (m)	1-5 yrs	ECR	5	E.O.	CS/IS-DRO	AD	N/A
62	Irrigation depth (m)	>5 yrs	ECR	2	E.O.	CS/IS-DRO	AD	N/A
63	Sprinkler nozzle impact energy factor	1-5 yrs	ECR	2	E.O.	IS-DRO	AD	N/A
64	Irrigation runoff ratio	1-5 yrs	LRA	2	E.O.	IS-DRO	AD	N/A
65	Maximum annual irrigation volume allowed for each crop	1-5 yrs	LRA	5	E.O.	CS/IS-DRO	AD	N/A
66	Irrigation water cost (\$ m-3)	1-5 yrs	PRO	1	E.O.	IS-DRO	AD	N/A
67	Irrigation volume (mm)	1-5 yrs	LRA	2	E.O.	IS-DRO	AD	N/A
68	Application rate (m sec-1)	1-5 yrs	LRA	2	E.O.	IS-DRO	AD	N/A
69	Ratio of appl'n depth:water to fill profile to field capacity	> 5 yrs	LRA	2	E.O.	IS-DRO	AD	N/A
70	Irrigation date	Yearly	LRA	1	E.O.	IS-DRO	AD	N/A
71	End date of period which irrigation occurs (derived from 70)	-	-	4	-	-	-	N/A
72	Min. applictn. interval for auto. irrigation (derived from 70)	-	-	4	-	-	-	N/A
73	Depletion ratio at which irrigation will occur	> 5 yrs	PRO	5	E.O.	IS-DRO	AD	N/A
74	Irrigation event code (derived from variables 67, 69 and 73)	-	-	4	-	-	-	N/A
Plant Management								
Grazing								
75	Grazing pasture size (m2)	1-5 yrs	ECR	2	E.O.	RMS/FS-DRO	AD	N/A
76	Number of grazing sequences per year	> 5 yrs	ECR	2	E.O.	RMS/FS-DRO	AD	N/A
77	Date that grazing begins	> 5 yrs	ECR	2	E.O.	RMS/FS-DRO	AD	N/A
78	Date that grazing ends	> 5 yrs	ECR	2	E.O.	RMS/FS-DRO	AD	N/A
79	Number of grazing animals	1-5 yrs	ECR	1	E.O.	RMS/FS-DRO	AD	N/A
80	Digestibility of a perennial crop	> 5 yrs	ECR	2	E.O.	BS-DRO	AD	N/A
81	Average body weight of a grazing animal	> 5 yrs	ECR	2	E.O.	BS-DRO	AD	N/A

TABLE 8. Data and Source Characteristics for Regional Assessments			DATA CHARACTERISTICS			SOURCE CHARACTERISTICS		
No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL ^a VARIATION	REGIONAL DATA TYPE	TYPE OF SOURCE ^b	SOURCE(s) ^c	REPORT-ING UNIT ^d	TIME PERIOD ^e
82	Grazing effect code (derived partially from 76, 79 and 81)	-	-	4	-	-	-	N/A
Cutting/Harvesting/Silage								
83	Harvest date	1-5 yrs	LRA	1	Published	EPIC-CRAM	CR	1991
84	Harvest height (m)	> 5 yrs	ECR	2	E.O.	CS-DRO	AD	N/A
85	Date cutting/harvest for perennial crop	> 5 yrs	LRA	2	E.O.	RMS/CS/FS-DRO	AD	N/A
86	Number of cuttings of a perennial crop	> 5 yrs	LRA	2	E.O.	RMS/CS/FS-DRO	AD	N/A
87	Harvest effect code (derived from 84, 88 and 100)	-	N/A	4	-	-	-	N/A
88	Conversion of veg. biomass to standing residue mass at harvest	> 5 yrs	ECR	2	E.O.	CS-DRO	AD	N/A
89	Date of silage removal	1-5 yrs	LRA	1	E.O.	CS-DRO	AD	N/A
Residue Management								
90	Crop residue (t ha-1) (derived from 15)	-	N/A	4	-	-	-	N/A
91	Percent cover of residue	1-5 yrs	LRA	1	E.O.	SCS/CS-DRO PFRA-RS	AD Soil zone	N/A 1988, 1992
92	Crop grown prior to the start of the simulation (derived from 18)	-	N/A	4	-	-	-	N/A
93	Supplementary residue additions (lb. ac-1)	1-5 yrs	LRA	1	E.O.	SCS/CS-DRO	AD	N/A
94	Supplementary residue additions (% cover)	1-5 yrs	LRA	1	E.O.	SCS/CS-DRO	AD	N/A
95	Residue added at harvest of crop (lb.ac-1) (derived from 15)	-	N/A	4	-	-	-	N/A
96	Veg. D.M. of a per. crop not harvested/grazed (derived from 15)	-	N/A	4	-	-	-	N/A
97	Res. management option (derived from management scenario)	-	N/A	4	-	-	-	N/A
98	Date of residue removal	1-5 yrs	LRA	2	E.O.	SCS/CS-DRO	AD	N/A
99	Fraction residue removed through a removal operation	1-5 yrs	LRA	2	E.O.	SCS/CS-DRO	AD	N/A
100	Fraction of vegetative to flat residue mass removed	1-5 yrs	LRA	2	Published	PFRA-RS	Soil zone	1988, 1992
101	Date of residue shredding/cutting (harvest date in Alberta)	1-5 yrs	LRA	2	E.O.	SCS/CS-DRO EPIC-CRAM	AD CR	N/A 1991
					E.O.	SCS/CS-DRO	AD	N/A

TABLE 8. Data and Source Characteristics for Regional Assessments			DATA CHARACTERISTICS			SOURCE CHARACTERISTICS		
No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL VARIATION	REGIONAL DATA TYPE	TYPE OF SOURCE ^b	SOURCE(s) ^c	REPORT-ING UNIT ^d	TIME PERIOD ^e
102	Fraction of residue mass mechanically shredded/cut	1-5 yrs	ECR	2	E.O.	SCS/CS-DRO	AD	N/A
103	Date of burning residue	1-5 yrs	LRA	5	E.O.	SCS/CS-DRO	AD	N/A
104	Fraction of standing residue mass lost by burning	> 5 yrs	ECR	5	E.O.	SCS/CS-DRO	AD	N/A
105	Fraction of flat residue mass lost by burning	> 5 yrs	ECR	5	E.O.	SCS/CS-DRO	AD	N/A
106	Fire effect code (derived from 104 and 105)	-	-	5	-	-	-	N/A
SUPPORT PRACTICES (P factor--RUSLE)								
107	Runoff index value	1-5 yrs	LRA	3	Published	RUSLE-UG	-	N/A
108	PEC value (erosion control practice factor)	1-5 yrs	LRA	3	Published	EPIC-UM	-	N/A
109	Contouring - ridge height (m)	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
110	Contouring - furrow grade	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
111	Contouring - slope steepness (m/m)	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
112	Contouring - slope length	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
113	Contouring - row length (m)	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
114	Contouring - row spacing (m)	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
115	Stripcropping - strip width as function of slope length	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
116	Stripcropping - slope steepness	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
117	Stripcropping - location of lower edge of each strip	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
118	Terracing - terrace grade	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A
119	Terracing - spacing	> 5 yrs	ECR	5	E.O.	SCS/CE-DRO	AD	N/A

a) LRA=Land Resource Area; ECR=Ecoregion; PRO=Province; N/A=Not applicable.

b) E.O.=Expert Opinion; CC=Chemical Company.

c) CRITICALE=Hiley et. al 1989; CENSUS=Statistics Canada 1986; ARA database= Kirkwood et. al., 1993; CS-DRO=Crop Specialist located in a District or Regional Office (DRO), Alberta Agriculture; EPIC-CRAM=report, Agriculture and Agri-food Canada 1994; CSGA=Canadian Seed Growers Association; ; ASY-SB=Agricultural Statistical Yearbook-Statistics Branch, Alberta Agriculture (annual publication); UNIV=University of Alberta; RS=Research Station; AFS=Alberta Financial Services (see Hail and Crop insurance); CS/SCS/CE-DRO=Crop Specialist, Soil Conservation Specialist and Conservation Engineer at the District or Regional Offices, Alberta Agriculture; ACTS=Alberta Conservation Tillage Surveys, Dept. of Rural Economy, University of Alberta, Jensen 1988; Haigh and Haigh 1992a,b; WEPP-MD=WEPP Model Documentation (Flanagan et al., 1994); ES-DRO=Engineering Specialist in a District or Regional Office, Alberta Agriculture; EPIC-UM=EPIC Users Manual (Williams et al., 1990); CS/IS-DRO=Crop Specialist or Irrigation Specialist at a District or Regional Office, Alberta Agriculture; RMS/FS-DRO=Range Management Specialist/Forage Specialist at a District or Regional Office (DRO), Alberta Agriculture; BS-DRO=Beef Specialist located in a District or Regional Office, Alberta Agriculture; PFRA-RS=Prairie Farm Rehabilitation Administration-Residue Surveys; RUSLE-UG=RUSLE User's Guide (Yoder et al., 1992).

d) LRA=Land Resource Area; EA=Enumeration Area; AD=Agricultural District, which, for the purposes of this report, is a generic reporting area for the Ag Specialists, CR=Cram Region, Agriculture and Agri-food Canada 1994; CD=Census Division.

e) N/A=Not applicable.

4.1 Crop Related Parameters

Published data sources for selected years are available for the 4 of 22 parameters that change on a yearly basis at different levels of spatial variability (Table 8). Seed costs and market price for the crop are not expected to vary across the province and annual publications or industry sources can provide the requisite data. Crop name (type of crop) and yield vary spatially at the level of LRAs, however, published sources are only available for selected years or broader reporting units, respectively.

Seven of the 22 crop-related parameters show lower temporal, and in some cases, spatial variation than those discussed above and regional experts are a likely source of these data. Variables related to rotational parameters like number of years in rotation, number of crops grown annually and crop species of previous harvests are expected to vary within a 1 to 5 year period and at about the level of LRAs. Data collected by Alberta Financial Services (previously the Alberta Hail and Crop Insurance Corporation) may provide useful information in this regard at the level of risk areas. Seeding rate and age of residue in the field are also expected to vary in the mid-term, but at the level of ecoregions.

Expert opinion is the main data source for 8 of the 22 parameters that show little temporal and spatial variation. Variables such as crop seeding location, row width, in-row plant spacing and number of rows are not expected to change over a 5 year period and spatial variation in the value of these variables occurs amongst ecoregions. Regional experts could provide data on these variables over reporting units like agricultural districts.

The remaining 3 are derived from the values of other parameters in this subsection.

4.2 Tillage Related Parameters

Four of the 8 tillage-related parameters vary in the mid-term at the level of LRA's (Table 8). Further, a number of published data sources of various reporting units and time periods are available for these variables. The tillage operation type and date as well as ridge height and spacing will vary in a 1 to 5 year time period amongst LRAs. Correlation of a number of published sources at various scales and time periods will be required to obtain the appropriate values for these variables. Supplementation from expert opinion may be required as well.

Only 1 of the 8 parameters in this category shows little temporal and spatial variation (Table 8). Regional expertise will be required to determine cultivator position, a parameter that is expected to vary in the longer term and over very broad areas (provincial level).

The remaining 3 tillage related variables are derived from one or more of the parameters previously discussed in this subsection.

4.3 Drainage

There is considerable uniformity in the data and source characteristics for the 6 drainage parameters (Table 8). These parameters are expected to vary only in the long-term and amongst LRAs. Expert opinion is the suggested source of data, with engineering specialists and experts in regional and district offices providing estimates on broad reporting units.

4.4 Fertilizers/Amendments

Six of the 15 fertilizer/amendment variables are expected to vary in the short-term (Table 8). Data on the composition and amount of fertilizer applied varies amongst LRAs and a combination of published sources and expert opinion can be used to determine appropriate values. Fertilizer costs are expected to be uniform for the entire province and may be determined from regional experts and fertilizer industry representatives.

Another six of the 15 variables show less temporal variation, with the majority varying spatially at the LRA level. A mixture of sources are available for these variables. Date of fertilizer application and fraction of maximum N fertilizer potentially applied at planting should be available from EPIC-CRAM studies. However, the EPIC-CRAM study made no allowance for regional differences in management, therefore this data would have to be supplemented with expert opinion. Depth of fertilizer placement is expected to vary amongst ecoregions, with expert opinion from crop and engineering specialists providing these data for broad agricultural districts. Data for the remaining 3 parameters may be obtained from regional experts. There were no variables in this category which showed long-term variation.

The remaining 3 parameters are derived from one or more of the variables discussed in this subsection.

4.5 Pesticides

Two of the 4 variables in this category show high temporal variation and appropriate data can be obtained from a combination of expert opinion and published sources (Table 8). Pesticide application rates are expected to vary on an annual basis and amongst LRAs. Expertise will be required to translate estimates from agricultural districts to this level. Estimates of the costs of pesticides and herbicides may be derived from published sources like agricultural statistical yearbooks, chemical company representatives, supplemented with input from regional experts.

Published sources in conjunction with expert opinion may provide data on 2 of the 4 pesticide parameters that have moderate temporal variation. Studies using the EPIC model may provide information on date of pesticide application and the EPIC manual will indicate the tillage implement that carries a pesticide operation code, however, these data are reported at a level more consistent with ecoregions than LRAs. Expertise from regional offices will be required to translate these data to the required biophysical units.

4.6 Irrigation

The irrigation date is the only variable expected to vary on a yearly basis and regional expertise will be required to provide the appropriate data (Table 8). The parameter is expected to vary on an LRA basis.

Expert opinion will be required to provide data on 10 of the 19 parameters that show less temporal variation than irrigation date. Six of the 10 variables, such as volumes and depth for automatic irrigation, water costs and impact factors are expected to vary amongst ecoregions or at the provincial level. The remaining 4 parameters, irrigation rates, irrigation runoff ratio and volumes for manual irrigation, show more spatial variation to the level of LRAs. In both cases, irrigation specialists will be the likely source of data for these parameters.

Five of the 19 irrigation variables show little temporal and spatial variation with expert opinion a likely data source. Parameters such as irrigation type and irrigation depth will be constant over a 5 year period at the level of ecoregions. Water stress and depletion ratios for automatic irrigation will also vary in the long-term and only at the provincial level. Expertise from irrigation specialists will be required to obtain the requisite data.

The remaining 3 parameters are derived from other variables previously discussed in this subsection.

4.7 Plant Management

4.7.1 Grazing

Data for all 8 of the grazing parameters will be generated by regional experts (Table 8). Grazing pasture size and the number of grazing animals are expected to vary in the mid-term and at the ecoregion level.

Five of the 8 variables show less temporal variation than those parameters discussed above. Parameters related to grazing dates and number of grazing sequences are expected to vary for periods longer than 5 years and amongst ecoregions. Specialists in range management and forages will be potential sources of such data. Beef specialists will be of particular importance in estimating values for the other 2 variables that vary in the long-term. Their expertise will be required to determine the digestibility of a perennial crop and average body weight of a grazing animal.

The remaining variable, grazing effect code, is derived from one or more of the parameters previously discussed in this subsection.

4.7.2 Cutting/Harvesting/Silage

Two of the 7 parameters in this subcategory, harvest date and date of silage removal, show high temporal variation and require estimates at the level of LRAs (Table 8). Expert opinion, in the form of crop, range management and forage specialists will be able to provide data on these parameters.

A variety of experts will again be required to provide data on 4 of the 7 parameters that show little temporal variation. These experts will help to determine harvest heights, number of cuttings of a perennial crop, and conversion of vegetative biomass to standing residue mass at harvest. These data will show differing spatial variation, from LRAs (number of cuttings) to ecoregions (conversion values).

The remaining parameter, harvest effect code, is derived from one or more of the variables previously discussed in this subsection.

4.8 Residue Management

Nine of the 17 residue parameters are expected to vary over the mid-term, at an LRA level, with expert opinion as the main source of appropriate data (Table 8). Data for variables like percent cover of residue, supplementary residue additions and date of residue removal have not been published to date on a 1 to 5 year period by LRA. Again, soil conservation and crop specialists, in addition to some published studies by PFRA, will be useful in estimating values for these variables.

Experts will again be required to determine appropriate data for 2 of the 17 parameters that show both little temporal and spatial variation. Fraction of standing residue mass at burning and fraction of flat residue mass lost by burning are not expected to vary within a 5 year period and only at the level of ecoregions. Soil conservation and cropping specialists in regional offices should be consulted in the determination of values for these parameters.

The remaining 6 variables are derived from one or more of the parameters previously discussed in this subsection.

4.9 Support Practices (P factor RUSLE)

Two of the 13 parameters in this category show temporal variation in the 1 to 5 year range and a requirement for expert opinion to provide the necessary estimates per LRA's (Table 8). The runoff index value and erosion control practice factor, both vary over the mid-term and published sources like the RUSLE and EPIC manuals provide guidance for selecting an appropriate value.

For the remaining 11 variables, soil conservation specialists and conservation engineers will be of assistance in generating the appropriate values. These support practice variables are expected to vary over the long-term and at the level of ecoregions.

4.10 Summary

A comparison of the data and source characteristics for a regional land use database shows that, in general, considerable gaps exist in the temporal and spatial scales of the required information and the scales of available published reports and regional expertise. Of the 118 variables identified, 18 parameters are derived through the values of others (Table 8, Type 4 variables). For ease of presentation, the summary discusses the information requirements of the remaining 100 variables below.

4.11 Spatial Comparisons

The comparison of required data characteristics with available source characteristics for each of the 100 land use variables highlights the magnitude of the problem at hand. Quite often, if a study involving land use for the particular variable has been done, and a published source is available, the reporting unit of the source does not match the required spatial variation of the data for the variable. Almost 50% of the parameters show a spatial variation consistent at an LRA level, and yet only a few publications exist with information suitable to that scale (Table 8). The majority of the sources report at much broader units. The EPIC-CRAM study for example, made no allowance for regional variations for variables like planting date, harvest date and other management related activities. Further, land use were organized according to CRAM regions which are delineated largely on the basis of economic criteria and not biophysical units. The use of sources such as the EPIC-CRAM report, which is the largest of its kind, is limited due to the incompatibility in spatial variation with the data requirements for the land use variables. Therefore some extrapolation will be necessary to match the scales of what is available with what is required, and in most cases will require supplemental information from expert systems. Expert opinion remains one of the most important sources of land use information, especially for the last seven categories of variables.

4.12 Temporal Comparisons

In general, published sources for the majority of the land use variables are available for selected time periods only, which emphasizes the inadequacy of these sources for variables which vary on a yearly basis. Only about 13% of the 100 variables vary over the short-term, with the majority of them in the fertilizer/amendment category. Even those variables whose data requirements are expected to vary on a 1-5 year basis (44% of the total) may not be satisfied by sources published on selected time periods. Published census reports, both federal and provincial, can be valuable sources for yearly, 5 year and long-term information. Approximately 42% of the land use variables vary in the long-term, comprising 8 of the 23 crop-related parameters. Expert opinion will be required to supply values for these variables. The remaining variables are distributed amongst the remaining 8 categories. Expert opinion remains one of the most important sources for those variables with greater temporal variation.

5.0 Regional Assessments of Soil Quality

5.1 The Issue

The key to adapting detailed process or equation -based models for application to broader regions lies in carefully selecting or adjusting the scale of the database that will be used to run the models at the appropriate regional level. Dumanski et al. (1993) state that in order to be successful at matching database scale with the scale of the model used in the analysis, one must examine the functional subroutines of the model under consideration and determine the role of each variable within the context of the particular subroutine or empirical function. Once the role of the variable is understood, one is better able to make decisions on the appropriateness of the particular variable in regional analysis.

In Sections 1 and 2, subroutines for each model relating to land use and management were examined to distinguish between the “user-specified” and “model-supplied” variables and understand the functional role of each “user-specified” variable in the respective models. The list of “user-specified” land use variables was condensed and summarized into 9 categories and 118 variables, organized to eliminate duplication and integrate the various model data requirements (Section 3). This process identified the contents and structure for a preliminary database.

For regional analysis, the manner in which data is gathered, organized and presented differs from the collection of site (or farm) specific information (Dumanski et al., 1993). The intent is to obtain and generalize broad-scale information that represent patterns of agricultural production within chosen agricultural regions. In keeping with those objectives, the extent to which the required data for the land use variables was expected to vary both on a spatial (biophysical land units) and temporal (time classes) basis was characterized in Section 4. This characterization accomplished two things: (1) it identified the need for grouping, categorizing and generalizing the highly variable, detailed data for regional representation, and (2) allowed for a direct comparison of the information required for regional analysis with what is available. Available sources of regional information for the land use variables were identified, characterized by type; scale or reporting unit; and the time period of the source.

The comparison of data needs and available sources identified two major concerns: data was often not available and when it was, there was a question of consistency. For most of the 118 variables, available published sources did not match exactly, either spatially, or temporally, with what was required. This meant that either new data had to be collected or that available data needed to be modified. In both cases it was apparent that assumptions would need to be made, in essence adding intellectual value to the data. While expert opinion is a valid source of regional data, inconsistencies in reporting of the land use data in a given region can occur, either because of a miscommunication or misinterpretation of spatial and temporal delineations, or subjective differences in reporting due to consultation with various regional specialists. Further, it follows that if every analyst or user were to proceed on their own, there would be both a great deal of duplication of effort and the development of databases which, while not likely very different, would nonetheless not be identical. Coordinated data input for all regions would increase the consistency of soil quality reporting.

5.2 Regional Considerations

The design of land-related databases has changed with the growing emphasis on broad-scale, regional analysis. The move away from site-specific, single factor research to regional, integrated, holistic analysis has many implications. One is that, in order to be efficient, analysis and output impose a degree of structure on the database. Another is that 'regional' by its nature, can cross several geographic or political boundaries and data consistency is again a concern.

The linkage of process-based, mechanistic models to eventual GIS-type databases is often unsuccessful due to the incongruity between the detailed subroutines of the models and the spatial and temporal resolution of the regional databases used to run them (Burrough 1989). However, Bouma et al. (1994) emphasize that in order to assess the environmental impacts of management practices on natural resources, it is necessary to use a quantitative approach involving mechanistic or process-based models, ideally suited more to site-level analysis than regional analysis. Computers facilitate the detailed analysis but rules need to be developed for generalization to a regional analysis. A landscape or ecologically based model would appear to be the best basis for generalization, but specific links need to be developed and these work best if based on an understanding of process. For example, an average value for a province, a country or even a field can mask significant problems or solutions associated with a part of the area.

A primary issue that must be considered is a clear analysis of the problem, including a review of the data demands with the availability of data required to run any particular model (Bouma et al., 1994). This issue has been addressed in Sections 1 to 4, where the essential variables were identified, summarized, categorized and evaluated in terms of data requirements and data availability for regional analysis. This exercise is needed to aid in the linkage of the mechanistic model(s) to the problem of regional analysis.

A second critical issue is the operational context in which the model(s) is to be applied (Bouma et al., 1994). This brings into focus a set of related issues which deal with the application of the model at the chosen regional level. These issues are clearly the crux of the matter when attempting to select the appropriate spatial and temporal resolution of the database. These issues include (1) the use of the model(s) in regional analysis; (2) the spatial scale of application; (3) the temporal scale of application; and (4) targeted user's groups.

5.2.1 Use of the Model(s) at a Regional Level

A number of decisions regarding the use of the model(s) at the appropriate regional level must be made. Most notably, one must decide on the degree of computation involved and the complexity of the model desired (Bouma et al., 1994).

5.2.1.1 Degree of Computation

It has already been established that quantitative, mechanistic or process-based models are needed to assess the environmental, economic and social impacts of land use on soil or environmental quality (see above). However, if these types of models, which are typically used for site-level analysis with highly detailed data demands, are applied to broad-scale evaluations, the amount of computation time can become overwhelming. Thus, in order to adapt mechanistic models to

regional applications, one must review the data requirements, which leads to a discussion of the degree of complexity involved in the approach.

5.2.1.2 Degree of Complexity

Broad-scale analysis prohibits the definition of a unique dataset for each particular farm within each spatial unit because of the high degree of internal variability. However, given that the proposed models require complex data, a functional approach used in conjunction with the process-based, mechanistic models is needed to reduce the complexity (Bouma et al., 1994). A statistical or “fuzzy” approach might be appropriate. Other ways to reduce complexity would be to use a limited number of landscape models or crop rotations that represent the majority of situations. The lack of data for this approach can be overcome by using “expert opinion”.

The first step in the functional approach to the use of process-based model(s) should involve an examination of each variable (Sections 1 and 2) in the model(s) subroutines to determine whether that variable is appropriate in a regional analysis. Very often, variables important at a site-level, do not have to be processed individually at a broader scale. The distinction between those variables that function at a broad scale and those that do not, can greatly simplify the data needs of the models for regional analysis.

The ‘regional data type’ classification shown in Table 9 is an attempt to classify the data required by the different variables at a regional level in order to minimize the data requirements for each analysis. The number 1 types vary geographically in a systematic fashion, making regular data collection necessary. The number 2 types either do not vary (< 10% value) or vary randomly such that it is appropriate to use a “constant” number in the model. For example, variable # 6, row width, generally has a range of 18 to 20 cm, but the overall impact is small. Further, the variation from operator to operator is completely random within any one region and would not be an important consideration in a comparative assessment. It would seem appropriate to assign a single, “constant” value to this variable. Conversely, variable # 1, crop name or type, changes in response to a number of (generally) economic pressures or opportunities and needs to be determined on a regular basis. This would alter the proportion of cropping systems in an area, but would probably not have a large impact on specific rotations associated within the different “systems”.

Type 3 variables are either derived from the literature, in the case of variable #20, pounds of grain per bushel of grain, or are a theoretical value such as variable #17, the approximate age of residue in a given field. In either case, it is not necessary to physically collect values for these variables on a regular basis.

Type 4 variables are derived from the values of other variables in the database, and therefore do not need to be addressed at the time of data collection. Variables assigned a type 5, are candidates for deletion in the regional land use database. Some of these variables simply do not have a practical application, such as # 38, a variable involved in automatic fertilization. Others represent practices which are not applicable to Canadian situations, such as automatic irrigation, residue burning, and several of the support practices in category nine.

Assuming the above arguments are reasonable, Table 8 could be reorganized to group those factors for which data needs to be collected on a regular basis (Type 1) and those which can be assigned “constants” (Type 2). The result of such a reorganization (Table 9) could become part of the decision process for establishing a regional land use database.

Table 9. Classification of land use variables by Regional Data Type.

No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL ^a VARIATION	REGIONAL ^b DATA TYPE
Type 1 Data				
1	Crop name	Yearly	LRA	1
2	Long term planting date (or start of fallow period)	>5 yrs	LRA	1
3	Seeding rate (kg ha-1)	1-5 yrs	ECR	1
9	Seed cost (\$ kg-1)	Yearly	PRO	1
10	Market price for crop (\$ t-1)	Yearly	PRO	1
11	Potential HU/GDD for growing region	>5 yrs	LRA	1
12	Approx. date to reach senescence/end of a fallow period	1-5 yrs	LRA	1
15	Crop yield (kg ha-1)	Yearly	LRA	1
18	Crop species of last harvest	1-5 yrs	LRA	1
19	Crop species of the second last harvest	1-5 yrs	LRA	1
21	Number of years in the rotation	1-5 yrs	LRA	1
22	Number of crops grown annually	1-5 yrs	LRA	1
23	Tillage operation type	1-5 yrs	LRA	1
25	Date of tillage	1-5 yrs	LRA	1
37	Date of fertilizer application	1-5 yrs	LRA	1
40	Nitrogen fertilizer applied (kg ha-1)	Yearly	LRA	1
42	Phosphorus fertilizer applied(kg ha-1)	Yearly	LRA	1
43	Sulphur fertilizer applied (kg ha-1)	Yearly	LRA	1
46	Nitrogen fertilizer cost (\$ kg-1)	Yearly	PRO	1
47	Phosphorus fertilizer cost (\$ kg-1)	Yearly	PRO	1
49	Lime cost (\$ t-1)	Yearly	PRO	1
51	OM addition type (effect code)	1-5 yrs	LRA	1
53	Pesticide/herbicide application rates (kg ha-1)	Yearly	LRA	1
54	Pesticide/Herbicide cost (\$ ha-1)	Yearly	PRO	1
66	Irrigation water cost (\$ m-3)	1-5 yrs	PRO	1
70	Irrigation date	Yearly	LRA	1
79	Number of grazing animals	1-5 yrs	ECR	1
89	Date of silage removal	1-5 yrs	LRA	1
91	Percent cover of residue	1-5 yrs	LRA	1
93	Supplementary residue additions (lb. ac-1)	1-5 yrs	LRA	1
94	Supplementary residue additions (% cover)	1-5 yrs	LRA	1
Type 2 Data				
5	Crop seeding location in relation to ridge	>5 yrs	ECR	2
6	Row width (m)	>5 yrs	ECR	2
7	Number of rows	>5 yrs	ECR	2
8	In-row plant spacing (m)	>5 yrs	ECR	2
14	Optimal yield under no-stress cond. of a crop (kg m-2)	>5 yrs	ECR	2
26	Ridge height	1-5 yrs	LRA	2
27	Ridge spacing	1-5 yrs	LRA	2
28	Cultivator position	>5 yrs	PRO	2
31	Depth to tile drain	>5 yrs	LRA	2
32	Drainage coefficient	>5 yrs	LRA	2

No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL ^a VARIATION	REGIONAL ^b DATA TYPE
33	Drain tile diameter	>5 yrs	LRA	2
34	Drain tile spacing	>5 yrs	LRA	2
35	Drainage area (ha)	>5 yrs	LRA	2
36	Time required for drainage system to eliminate plant stress	>5 yrs	LRA	2
39	Fraction of maximum N fertilizer potentially applied at planting	1-5 yrs	LRA	2
45	Depth of fertilizer placement (mm)	1-5 yrs	ECR	2
48	Liming code -(0 applies lime ;1 applies no lime)	1-5 yrs	LRA	2
50	Date of organic matter addition	1-5 yrs	LRA	2
52	Date of pesticide/herbicide application	1-5 yrs	LRA	2
56	Irrigation type	>5 yrs	ECR	2
62	Irrigation depth (m)	>5 yrs	ECR	2
63	Sprinkler nozzle impact energy factor	1-5 yrs	ECR	2
64	Irrigation runoff ratio	1-5 yrs	LRA	2
67	Irrigation volume (mm)	1-5 yrs	LRA	2
68	Application rate (m sec-1)	1-5 yrs	LRA	2
69	Ratio of appl'n depth:water to fill profile to field capacity	1-5 yrs	LRA	2
75	Grazing pasture size (m2)	1-5 yrs	ECR	2
76	Number of grazing sequences per year	> 5 yrs	ECR	2
77	Date that grazing begins	> 5 yrs	ECR	2
78	Date that grazing ends	> 5 yrs	ECR	2
80	Digestibility of a perennial crop	> 5 yrs	ECR	2
81	Average body weight of a grazing animal	> 5 yrs	ECR	2
84	Harvest height (m)	> 5 yrs	ECR	2
85	Date cutting/harvest for perennial crop	> 5 yrs	LRA	2
86	Number of cuttings of a perennial crop	> 5 yrs	LRA	2
88	Conversion of veg. biomass to standing residue mass at harvest	> 5 yrs	ECR	2
98	Date of residue removal	1-5 yrs	LRA	2
99	Fraction residue removed through a removal operation	1-5 yrs	LRA	2
100	Fraction of vegetative to flat residue mass removed from the field	1-5 yrs	LRA	2
101	Date of residue shredding/cutting (harvest date in Alberta)	1-5 yrs	LRA	2
102	Fraction of residue mass mechanically shredded/cut	1-5 yrs	ECR	2
Type 3 Data				
17	Age of residue	1-5 yrs	ECR	3
20	Pounds of grain per bushel of grain	>5 yrs	PRO	3
55	Tillage implement that carries a pesticide operation code	1-5 yrs	N/A	3
107	Runoff index value	1-5 yrs	LRA	3
108	PEC value (erosion control practice factor)	1-5 yrs	LRA	3
Type 4 Data				
4	Crop seeding density (p m-2) (derived from 3)	-	N/A	4
13	End date of perennial crop growth (derived from variable 12)	-	N/A	4
16	Dry matter mass of a specific crop (derived from 15)	-	N/A	4

No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL ^a VARIATION	REGIONAL ^b DATA TYPE
24	Operation/Implement effect code(s) (derived from variable 23)	-	N/A	4
29	No. of months when tillage takes place (derived from 23 and 25)	-	N/A	4
30	Fragile/nonfragile operation MFO values (derived from 1 and 23)	-	N/A	4
41	Max. annual N fertilizer application for a crop (derived from 40)	-	N/A	4
44	Fertilization effect code (derived from variables 40, 42 and 43)	-	N/A	4
71	End date of period in which irrigation occurs (derived from 70)	-	-	4
74	Irrigation event code (derived from variables 67, 69 and 73)	-	-	4
82	Grazing effect code (derived partially from 76, 79 and 81)	-	-	4
87	Harvest effect code (derived from 84, 88 and 100)	-	N/A	4
90	Crop residue (t ha ⁻¹) (derived from 15)	-	N/A	4
92	Crop grown prior to the start of the simulation (derived from 18)	-	N/A	4
95	Residue added at harvest of a crop (lb.ac ⁻¹) (derived from 15)	-	N/A	4
96	Veg. D.M. of a per. crop not harvested/grazed (derived from 15)	-	N/A	4
97	Res. management option (derived from management scenario)	-	N/A	4
Type 5 Data				
38	N stress factor to trigger automatic fertilizer	-	PRO	5
57	Water stress factor to trigger automatic irrigation	> 5 yrs	PRO	5
58	Minimum single application volume allowed for automatic (mm)	1-5 yrs	PRO	5
59	Maximum single application volume allowed for automatic (mm)	1-5 yrs	PRO	5
60	Minimum irrigation depth (m)	1-5 yrs	ECR	5
61	Maximum irrigation depth (m)	1-5 yrs	ECR	5
65	Maximum annual irrigation volume allowed for each crop	1-5 yrs	LRA	5
73	Depletion ratio at which irrigation will occur	> 5 yrs	PRO	5
103	Date of burning residue	1-5 yrs	LRA	5
104	Fraction of standing residue mass lost by burning	> 5 yrs	ECR	5
105	Fraction of flat residue mass lost by burning	> 5 yrs	ECR	5
106	Fire effect code (derived from 104 and 105)	-	-	5
109	Contouring - ridge height (m)	> 5 yrs	ECR	5
110	Contouring - furrow grade	> 5 yrs	ECR	5
111	Contouring - slope steepness (m/m)	> 5 yrs	ECR	5
112	Contouring - slope length	> 5 yrs	ECR	5
113	Contouring - row length (m)	> 5 yrs	ECR	5
114	Contouring - row spacing (m)	> 5 yrs	ECR	5
115	Stripcropping - strip width as function of slope length	> 5 yrs	ECR	5
116	Stripcropping - slope steepness	> 5 yrs	ECR	5

No.	VARIABLE NAME	TEMPORAL VARIATION	SPATIAL ^a VARIATION	REGIONAL ^b DATA TYPE
117	Stripcropping - location of lower edge of each strip	> 5 yrs	ECR	5
118	Terracing - terrace grade	> 5 yrs	ECR	5
119	Terracing - spacing	> 5 yrs	ECR	5

a) LRA=Land Resource Area; ECR=Ecoregion; PRO=Province, N/A=Not applicable.

b) For a definition of regional data type, see Section 4.0: Data and Source Characteristics for Regional Land Use Databases.

5.2.2 Spatial scale of application

Arguments relating to complexity and the need for integration of many types of data, point strongly to the need for and benefits of a standard (constant) spatial framework. Given that the purpose for the application of these models in regional analyses centers around evaluating the effect of changing land use patterns on the environmental sustainability of the land resource, the spatial framework would likely have more of an impact if it was based on a natural, land resource concept, rather than on economic or demographic units. In effect, by organizing the data within the framework of an ecologically-based system, one would be linking land use to the land resource base.

The national ecological framework developed by the departments of Agriculture and Environment (Ecological Stratification Working Group 1994), with cooperation from forestry and wildlife provides a natural resource base. Further, it is a hierarchical system which can address several scales ranging from subregional to national and is directly linked to the Soil Landscapes of Canada Series. These natural biophysical landscape units that exist within a definite ecological stratification, provide a natural resource framework in which to conduct broad-scale environmental assessments. They form natural boundaries for the collection of climate, land use and soils information for regional assessments.

The most appropriate natural landscape unit for regional assessments would appear to be the Land Resource Area (LRA). LRA's represent subdivisions of Ecoregions, approximately 100,000 ha in size, with generally similar agroclimate, landform and agricultural (Kirkwood et al., 1993). Studies have shown that the LRA, which can be effectively linked to census data, is a meaningful landscape unit for broad-scale agricultural assessments (Hiley et al., 1989; Hiley and Wehrhahn 1991; Izaurralde et al., 1992).

5.2.3 Temporal scale of application

The temporal scale of application largely depends on the objectives of the analysis. If year to year variability is the goal of the analysis, then clearly, short-term, detailed data is required. If, however, the objectives of the analysis are to assess changes in a particular quality(s) over time, or to assess impacts of major programs or policies, then longer term data sources are required. It is assumed that regional analyses are generally more concerned with trends than annual variation resulting in most of the variables assigned a temporal variation of either 1-5 years, or longer than 5 years. The majority of the variables that vary on an annual basis were commodity-related items such as market prices; crop type and yields; application rates and costs of seed, fertilizers and pesticides.

5.2.4 Model Users

Soil degradation models are currently interfaced in ways that make them accessible to a wide range of users. This can lead to an increased danger in improper application of the models. Misuse can arise when there is a lack of consistent data or the inherent conditions of the model are not understood or met. A single, standard land use regional database would be helpful to a wide range of users, from those who are just beginning and uninterested in the mechanics of the models, to those who are quite sophisticated in their approach and wish to explore the process further. At the very least, a common basis for comparison is provided by the proposed database.

5.3 Conclusions

Based on the above discussion, the following conclusions can be drawn:

1. The principal models being used to assess soil degradation and sustainability require a large number of land use inputs. The analysis of the “user-specified” land use requirements identified some 200 different attributes which could be summarized into 118 unique variables in 9 main categories. When considered within a regional context the number could be further reduced to about 85. Approximately 20 of those are needed on an annual basis, with the remainder being longer term types of variables.
2. Precise databases for regional analyses are largely unavailable and expert opinion was identified as the main source of land use and management data. Of the 85 variables required, data for 12 to 13 could be obtained or inferred from public sources such as Statistics Canada, 4 could be found by consulting the literature, 18 were derived from other variables, while values for the remainder (approximately 40 variables) would need to be obtained by canvassing regional experts.
3. A standard, regional land use database would help address the dangers of unrealistic and inconsistent regional representation. Coordinated data input for all regions would enable consistent reporting of and direct comparisons amongst model output on soil quality, regardless of the users or nature of the studies involved. The database would also function as a means for integrating various model outputs to obtain an overall assessment of soil quality within a given agricultural region, at a given time.
4. Concomitant with the concept of a standard database is the need for a standard geographical reference. This would be the basis for consistent comparisons and areal representation.

6.0 Recommendations

Based on the discussion and conclusions, the following recommendations are suggested:

1. A standard, regional land use database should be developed as a basis for regional assessments of soil quality and environmental sustainability.
2. Since much of the land use data must be obtained from expert sources, a major coordinated survey should be conducted.
3. Since many different agencies are identified, as both sources and users of information, multi-agency collaboration and coordination should be pursued for considerations of efficiency and duplication.
4. The national ecological stratification should be considered as a standard natural resource base for spatial integration.

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8.0 Appendices

Appendix 1. The complete list of model-supplied and “user-specified” land use variables for the EPIC model.

EPIC VARIABLE DESCRIPTION	VARIABLE NAME
CROP GROWTH MODEL	
Crop name	CPNM
Crop category number (1-WSAL; 2-CSAL; 3-PL; 4-WSA; 5-CSA; 6-P; 7-T)	IDC
Seeding rate (kg ha-1)	SDW
Crop residue* (t ha- 1)	RSD
Seed cost (\$ kg-1)	COSD
Price for yield (\$ t-l)	PRY
Biomass energy ratio	WA (t ha-1MJ-1)
Biomass-energy ratio decline rate parameter	RBMD
Optimal temperature for plant growth (oC)	TB
Minimum/Basal air temperature for plant growth (oC)	TG
Potential heat units/GDD for growing season (crop/region specific)	PHU1
Maximum potential leaf area index	DMLA
Leaf area index decline rate parameter	RLAD
Fraction of growing season (HUI) when leaf area starts declining	DLAI
First point on optimal LAI development curve (%)	DLAP1
Fraction LAI development at first point	*
Second point on LAI development curve (%)	DLAP2
Fraction LAI development at the second point	*
Harvest Index of an unstressed crop (kg kg-1)	HI
Maximum crop/canopy height (m)	HMX
Maximum root depth (m)	RDMX
Critical aeration factor	CAF
Aluminum tolerance index (1 = sensitive; 5-tolerant)	ALT
Water stress--crop yield factor	WSYF
Pest (insects, weeds and disease)	PST
Fraction water in yield	WCY
Fraction of nitrogen in yield (kg kg-1)	CNY
Nitrogen uptake parameter (N fraction in plant at emergence)	BN1
Nitrogen uptake parameter (N fraction in plant at 0.5 maturity)	BN2
Nitrogen uptake parameter (N fraction in plant at maturity)	BN3
Fraction of phosphorus in yield (kg kg-1)	CPY
Phosphorus uptake parameter (P fraction in plant at emergence)	BP1
Phosphorus uptake parameter (P fraction in plant at 0.5 maturity)	BP2
Phosphorus uptake parameter (P fraction in plant at maturity)	BP3
Wind erosion factor for standing live biomass	BW1
Wind erosion factor for standing dead crop residue	BW2
Wind erosion factor for flat residue	BW3
First point on frost damage curve minimum temperature (oC)	FRST1
Fraction of yield lost at above temperature	*
Second point on frost damage curve minimum temperature (oC)	FRST2
Fraction of yield lost at above temperature	*

EPIC VARIABLE DESCRIPTION	VARIABLE NAME
TILLAGE SUBMODEL	
Tillage operation ID No.	LT
Month of tillage operation	MT
Day of month of tillage	IT
Crop ID No. (used only at planting)	KDC
Operation/Implement effect code	IHC
Runoff curve number	CN21
Equipment name (up to 8 characters)	TIL
Cost of operation \$ ha-1	COTL
Mixing efficiency of operation	EMX
Surface random roughness created by operation (mm)	RR(m)
Tillage depth (mm)	TLD (+/-)
Ridge height after tillage operation (mm)	RHT
Ridge interval (m)	RIN
Furrow dike height (mm)	DKH
Furrow dike interval (m)	DKI
Harvest efficiency	HE
Override of harvest index (HI)	ORHI
PLANT ENVIRONMENTAL CONTROL SUBMODEL - IRRIGATION	
Irrigation code /Flag indicating irrigation system (SS)	IRR
Min. appln interval for auto. irrigation (d); For manual irrigation--0 applies volume	IRI
Water stress factor to trigger automatic irrigation	BIR
Min. single application vol. allowed for auto.(mm)	ARMN1
Max. single application vol. allowed for auto. (mm)	ARMX1
Irrigation runoff ratio	EFI
Maximum annual irrigation volume allowed for each crop (mm)	VIMX1
Month of irrigation application	MO
Day of month of irrigation application	IDA
Irrigation water cost (\$ m-3)	COIR
Irrigation volume (mm)	VIRR
PLANT ENVIRONMENTAL CONTROL SUBMODEL - FERTILIZERS/AMENDMENTS	
Minimum fertilizer application interval for automatic option (d)	IFA
Liming code --(0 applies lime automatically; 1 applies no lime)	LM
N stress factor to trigger automatic fertilizer	BFT
Fraction of maximum N fertilizer potentially applied at planting	FNP1
Maximum annual N fertilizer application for a crop (kg ha-1)	FMX1
Month of fertilizer application	MO
Day of month of fertilizer application	IDA
Nitrogen fertilizer applied	FN (kg ha-1)
Phosphorus fertilizer applied	FP (kg ha-1)
Depth of fertilizer placement (mm)	FDP
Nitrogen fertilizer cost (\$ kg-1)	CON
Phosphorus fertilizer cost (\$ kg-1)	COP
Lime cost (\$ t-1)	COL
PLANT ENVIRONMENTAL CONTROL SUBMODEL - DRAINAGE	
Drainage area (ha)	DA

EPIC VARIABLE DESCRIPTION	VARIABLE NAME
Drainage code (0- no drainage; 1-10 for soil layer with drainage system)	IDR
Time required for drainage system to eliminate plant stress	DRT
PESTICIDE FATE SUBMODEL	
Tillage implement that carries a pesticide operation code	*
Pesticide application date	*
Pesticide application rate (kg ha-1)	*
Pesticide ID number	*
SUPPORT PRACTICES (P Factor)	
PEC Value (erosion control practice factor)	PEC

Appendix 2. The complete list of model-supplied and “user-specified” land use for the WEPP model.

WEPP VARIABLE DESCRIPTION	VARIABLE NAME
CROP GROWTH SUBMODEL	
Cropland	
Landuse type (cropping type) (1-crop, 2-range, 3-forest, 4-roads)	IPLANT
Cropping type (1-annual, 2-perennial, 3-fallow)	IMNGMT
Number of years in the rotation	NYEARS
Number of crops grown annually	NYCROP
Crop name	*
Crop ID No.	RESMAN
Julian date of planting	JDPLT
Row width (m)	RW
Number of rows	NUMOF
In-row plant spacing (m)	PLTSP
Crop residue* (t ha- 3)	RESMAN
Crop grown prior to the start of the simulation	IRES
Canopy height parameter (biomass vs. canopy ht.)	BBB
Canopy cover parameter (biomass vs. canopy cover)	BB
Biomass energy ratio	BEINP (kg MJ-1)
Optimal temperature for plant growth (oC)	OTEMP
Minimum/Basal air temperature for plant growth (oC)	BTEMP
Growing degree days(GDD) to plant emergence	CRIT
Potential heat units/GDD for growing season (crop/region specific)	GDDMAX
Maximum potential leaf area index	MXLAI
Fraction of growing season (HUI) when leaf area starts declining	DLAI
Harvest Index of an unstressed crop (kg kg-1)	HI
Equation of biomass remaining after senescence	DROPFC
Radiation extinction coefficient	EXTNCT
Residue mass to % surface cover conversion	CF
Critical grazing biomass (kg m-2)	CRITVM
Period over which senescence occurs (days)	SPRIOD
Critical freezing temp. of a perennial crop (oC)	TMPMIN
Critical upper temp. of a perennial that induces dormancy (oC)	TMPMAX
Approx. date to reach senescence (perennial crop)/end of fallow period	JDHARV
Perennial crop growth stop date (Julian date)	JDSTOP

WEPP VARIABLE DESCRIPTION	VARIABLE NAME
Max. root biomass of a perennial crop (kg m ⁻²)	RTMMAX
Cutting height (m)	CUTHGT
Maximum crop/canopy height (m)	HMAX
Maximum root depth (m)	RDMAX
Root to shoot ratio	RSR
Fraction of canopy cover remaining after senescence	DECFACT
Plant stem diameter at maturity (m)	DIAM
Plant drought tolerance factor	PLTOL
Nitrogen uptake parameter (N fraction in plant at emergence)	BN1
Nitrogen uptake parameter (N fraction in plant at 0.5 maturity)	BN2
Nitrogen uptake parameter (N fraction in plant at maturity)	BN3
Phosphorus uptake parameter (P fraction in plant at emergence)	BP1
Phosphorus uptake parameter (P fraction in plant at 0.5 maturity)	BP2
Phosphorus uptake parameter (P fraction in plant at maturity)	BP3
Hydraulic roughness factor for a living plant	FLIVMAX
Wind/snow adjustment factor for standing to flat residue	FACT
Optimal yield under no-stress conditions (kg m ⁻²)	YLD
Pounds of grain per bushel of grain	Y4
Harvest units (bu a-1, kg ha-1, t a-1, etc.)	CRUNIT
Rangeland (Native range)	
Surface residue mass coefficient	ACA
Root mass coefficient	AR
Insect removal of surface organic material (kg m ⁻² , daily)	BUGS
Soil surface covered by coarse fragments	WCF
Soil surface covered by cryptogams	CRYPTO
C:N ratio of residue and roots	CN
Standing biomass, canopy cover = 100% (kg m ⁻²)	COLD
Frost free period	FFP
Min. temp. to initiate growth	GTEMP
Projected plant area coeff. for herbaceous plants	GCOEFF
Average diameter for herbaceous plants (m)	GDIAM
Average no. of herbaceous plants along a 100 m transect	GPOP
Proportion of biomass produced during 1st growing season	CF1
Proportion of biomass produced during 2nd growing season	CF2
Parameter value for canopy height equation	BBB
Initial frost depth	FRDP
Mean height for grasses (m)	GHGT
Max. herbaceous plant height (m)	HMAX
Average shrub height (m)	SHGT
Average no. of shrubs along a 100m transect	SPOP
Projected plant area coeff. for shrubs	SCOEFF
Average canopy diameter for shrubs (m)	SDIAM
Average tree height (m)	THGT
Projected plant area coeff. for trees	TCOEFF
Average canopy diameter for trees	TDIAM
Average no. of trees along a 100 m transect	TPOP
Leaf wt.:leaf area coefficient (m ² kg ⁻¹)	ALEAF
Min. amount of live biomass	RGCMIN
Initial standing non-decomposable woody biomass (trees)	WOOD

WEPP VARIABLE DESCRIPTION	VARIABLE NAME
Initial standing AG biomass (kg m-2)	OLDPLT
Max. potential standing live AG biomass (kg m-2)	PLIVE
Date of peak standing crop(1st growing season)	PSCDAY
Date of peak standing crop(2nd growing season)	SCDAY2
Root mass in top 0.10 m (kg m-2)	ROOT10
Initial fraction of live and dead roots	ROOTF
Min. temp. to initiate senescence	TMPMIN
Critical upper temp. of a perennial crop that induces dormancy	TMPMAX
Plant drought tolerance factor	PLTOL
DECOMPOSITION (Crop specific parameters)	
Fragile or nonfragile operation MFO values (RESMAN)	MFOCOD
Decomposition constant (mass change in AG biomass) (RESMAN)	ORATEA
Decomposition constant (mass change in BG biomass) (RESMAN)	ORATER
Residue mgmt. option (1-herbicide, 2-burning, 3-silage, 4-shred/cut, 5-removal, 6-none)	RESMGT
MANAGEMENT SUBMODEL	
TILLAGE OPERATIONS	
Julian date of tillage	MDATE
Operation/Implement effect code (CENTURY-C, R, D, H etc.)	PCODE
Cultivator position	CLTPOS
Number of rows of tillage implement	NUMOF
Tillage type	TYPTIL
Random roughness (in)	RRO (m)
Tillage depth (in)	TILDEP (m)
Tillage depth (mm)	TDMEAN (m)
Ridge height after tillage operation (mm)	RHO (m)
Ridge interval (m)	RINT
Fraction of surface area disturbed	SURDIS
Rill/interrill tillage intensity for fragile crops (RESMAN)	MFO1
Rill/interrill tillage intensity for nonfragile crops (RESMAN)	MFO2
Primary tillage layer (m)	TILLAY (1)
Secondary tillage layer (m)	TILLAY (2)
DRAINAGE OPERATIONS	
Depth to tile drain (m)	DDRAIN
Drainage coefficient (m/day)	DRAINC
Drain tile diameter (m)	DRDIAM
Drain tile spacing (m)	SDRAIN
PLANT MANAGMENT	
GRAZING	
Grazing pasture size (m2; perennial and rangeland)	AREA
No. of grazing sequences per year	JGRAZ
Fraction of forage available for consumption	ACCESS
Date that grazing begins	GDAY
End of a grazing period	GEND
No. of annual grazing cycles	NCYCLE
No. of grazing animals	ANIMAL

WEPP VARIABLE DESCRIPTION	VARIABLE NAME
Digestibility of a perennial crop	DIGEST
Maximum digestibility of forage (rangeland)	DIGMAX
Minimum digestibility of forage (rangeland)	DIGMIN
Supplemental feed (day starts)	SEND
Supplemental feed (day ends)	SSDAY
Average amount of supplement feed per day (kg animal-1)	SUPPMT
Average body weight of a grazing animal	BODYWT
CUTTING/HARVEST	
Date cutting/harvest for perennial crop	CUTDAY
Number of cuttings of a perennial crop	NCUT
Harvest date (annual crop)	JDHARV
Date of silage removal	JDSLGE
Vegetative D.M. of a perennial crop not harvested/grazed (kg m-2)	TOTHAV
HERBICIDE	
Soil/foliar herbicide	ACTIVE
Fraction of change in evergreen biomass after herbicide	HERB
Date of herbicide applications rangelands	IHDATE
Date of herbicide application (cropland, rangeland/perennial, fallow)	JDHERB
Fraction decrease in live AG biomass from herbicide	DLEAF
Fraction change in AG/BG potential biomass production from herbicides	REGROW
Fraction increase in forage foliage	UPDATE
Decomposition of woody biomass due to herbicides	WOODY
RESIDUE MANAGEMENT	
SHREDDING	
Fraction of standing residue mass mechanically shredded/cut	FRCUT
Date of residue shredding/cutting	JDCUT
RESIDUE HARVESTING	
Fraction of veg./flat residue mass removed from the field	FRMOVE
Conversion of veg. biomass to standing res. mass at harvest	PARTCF
Date of residue removal	JDMOVE
BURNING	
Fractional increase in forage accessibility after burning (Rangeland)	ALTER
Fraction of change in standing dead biomass from burning (Rangeland)	BURNED
Change in potential AG biomass production from burning (Rangeland)	CHANGE
Fraction of standing residue mass lost by burning (Cropland)	FBRNAG
Fraction of flat residue mass lost by burning (Cropland)	FBRNOG
Fraction of change in evergreen biomass after burning (Rangeland)	HURT
Julian date of burning residue (Julian date) (Cropland)	JDBURN
Julian day of burning rangeland (Julian date)	JFDATE
Fraction of reduction in litter and organic residue form burning (Rangeland)	REDUCE
IRRIGATION SUBMODEL	
Irrigation code /Flag indicating irrigation system (SS)	IRSYST
Irrigation scheduling option (0-None; 1-Depletion level; 2-Fixed Date; 3-Combination)	IRTYPE
Min. single application vol. allowed for auto.(mm)/Minimum irrigation depth (m)	IRDMIN
Max. single application vol. allowed for auto. (mm)/Maximum irrigation depth (m)	IRDMAX

WEPP VARIABLE DESCRIPTION	VARIABLE NAME
Sprinkler nozzle impact energy factor	NOZZLE
Depletion level Irrigation	
Flag identifying the OFE's for which the remaining elements of the line apply (SS&FI)	OFEFLG
Application rate of the irrigation system (m sec-1)	IRRATE
Ratio of appln. depth to water needed to fill profile to FC for max. rooting depth	APRATI (MXPLAN)
Julian date at beginning of period for which irrigation might occur	IRBEG
Year of beginning of period during which irrigation might occur (year)	YRBEG
Julian date at end of period during which irrigation might occur	IREND
Depletion ratio at which irrigaiton will occur	DEPLEV
Year of end of period during which irrigation might occur (year)	YREND
Fixed Date Irrigation (WEPP)	
Flag identifying the OFE for which the remaining elements of the line apply	OFEFLG
Application rate of the system (m sec-1)	IRRATE
Irrigation depth (m)	IRAMT
Julian date of an irrigation event (Julian date)	IRDAY
Year of the irrigation event (Year)	IRYR
FERTILIZERS/AMENDMENTS	
SUPPORT PRACTICES	
Contouring - ridge height	RDGHGT (m)
Contouring - slope steepness	CNTSIP (m/m)
Contouring - row length	ROWLEN (m)
Contouring-row spacing	ROWSPC (m)

Appendix 3. The complete list of model-supplied and “user-specified” land use variables for the WERM model.

WERM VARIABLE DESCRIPTION	VARIABLE NAME
CROP GROWTH SUBMODEL	
Crop name	NAM
Crop ID No.	ID
Crop seeding density (p m-2)	POP
Crop seeding location in relation to ridge	RG
In-row plant spacing (m)	ROW
Plant population density (p m-2)	PPD
Ht. a for LAIZ/SAIZ/LAI/canopy estimation*(m)	HTA
Ht. b for LAIZ/SAIZ/LAI/canopy estimation*(m)	HTB
Canopy cover a for canopy cover estimation*	CCA
Canopy cover b for canopy cover estimation*	CCB
Parameter in the radiation use efficiency 's-curve'	A-CO
Parameter in the frost damage 's-curve'	A-FR
Parameter in the plant height 's-curve'	A-HT
Parameter in the HI 's-curve'	A-HI
Parameter in the leaf area index 's-curve'	A-LA
Parameter relating stem mass to leaf area 's-curve'	A-ST
Parameter in the radiation use efficiency 's-curve'	B-CO
Parameter in the frost damage 's-curve'	B-FR
Parameter in the plant height 's-curve'	B-HT
Parameter in the HI 's-curve'	B-HI
Parameter in the leaf area index 's-curve'	B-LA
Parameter relating stem mass to leaf area 's-curve'	B-ST
Leaf area index a for LAI estimation*	LAA
Leaf area index b for LAI estimation*	LAB
x and y coordinate for 1st pt. on optimal LAI curve	PT1
x and y coordinate for 2nd. pt. on optimal LAI curve	PT2
Leaf area a for LAIZ estimation*(m2)	LZA
Leaf area b for LAIZ estimation*(m2)	LZB
Biomass energy ratio	BE (kg MJ-1ha-1)
Biomass-energy ratio decline rate parameter	BED
Optimal temperature for plant growth (oC)	TOPT
Minimum/Basal air temperature for plant growth (oC)	TBAS
Potential heat units/GDD for growing season (crop/region specific)	PHU
Maximum potential leaf area index	SLAIX
Specific leaf area (m2 g-1)	SLA
Leaf area index decline rate parameter	RLAD
Fraction of growing season (HUI) when leaf area starts declining	HUIO?
LAI when senescence begins	SLAJO
Percent of total leaf area in 1/5 of crop height (%)	PLA(L)
Harvest Index of an unstressed crop (kg kg-1)	HI
Radiation extinction coefficient	CK
Maximum crop/canopy height (m)	HMX
Maximum root depth (m)	RDMX
Genotype specific rooting coefficient	WCG
Depth to the middle of a soil layer (m)	ZA
Depth to the bottom of the root zone(m)	Z(NS)
Crop C:N ratio	CN

WERM VARIABLE DESCRIPTION	VARIABLE NAME
Critical aeration factor	CAF
Aluminum tolerance index (1 = sensitive; 5-tolerant)	ALT
Stress factor	REG
Fraction water in yield	FWY
Fraction of nitrogen in yield (kg kg ⁻¹)	FNY
Fraction of phosphorus in yield (kg kg ⁻¹)	FPY
Wind erosion factor for standing live biomass	BW1
Wind erosion factor for standing dead crop residue	BW2
Wind erosion factor for flat residue	BW3
Minimum value of C factor for water erosion	CMN
DECOMPOSITION SUBMODEL	
Mass to cover conversion coeff. fresh residue (crop specific table value)	CF1
Mass to cover conversion coeff. old residue (crop specific table value)	CF2
Mass to cover conversion coeff.	COVFACT
Decomposition rate constant (using pool id)	DKORATEA
Decomposition constant (species specific) leaves and stems	DKRATE
Decomposition constant (species specific) roots	DKRATER
Decomposition constant for stem number (species specific)	DKRATESN
Age of residue	IAGE
Species ID of most recent harvest	IDRES
Species ID of the penultimate harvest	IDRESO
Stem diameter	STMDIAM(iage)
Stem height	STMHT(iage)

Appendix 4. The complete list of model-supplied and “user-specified” land use variables for the Century model.

CENTURY VARIABLE DESCRIPTION	VARIABLE NAME
CROP INPUT FILE	
Number of years in the rotation	*
Crop name	*
Value of aglive at full canopy cover, above which potential production is not reduced	FULCAN
Optimal temperature for plant growth (oC)	PPDF(1)
Minimum/Basal air temperature for plant growth (oC)	
Max. temp. for production (Poisson Density Function curve for temp. effect on growth)	PPDF(2)
Left curve shape for Poisson Density Function curve	PPDF(3)
Planting month red. factor to limit seedling growth; should be 1.0 for grass (Range: 0-1)	PLTMRF
Harvest Index of an unstressed crop (kg kg-1)	HIMAX (C mass)
Fall rate (fraction of standing dead which falls each month)	FALLRT
Max. root death rate for dry soil cond's. modified by soil moisture status (fraction/month)	RDR
Physiological shutdown temp. for root death and change in shoot/root ratio	RTDTMP
Initial fraction of C allocated to roots; for Great Plains equation based on precip., set to 0	FRTC(1)
Final fraction of carbon allocated to roots	FRTC(2)
Time after planting (months with soil temp. > rtdtmp) at which final value is reached (root C)	FRTC(3)
Intercept param. for computing min. C/N ratio for BG matter as a linear function of annual precip.	PRNMN(1,1)
Slope param. for above equation	PRBMN(1,2)
Intercept param. for computing min. C/P ratio for BG matter as a linear function of annual precip.	PRBMN(2,1)
Slope param. for above equation	PRBMN (2,2)
Intercept param.r for computing min. C/S ratio for BG matter as a linear function of annual precip.	PRBMN (3,1)
Slope param. for above equation	PRBMN (3,2)
Intercept param. for computing max. C/N ratios for BG matter as a linear function of annual precip.	PRBMX (1,1)
Slope param. for above equation.	PRBMX (1,2)
Intercept param. for computing max. C/P ratios for BG matter as a linear function of annual precip.	PRBMX (2,1)
Slope param. for above equation.	PRBMX (2,2)
Intercept param. for computing max. C/S ratios for BG matter as a linear function of annual precip.	PRBMX (3,1)
Slope param. for above equation	PRBMX (3,2)
Symbiotic nitrogen fixation maximum (g N fixed/g C new growth)	SNFXMX
Minimum C/N ratio with zero biomass	PRAMN (1,1)
Minimum C/N ratio with biomass equal biomas	PRAMN (1,2)
Minimum C/P ratio with zero biomass	PRAMN (2,1)
Minimum C/P ratio with biomass equal biomas	PRAMN (2,2)
Minimum C/S ratio with zero biomass	PRAMN (3,1)
Minimum C/S ratio with biomass equal biomas	PRAMN (3,2)
Maximum C/N ratio with zero biomass	PRAMX (1,1)

CENTURY VARIABLE DESCRIPTION	VARIABLE NAME
Maximum C/N ratio with biomass equal biomax	PRAMX(1,2)
Maximum C/P ratio with zero biomass	PRAMX(2,1)
Maximum C/P ratio with biomass equal biomax	PRAMX (2,2)
Maximum C/S ratio with zero biomass	PRAMX(3,1)
Maximum C/S ratio with biomass equal biomax	PRAMX(3,2)
Intercept for equation to predict lignin content fraction based on annual rainfall for AG material (Range: 0-1)	FLIGNI(1,1)
Slope for above equation; (Range: 0-1); For crops set to 0	FLIGNI(2,1)
Intercept for equation to predict lignin content fraction based on annual rainfall for BG material (Range: 0-1)	FLIGNI(1,2)
Slope for above equation ; (Range: 0-1); For crops set to 0	FLIGNI(2,2)
Level of AG standing dead + 10% strucc(l) C at which production is half max. (g/m2)	BIOK5
Level of AG standing dead + 10% strucc(l) C at which prod. is (half) max. (g/m2)	BIOMAX
Harvest index water stress factor	HIWSF
No. of months prior to harvest in which to begin accumulating water stress effect on HI	HIMON(1)
No. of months prior to harvest in which to stop accumulating water stress effect on HI	HIMON(2)
No. of soil layers in top level of water model; determines avh2o(l) for plant growth and root death	NLAYPG
Max. fraction of shoots dying each month due to drought (this is multiplied by effect of soil water on death)	FSDETH(l)
Fraction of shoots which die during senescence month; For crops set to 0.	FSDETH (2)
Add'l. fraction of shoots which die when AG live C is greater than fsdeth(4)	FSDETH (3)
The level of AG C above which shading occurs and increases senescence	FSDETH (4)
Fraction of AG nitrogen which goes to grain (Range: 0-1)	EFGRN(1)
Fraction of AG plant N which is volatilized (occurs only at harvest)	VIOSSP
Fraction of AG phosphorus which goes to grain (Range: 0-1)	EFGRN (2)
Fraction of AG sulphur which goes to grain (Range: 0-1)	EFGRN(3)
Potential above ground monthly production for crops (g/m2)	PRDX(1)
Delta 13C value for stable isotope labeling	DEL 13C
CULTIVATION INPUT FILE	
Month of tillage operation	*
List of months when cultivation takes place (number of cultivations)	CULTMO
Operation/Implement effect code (CENTURY-C, R, D, H etc.)	*
Fraction of above ground live transferred to standing dead	CULTRA (1)
Fraction of above ground live transferred to surface litter	CULTRA (2)
Fraction of above ground live transferred to the top soil layer	CULTRA (3)
Fraction of standing dead transferred to surface litter	CULTRA (4)
Fraction of standing dead transferred to top soil layer	CULTRA (5)
Fraction of surface litter transferred to top soil layer	CULTRA (6)
Fraction of roots transferred to top soil layer	CULTRA (7)
Cultivation factor for som1 decomposition	CLTEFF (1)
Cultivation factor for som2 decomposition	CLTEFF (2)
Cultivation factor for som3 decomposition	CLTEFF (3)
Cultivation factor for soil structural material decomposition	CLTEFF(4)

CENTURY VARIABLE DESCRIPTION	VARIABLE NAME
FERTILIZER INPUT FILE	
Fertilization effect code	*
Key for automatic fertilization	AUFERT
Aufert = 0: no automatic fertilization	
Aufert < 1.0: applied to a certain threshold value which is the fraction of potential	
C production (temperature and moisture limited) which will be maintained	
Aufert > 1.0: increase nutrient concentrations between min. & max. levels	
Aufert = 2 .0: applied to the maximum level	
Month of fertilizer application	*
Nitrogen fertilizer applied	FERAMT(1) (g m-2)
Phosphorus fertilizer applied	FERAMT(2) (g m-2)
S fertilizer applied	FERAMT(3) (g m-2)
HARVEST INPUT FILE	
Month of harvest operation	*
Harvest effect code	*
Fraction of AG live biomass which will not be affected by harvest operations	AGLREM
Fraction of BG live biomass which will not be affected by harvest operations	BGLREM
Is equal to 1 if the grain is to be harvested, 0 otherwise	FLGHRV
Fraction of veg./flat residue mass removed from the field	RMVSTR
Fraction of the remaining residue that will be left standing	REMWSD
Fraction of roots that will be harvested	HIBG
ORGANIC AMENDMENTS INPUT FILE	
Month of organic matter addition	*
OM addition effect code	*
Grams of C added with the addition of organic matter (g m-2)	ASTGC
Fraction of added C which is labeled (through OM additions; Range 0-1)	ASTLBL
Lignin content of organic matter (Range 0-1)	ASTLIG
C/N ratio of added organic matter	ASTREC(1)
C/P ratio of added organic matter	ASTREC(2)
C/S ratio of added organic matter	ASTREC(3)
BURNING INPUT FILE	
Month of fire event	*
Fraction of live shoots removed by a fire event (Range: 0-1)	FLFREM
Fraction of standing residue mass lost by burning (Cropland)	FDFREM (1)
Fraction of flat residue mass lost by burning (Cropland)	FDFREM (2)
Fire effect code	*
Fraction of C returned to surface litter by a fire event	FFCRET
Fraction of N in AG material returned by a fire event (Range: 0-1)	FRET(1)
Fraction of P in AG material returned by a fire event (Range: 0-1)	FRET(2)
Fraction of S in AG material returned by a fire event (Range: 0-1)	FRET(3)
Additive effect of burning on root/shoot ratio	FRTSH
Effect of fire on increase in maximum C/N ratio of shoots	FNUE (1)
Effect of fire on increase in maximum C/N ratio of roots	FNUE (2)
GRAZING INPUT FILE	
Month of grazing event	*
Fraction of live shoots removed by a grazing event (Range: 0-1)	FLGREM

CENTURY VARIABLE DESCRIPTION	VARIABLE NAME
Fraction of standing dead removed by a grazing event (Range: 0-1)	FDGREM
Fraction of above ground material returned by a grazing event for carbon	GFCRET
Fraction of N in AG material returned by a grazing event (Range: 0-1)	GRET (1)
Fraction of P in AG material returned by a grazing event (Range: 0-1)	GRET (2)
Fraction of S in AG material returned by a grazing event (Range: 0-1)	GRET(3)
Grazing effect code	*
Effect of grazing on production	GRZEFF
= 0 no direct effect	
= 1 moderate effect (linear decrease in production)	
=2 intensively grazed production effect (quadratic effect on production)	
Fraction of N in AG material returned as feces (Range: 0-1)	FECF(1)
Fraction of P in AG material returned as feces (Range: 0-1)	FECF(2)
Fraction of S in AG material returned as feces (Range: 0-1)	FECF(3)
Lignin content of feces (Range: 0-1)	FECLIG
IRRIGATION INPUT FILE	
Month of irrigation application	*
Irrigation event code	*
Controls application of automatic irrigation	AUIRRI
= 0 automatic irrigation is off	
= 1 irrigate to field capacity	
= 2 irrigate with a specified amount of water applied	
= 3 irrigate to field capacity plus PET	
Fraction of AWHC below which automatic irrigation will be used when auirri = 1 or 2	FAWHC
Amount of water to apply automatically when auirri = 2 (cm)	IRRAUT
Amount of water to apply regardless of soil water status (cm)	IRRAMT

Appendix 5. The complete list of model-supplied and “user-specified” land use variables for the RUSLE model

RUSLE VARIABLE DESCRIPTION	VARIABLE NAME
CROP DATABASE	
Number of years in the rotation	*
Number of CROP database sets	*
Crop name (up to 4 characters-EPIC)	*
Crop category (cultivated vs. pasture/rangeland)	*
Canopy cover development (15 d intervals; % land surface covered)	*
Canopy height development (15 d intervals; ft, Effective canopy droplet fall height	*
Senescence option	*
Root mass in upper 4 of soil (lb. ac-1)	*
Other residue additions (lb. ac-1)	*
Other residue additions (% cover)	*
Residue added at harvest of a crop (lb.ac-1)	*
Yield to residue conversion ratios	*
Residue cover to residue mass conversion factors (at 30, 60 and 90% cover; lb. ac-1)	*
Decay constants for surface residue (RUSLE-CROP)	*
Decay constants for subsurface residue (RUSLE-CROP)	*
Decay constants for root residue (RUSLE-CROP)	*

RUSLE VARIABLE DESCRIPTION	VARIABLE NAME
OPERATIONS DATABASE	
Operation type	*
Julian date of tillage	*
Random roughness (in)	*
Tillage depth (in)	*
% soil surface disturbed	*
Fraction residue removed through a removal operation (burning, baling, etc.)	*
% residue left on surface after each operation	*
Operation effect: - 1 No effect	*
- 2 Soil surface disturbed	*
- 3 Current crop residue added to surface	*
- 4 Other residue added to surface	*
- 5 Crop residue added to surface	*
- 6 Current crop harvested	*
- 7 Crop growth begins	*
- 8 Current crop is killed	*
- 9 Call in a new crop growth set.	*
SUPPORT PRACTICES (P factor)	
Runoff index value	*
Contouring - ridge height	*
Contouring - furrow grade	*
Contouring - slope steepness	*
Contouring - slope length	*
Stripcropping - strip width as function of slope length	*
Stripcropping - slope steepness	*
Stripcropping - location of lower edge of each strip; cover-mgmt for each strip	*
Terracing - terrace grade	*
Terracing - spacing	*

Appendix 6. "User-specified" land use variables for the rangeland land use type of WEPP.

VARIABLE LIST FOR NATIVE RANGE	WEPP
Crop Related Parameters	
Rangeland type	
Frost free period	X
Average no. of herbaceous plants along a 100 m transect	X
Proportion of biomass produced during 1st growing season	X
Proportion of biomass produced during 2nd growing season	X
Max. herbaceous plant height (m)	X
Average shrub height (m)	X
Average no. of shrubs along a 100m transect	X
Average tree height (m)	X
Average no. of trees along a 100 m transect	X
Initial standing non-decomposable woody biomass (trees)	X
Initial standing AG biomass (kg m ⁻²)	X

VARIABLE LIST FOR NATIVE RANGE	WEPP
Initial fraction of live and dead roots	X
Max. potential standing live AG biomass (kg m ⁻²)	X
Date of peak standing crop(1st growing season)	X
Date of peak standing crop(2nd growing season)	X
Dry matter mass of rangeland	
Percent cover of rangeland	
Herbicide	
Soil/foliar herbicide	X
Fraction of change in evergreen biomass after herbicide	X
Date of herbicide applications	X
Fraction decrease in live AG biomass from herbicide	X
Fraction change in AG/BG biomass	X
Change in forage accessibility	X
Decomposition of woody biomass due to herbicides	X
Herbicide cost (\$ ha ⁻¹)	
Plant Management	
Grazing	
Grazing pasture size (m ²)	X
Fraction of forage available for consumption	X
No. of grazing sequences per year	X
Date that grazing begins	X
Date that grazing ends	X
No. of grazing animals	X
Maximum digestibility of forage	X
Minimum digestibility of forage	X
Date that supplemental feed starts	X
Date that supplemental feed ends	X
Average amount of supplement feed per day (kg animal ⁻¹)	X
Average body weight of a grazing animal	X
Grazing effect code	
Residue Management	
Burning	
Fractional increase in forage accessibility after burning	X
Fraction of change in standing dead biomass from burning	X
Change in potential AG biomass production from burning	X
Fraction of change in evergreen biomass after burning	X
Date of burning rangeland	X
Fraction of reduction in litter and organic residue from burning	X
Fire effect code	

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