Manitoba Soil Sustainability in the 21st Century

Manitoba Envirothon Workshop, 11th April, 2003, Fairholme Hutterite Colony.
Comments by Geoffrey Scott, University of Winnipeg

Background: Farmers often say that, "the answer lies in the soil!" While they often use this statement with a smile on their faces, the reality is that the statement is very, very, true. Just consider what soils may have contributed to the food and beverages you have already consumed this morning!

Today the soils landscapes of Manitoba receive great attention from farmers, foresters sustainable resource people, conservationists and other experts. The more we learn about soils and plant relationships the more we are adjusting planting/tillage practices, plant nutrient management, and crops to overcome some of the abuses of the past, and to ensure our soil resources remain sustainable into the forseable future. Ensuring sustainability of agricultural soils is a difficult task because to use soil we must first remove that natural vegetation cover which both protected and gave rise to the development of that particular soil in the first place. Techniques which allow us to replicate as much as possible the effects of the original vegetation cover on reducing soil erosion and providing a healthy growing medium for plant roots must be improved and adopted wherever possible. Beyond simply conserving soil against say wind erosion, we must also consider techniques which can actually improve agricultural productivity, and we must consider how best to manage our soils if "global warming" becomes a reality.

To help us better appreciate our soils resources in Manitoba and how we can best protect their sustainability we will review the following topics:

1. Just what are soils and what are they made from?
2. Soil genesis, classification and mapping
3. Soil Capability for agriculture/forestry
4. Factors that influence soil capability
5. Factors influencing soil erosion and sustainability
6. Techniques that help promote soil sustainability
7.

1. Just what are soils and what are they made from?

The following two definitions suggest defining the term soil is difficult!

"A soil is a naturally occurring body of mineral and/or organic material on the surface of the Earth capable of supporting plant life"

"Soils are to the Earth as membranes are to the plant or animal cell - they act as the interface between the inorganic and the organic, the dead and the living."

There are four fundamental constituents in soil:

1. mineral material
2. organic material
3. water
4. air

While mineral material seems obvious, some 36% of Manitoba soils are actually classified as being made primarily from organic material (mostly peat associated with wetlands). In addition, mineral soils always contain small-to-large amounts of organic material, primarily soil humus. Typical mineral agricultural top-soils around Portage la Prairie, or Swan River, would have 4 - 8% organic matter contents. Retaining water for plant use also seems obvious, and we must remember that as in our own lungs, most plant roots need to take in dissolved oxygen directly from the soil solution in which they are in contact, and this can be easily achieved if there is a soil atmosphere well supplied with oxygen which can move through open passageways (macropores) from the soil surface.

2. Soil genesis, classification and mapping

Soils can be divided into three generalized groupings:

1. **Zonal**
2. **Intrazonal**
3. **Azonal**
4.

Zonal soils reflect the zonal nature of their climate/vegetation over time - for example the Black Chernozemic soils of our mixed and tall grass prairie, and of the Russian Steppe. **Intrazonal** soils reflect local peculiarities over time such as a high water table so could be found here close to the Fairholme Hutterite Colony, or even in our boreal forest or in the tropical rain forest of Brazil (i.e. found within any climatic zone as with our Gleysolic soils which are usually saturated with water except close to the surface). **Azonal** soils are simply those that for whatever reason have not yet had time to develop the profile characteristics which are inherent in the zonal and intrazonal groups - an example would be the Regosolic soils made from recent flood silt deposits along the Assiniboine floodplain just to the west of the Fairholme Colony.

We are fortunate that Canada has a well developed Soil Classification System. It is based on differing characteristics of soil profile genesis that reflect these zonal, intrazonal and azonal concepts. It is not based on their agricultural potential. At the most general level the system have ten Soil Orders (Table 1). Each order is in divided into Great-Groups, and each Great-Group is in turn divided into Sub-Groups. The accompanying soils map of Manitoba (Figure 1) contains a key using both Order and Great-Group levels. In addition to the eight orders shown in Figure 1, Manitoba also has small areas of Vertisolic soils. The only Order not found in Manitoba is the Podzolic, but Podzolic soils are common in the wetter parts of Canada's boreal forest. Both the Fairholme and Swan River areas are classified as having Black Chernozems on this map, while Regosolic soils are found to the west of the Fairholm Colony, and Gray Luvisols dominate the Duck Mountains south of Swan River. Check Figure 2 as well - this map provides even greater detail and polygon # 131 for the Swan River townsite area has a sandier version of this Black Chernozem, while the Duck Mountains have Grey Luvisols on finer textured soils.

Table 1. Soil Orders of Canada.

Soil Order	General Characteristics
Brunisolic	forest soils with moderately developed horizons (limited leaching) -free drainage
Chernozemic	dry to sub-humid prairie soil with humus-rich mineral topsoil - free drainage
Cryosolic	mineral and organic soils modified by permafrost in northern Canada
Gleysolic	water table close to surface limits oxidation of soil minerals/organic matter (i.e. gleying)
Luvisolic	sub-humid to humid forest profile usually on calcareous parent material - free drainage
Organic	>30% organic - results from soil saturation which limits organic matter oxidation
Podzolic	humid to very humid forest profiles usually on acidic parent material -- well leached and with free drainage
Regosolic	regolith ("fresh" mineral material) not yet altered into characteristic soil horizons
Solonetzic	dry to sub-humid profile with horizons greatly modified by high sodium content -- usually freely drained
Vertisolic	very high clay content allows shrinking and cracking in dry periods - cracks fill with topsoil -- freely drained to high water table

At the local level these groupings are further divided into Soil Series and Soil Asociations (closely allied groupings of soil series), and Canada has over 3,500 Soil Series! Areas classified at this level are shown in the Detailed-Reconnaissance Survey maps published the Canada-Manitoba Soil Survey. An example of these Series is the Almasippi Series of sandy, Black Chernozemic soils to the immediate east of the Fairholme Colony. Other examples include the Meharry Association of Black Chernozemic soils around the town of Swan River, the Gilbert Series of sandy loam Black Chernozems just east of Swan River, and the Duck Mountain Complex of moderately fine textured Gray Luvisols developing on glacial till to the south (Figure 3).

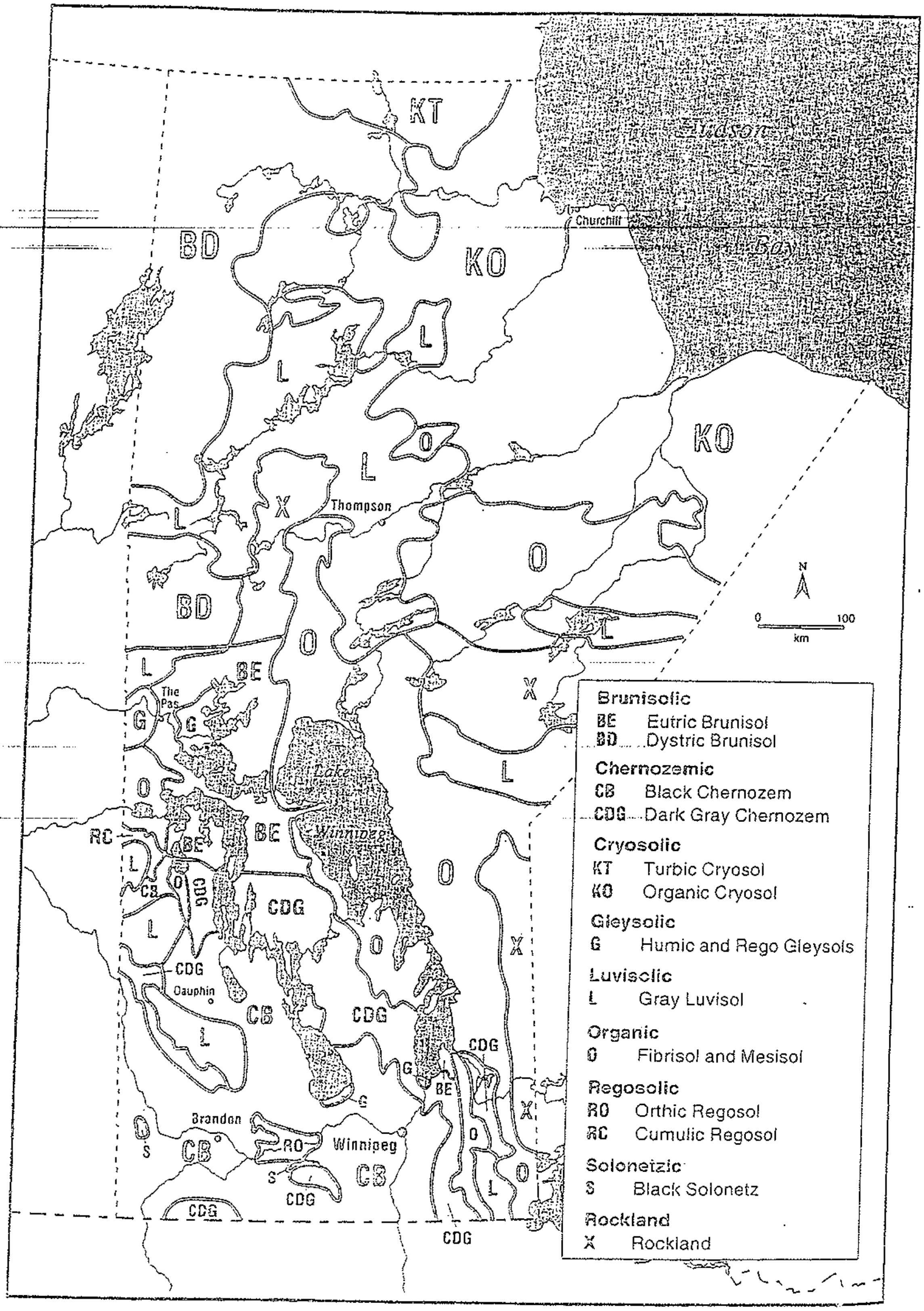


Figure 1. Dominant Soil Landscapes in central and southern Manitoba (Scott, 1996)

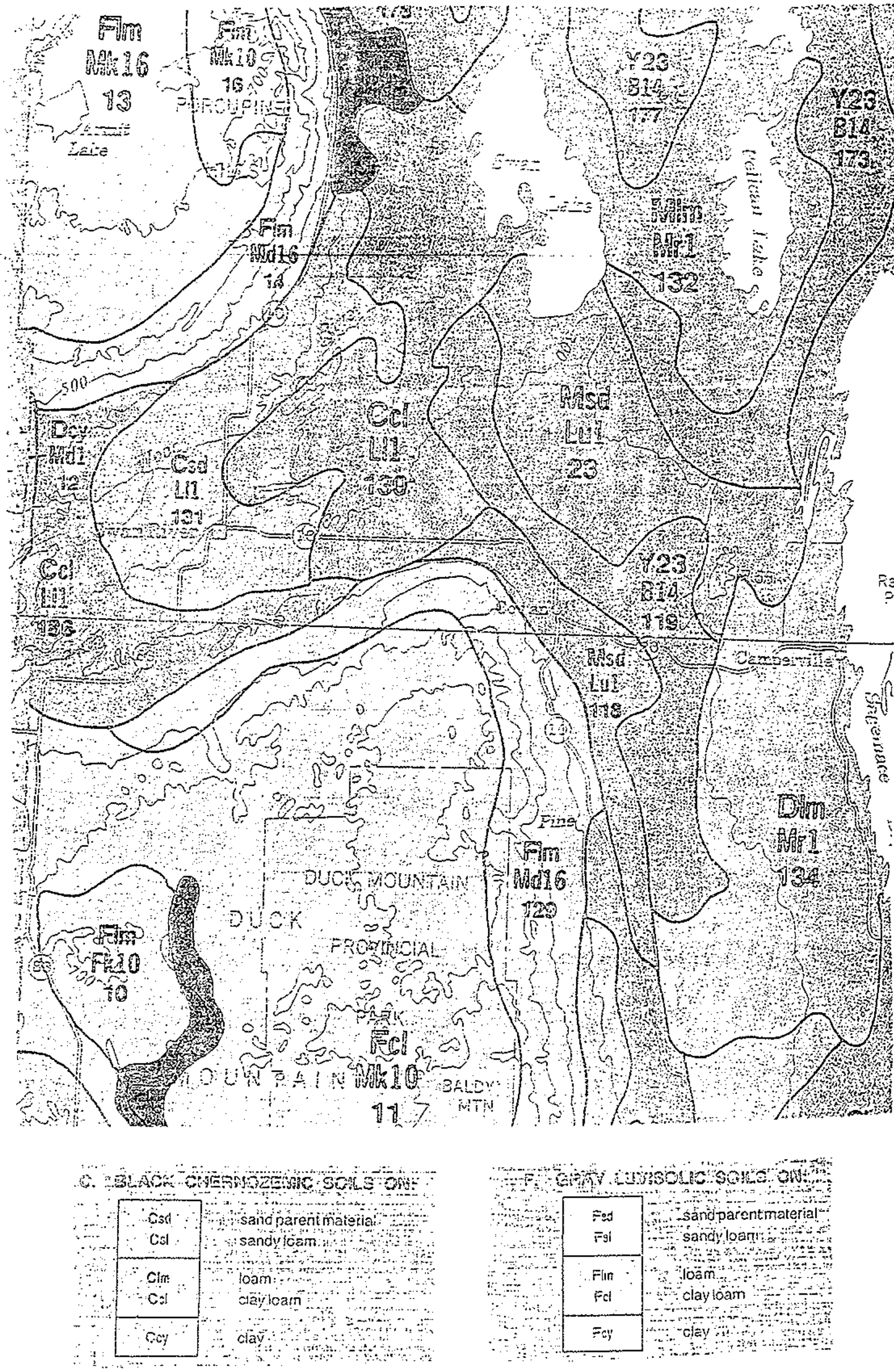


Figure 2. Soils of the Swan River/Duck Mountains. This is a portion of the Soils Landscapes of Canada: Manitoba map sheet - 1:1,000,000 (Agriculture Canada, 1989)

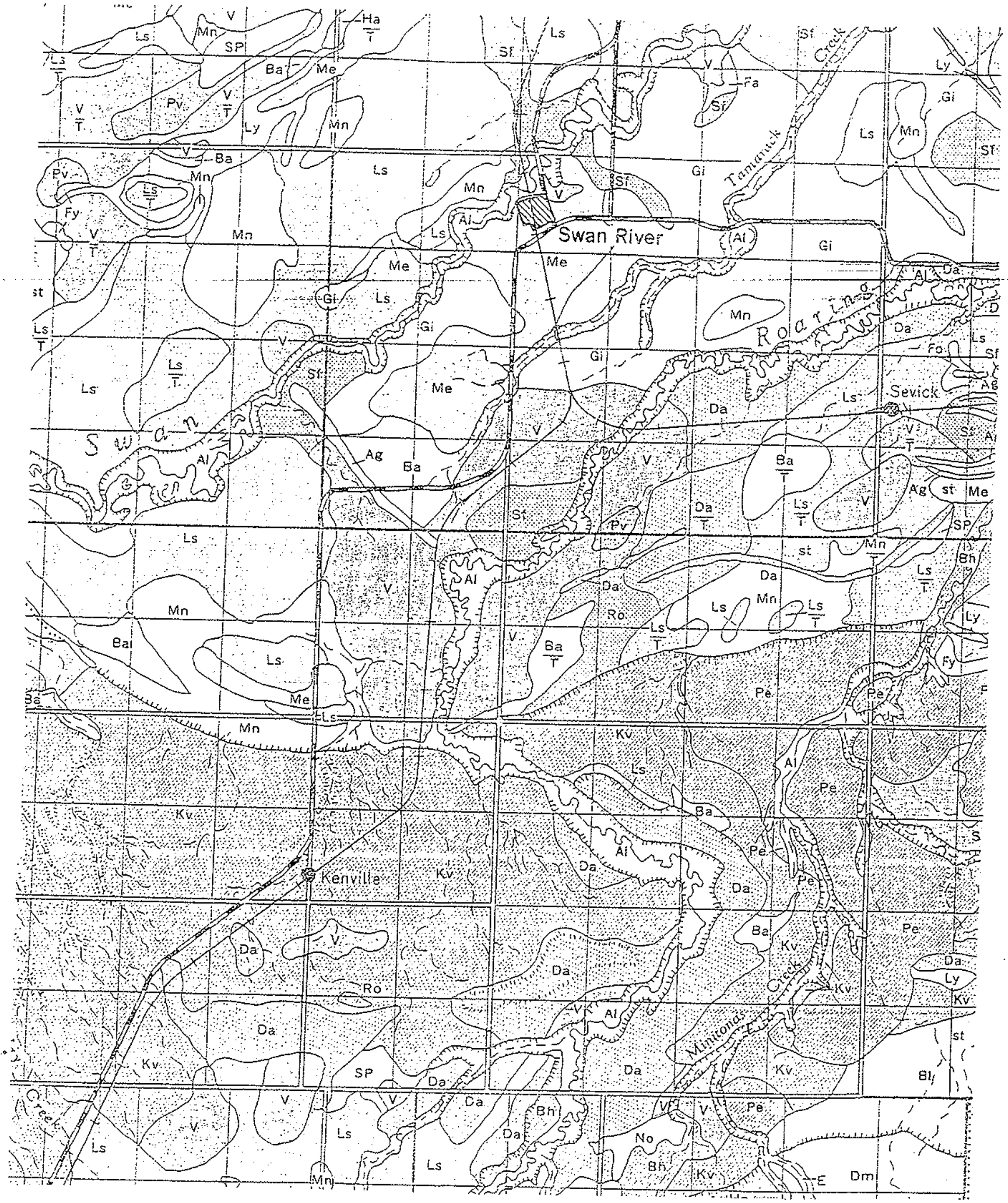


Figure 3. Soil Series of the Swan Lake/Swan River region. From the Swan Laker Map Sheet Area of Soils Report No. 13 (1962). Ls = Lenswood Series - Black Chernozemic - fine sandy loam, Gi = Gilbert Series - Black Chernozemic - sandy loam, M = Meharry Association - Black Chernozemic - medium textured till, Dm = Duck Mountain Complex - Gray Luvisol (old name of Grey Wooded soil used here) fine textured till.

Table 2. Canada Land Inventory ratings for Soil Capability for Agriculture (see Figures 4 and 5 for examples of these ratings on maps.)

DESCRIPTIVE LEGEND

In this classification the mineral soils are grouped into seven classes on the basis of soil survey information. Soils in classes 1, 2, 3 and 4 are considered capable of sustained use for cultivated field crops, those in classes 5 and 6 only for perennial forage crops and those in class 7 for neither.

Some of the important factors on which the classification is based are:

- The soils will be well managed and cropped, under a largely mechanized system.
- Land requiring improvements, including clearing, that can be made economically by the farmer himself, is classed according to its limitations or hazards in use after the improvements have been made. Land requiring improvements beyond the means of the farmer himself is classed according to its present condition.
- The following are not considered: distances to market, kind of roads, location, size of farms, type of ownership, cultural patterns, skill or resources of individual operators, and hazard of crop damage by storms.

The classification does not include capability of soils for trees, tree fruits, small fruits, ornamental plants, recreation, or wildlife.

The classes are based on intensity, rather than kind, of their limitations for agriculture. Each class includes many kinds of soil, and many of the soils in any class require unlike management and treatment.

CLASS 1 — SOILS IN THIS CLASS HAVE NO SIGNIFICANT LIMITATIONS IN USE FOR CROPS.

The soils are deep, are well to imperfectly drained, hold moisture well, and in the virgin state were well supplied with plant nutrients. They can be managed and cropped without difficulty. Under good management they are moderately high to high in productivity for a wide range of field crops.

CLASS 2 — SOILS IN THIS CLASS HAVE MODERATE LIMITATIONS THAT RESTRICT THE RANGE OF CROPS OR REQUIRE MODERATE CONSERVATION PRACTICES.

The soils are deep and hold moisture well. The limitations are moderate and the soils can be managed and cropped with little difficulty. Under good management they are moderately high to high in productivity for a fairly wide range of crops.

CLASS 3 — SOILS IN THIS CLASS HAVE MODERATELY SEVERE LIMITATIONS THAT RESTRICT THE RANGE OF CROPS OR REQUIRE SPECIAL CONSERVATION PRACTICES.

The limitations are more severe than for Class 2 soils. They affect one or more of the following practices: timing and ease of tillage; planting and harvesting; choice of crops; and methods of conservation. Under good management they are fair to moderately high in productivity for a fair range of crops.

CLASS 4 — SOILS IN THIS CLASS HAVE SEVERE LIMITATIONS THAT RESTRICT THE RANGE OF CROPS OR REQUIRE SPECIAL CONSERVATION PRACTICES, OR BOTH.

The limitations seriously affect one or more of the following practices: timing and ease of tillage; planting and harvesting; choice of crops; and methods of conservation. The soils are low to fair in productivity for a fair range of crops but may have high productivity for a specially adapted crop.

CLASS 5 — SOILS IN THIS CLASS HAVE VERY SEVERE LIMITATIONS THAT RESTRICT THEIR CAPABILITY TO PRODUCING PERENNIAL FORAGE CROPS, AND IMPROVEMENT PRACTICES ARE FEASIBLE.

The limitations are so severe that the soils are not capable of use for sustained production of annual field crops. The soils are capable of producing native or tame species of perennial forage plants, and may be improved by use of farm machinery. The improvement practices may include clearing of bush, cultivation, seeding, fertilizing, or water control.

CLASS 6 — SOILS IN THIS CLASS ARE CAPABLE ONLY OF PRODUCING PERENNIAL FORAGE CROPS, AND IMPROVEMENT PRACTICES ARE NOT FEASIBLE.

The soils provide some sustained grazing for farm animals, but the limitations are so severe that improvement by use of farm machinery is impractical. The terrain may be unsuitable for use of farm machinery, or the soils may not respond to improvement, or the grazing season may be very short.

CLASS 7 — SOILS IN THIS CLASS HAVE NO CAPABILITY FOR ARABLE CULTURE OR PERMANENT PASTURE.

This class also includes rockland, other non-soil areas, and bodies of water too small to show on the maps.

SUBCLASSES

Excepting Class 1, the classes are divided into subclasses on the basis of kinds of limitation. The subclasses are as follows:

SUBCLASS C: adverse climate—The main limitation is low temperature or low or poor distribution of rainfall during the cropping season, or a combination of these.

SUBCLASS D: undesirable soil structure and/or low permeability—The soils are difficult to till, absorb water slowly or the depth of the rooting zone is restricted.

SUBCLASS E: erosion damage—Past damage from erosion limits agricultural use of the land.

SUBCLASS F: fertility—Low natural fertility due to lack of available nutrients, high acidity or alkalinity, low exchange capacity, high levels of calcium carbonate or presence of toxic compounds.

SUBCLASS I: inundation—Flooding by streams or lakes limits agricultural use.

SUBCLASS M: moisture—A low moisture holding capacity, caused by adverse inherent soil characteristics, limits crop growth. (Not to be confused with climatic drought).

SUBCLASS N: salinity—The soils are adversely affected by soluble salts.

SUBCLASS P: stoniness—Stones interfere with tillage, planting, and harvesting.

SUBCLASS R: shallowness to solid bedrock—Solid bedrock is less than three feet from the surface.

SUBCLASS S: soil limitations—A combination of two or more subclasses D, F, M and N.

SUBCLASS T: adverse topography—Either steepness or the pattern of slopes limits agricultural use.

SUBCLASS W: excess water—Excess water other than from flooding limits use for agriculture. The excess water may be due to poor drainage, a high water table, seepage or runoff from surrounding areas.

SUBCLASS X: minor cumulative limitations—Soils having a moderate limitation due to the cumulative effect of two or more adverse characteristics which individually would not affect the class rating. (This subclass is always used alone and only one class below the best possible in a climatic subregion).

CONVENTIONS

Large arabic numerals denote capability classes.
Small arabic numerals placed after a class numeral give the approximate proportion of the class out of a total of 10. Letters placed after class numerals denote the subclasses, i.e. limitations.

*Denotes class or subclass not present on this map.

EXAMPLES

An area of Class 4 land with topography and stoniness limitations is shown thus: 4^{T}_{P}

An area of Class 2 with topographic limitation, and Class 4 with stoniness limitation, in the proportions of 7:3 is shown thus: $2^{7}_{T}4^{3}_{P}$

N.B. The color used for a complex area is determined by the first digit of the symbol. Generally the dominant class appears first in a complex symbol. However, in complexes of two arable classes (1–4) and one non arable class (5-7), the arable classes are shown first if they total one half or more of the map unit.

This pattern is overprinted on the color in complex areas, except those having ratios of 8:2, 8:1:1 and 9:1.

3. Soil Capability for agriculture/forestry

In addition to classifying soils from the perspective of soil genesis, we can rate soils on the basis of their agricultural potential/productivity. Many factors go into rating soils in terms of their agricultural productivity, and these include, 1) climate, 2) moisture supply, retention and drainage, 4) ability to supply, hold, retain and recycle nutrients, 5) resistance to alteration by degradation processes such as erosion, and 6) a suitable soil atmosphere. The "*Canada Land Inventory - Soil Capability for Agriculture*" map series rates all potential agricultural land using Capability Class one as their highest quality rating, all the way to Class seven as their lowest-quality rating (Table 2). In the southern Prairie Provinces in general we can compare the relationship between soil type (Figure 4) and soil capability class ratings one-to-three (Figure 5), and it is clear that while the soil classification terms given in Table 1 are not based on agricultural productivity, that certain soil types are never-the-less more suited than are others to crop production. It the local level (Figure 6) it can be seen that the Fairholme Colony has class ratings of two-to-three along the floodplain of the Assiniboine River, while agricultural potential drops to class 6 on the valley slopes and improves to class 5 and 4 on the sandy soils of the Almasippi Series. Note that closer to Portage agricultural ratings generally improve. In the Swan River region ratings of two, three and four attest to the quite good agricultural productivity of local soils (Figure 7).

4. Factors that influence soil capability

If you re-examine Table 2 you will note that only Capability Classes 1-4 are considered suitable for the sustained production of cultivated field crops (such as wheat, canola, barley and flax), while classes 5 and 6 are, at best, suited only for perennial forage crops and/or grazing by cattle. Class 7 has no capability for either cropping or grazing. Some of the important factors which go into this class rating include, parent material, soil texture, soil structure, and the natural nutrient supply.

Parent Material. Parent material is that material out of which a mineral soil profile develops. In southern Manitoba practically all or our parent materials have been transported and deposited by glacial activity, by rivers, as lake sediments, and by wind (Figure 8). All are late glacial or post glacial in age, and they vary in terms of particle size (texture) and particle composition. If you were to drive west from Winnipeg to this Hutterite Colony on the banks of the Assiniboine River you would note very different parent materials and agricultural practices. Winnipeg is located in the centre of what was once Glacial Lake Agassiz. During the approximately 4,000 years that this lake covered the Winnipeg region fine silts and clays that can float long distances from the lake shore settling out to form many meters of the fine sediment we now nickname gumbo. As a result the soils around Winnipeg are very fine textured (clay rich) and have good Capability Class ratings if suitably drained and managed well. Travelling west to Portage la Prairie the land rises gently across the outer edges of what was once the delta of the Assiniboine as it flowed from the west into Lake Agassiz. Along this delta margin clay and silt settled out along with fine sand to form loans (mixes of particle sizes) - in addition, in

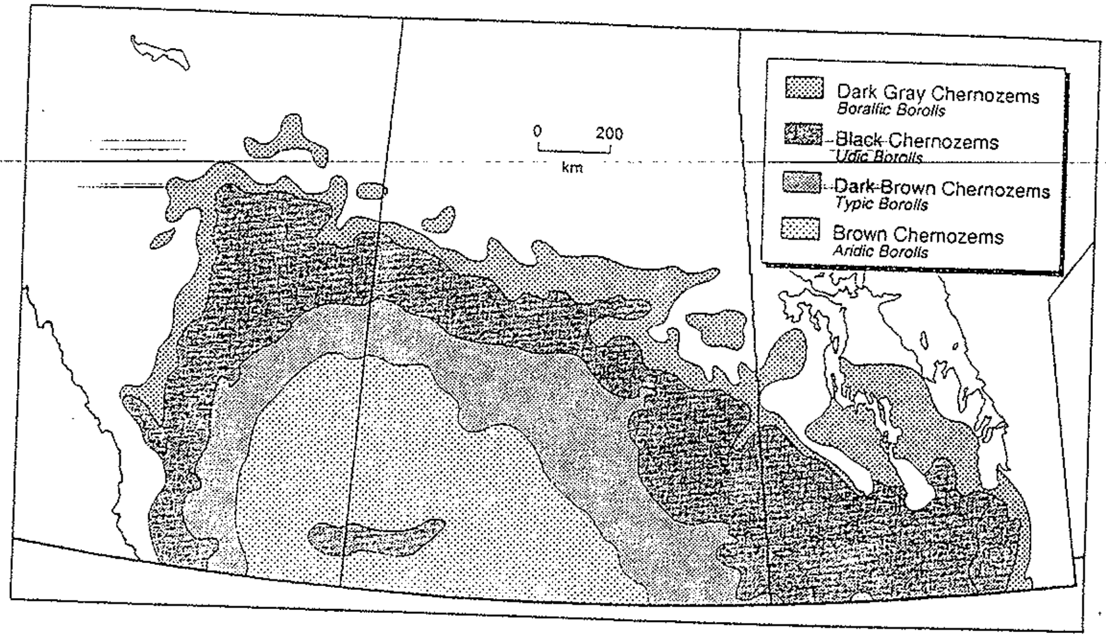


Figure 4. Distribution of the four Great-Groups of the Chernozemic Order in the Canadian prairie provinces (Scott, 1995)

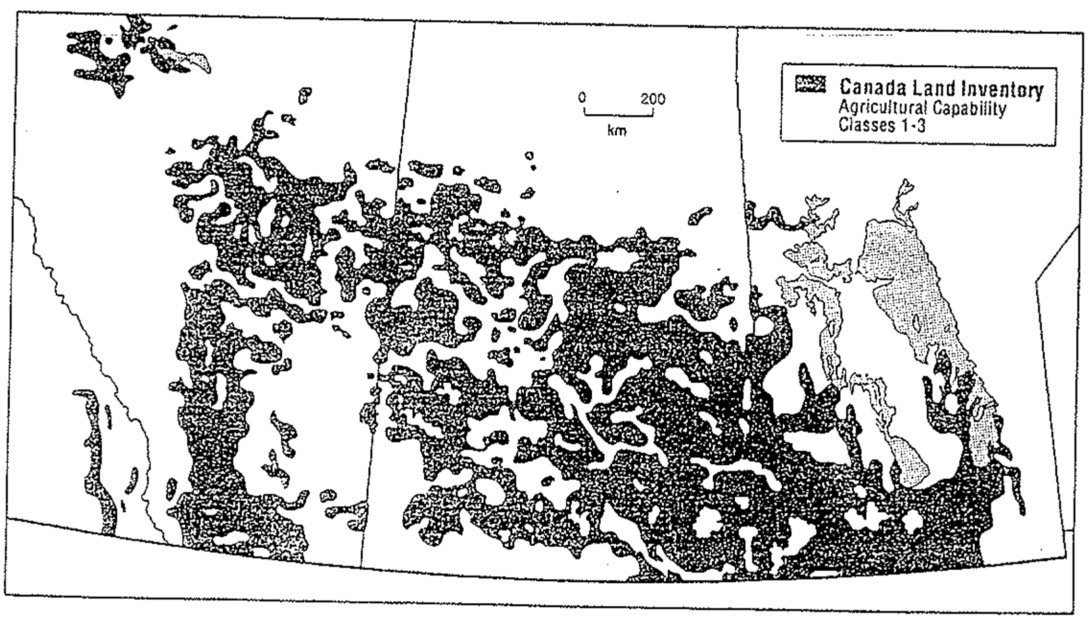


Figure 5. Agricultural Capability Classes 1 - 3 for the prairie provinces (Scott, 1995)

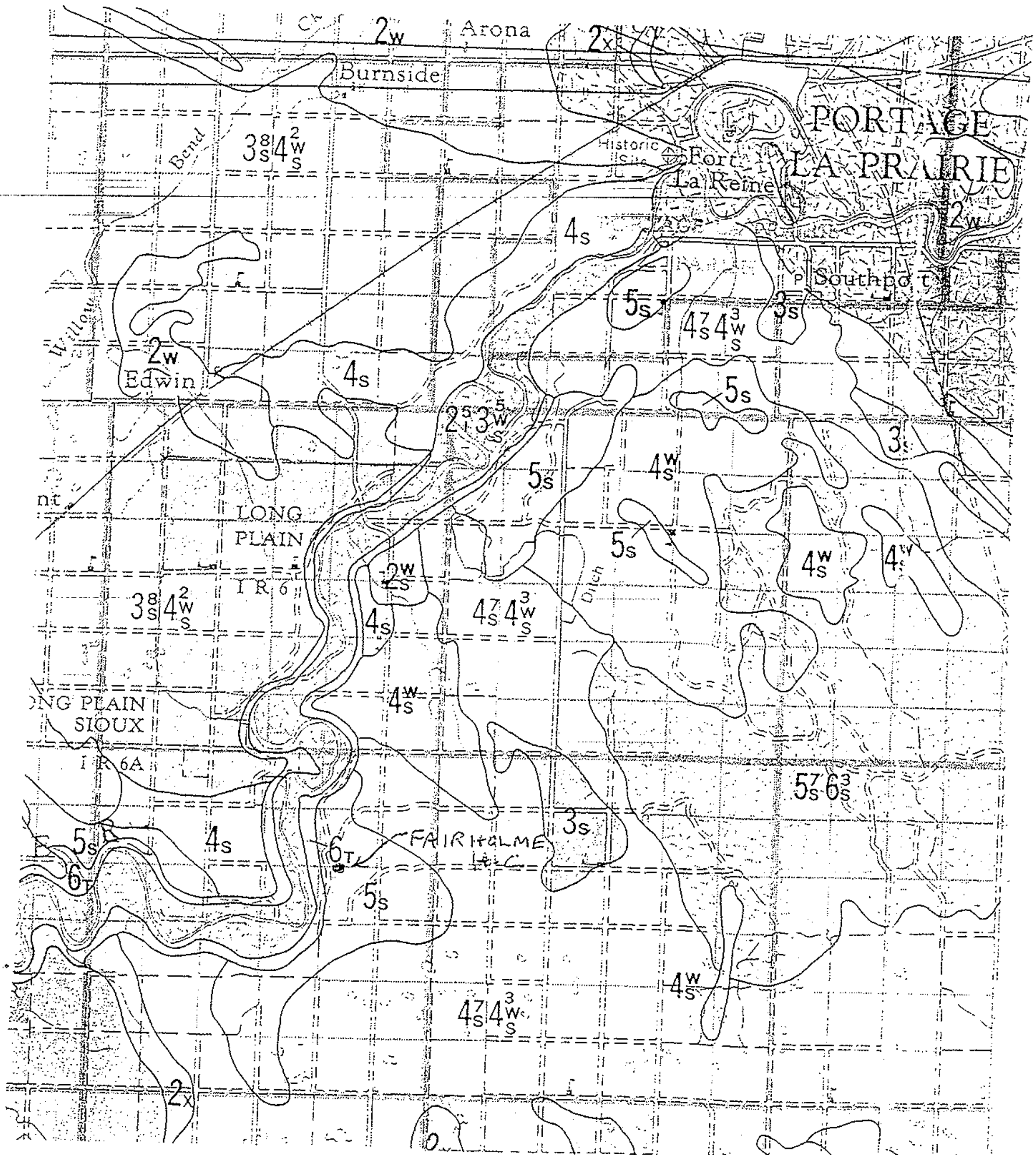


Figure 6. Soil Capability for Agriculture classes for part of the "Brandon - 62-G" mapping region (1:250,000 -- Environment Canada, 1973)

Figure 7. Soil Capability for Agriculture classes for part of the "Swan Lake 63 C" mapping region (Environment Canada, 1973)

post Lake Agassiz times much of this area collected loamy deposits as the Assiniboine flooded many times forming the Portage alluvial fan. Together these loams usually have very high Capability Class ratings. Still farther to the west, rising into the Assiniboine delta proper, fine to course sands were deposited, and often later blown around. As sand has limited ability to hold both nutrients and water this parent material is given very low Capability Class ratings. Farther to the west and the north, in addition to river and lake deposits there are large areas of irregularly deposited glacial till. The Duck mountains to the South of Swan river (as well as the Porcupine Mountains to the north) have this till which is usually a mix of clay to boulders of limited agricultural potential, but rated well in terms of forestry potential for softwood trees such as spruce. In the lowland plains around Swan River soils good ratings for growing hardwoods such as aspen, a species useful for the production of oriented strand board.

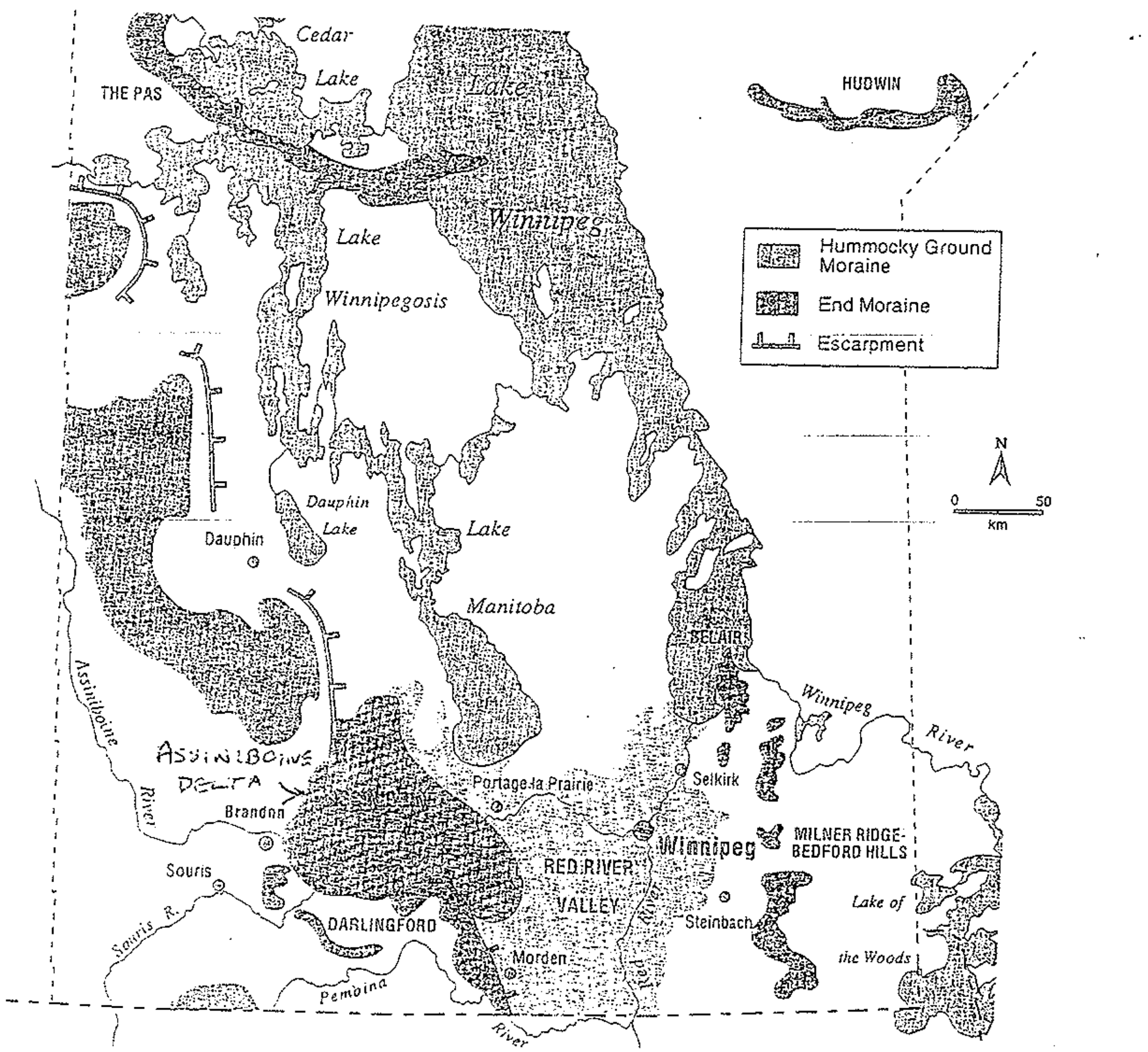


Figure 8. Generalized glacial depositional features (parent materials) in southern Manitoba (Corkery, 1996). The Old Delta of the Assiniboine is sandy, while Winnipeg is located in the clay-silt deposits of central Glacial Lake Agassiz.

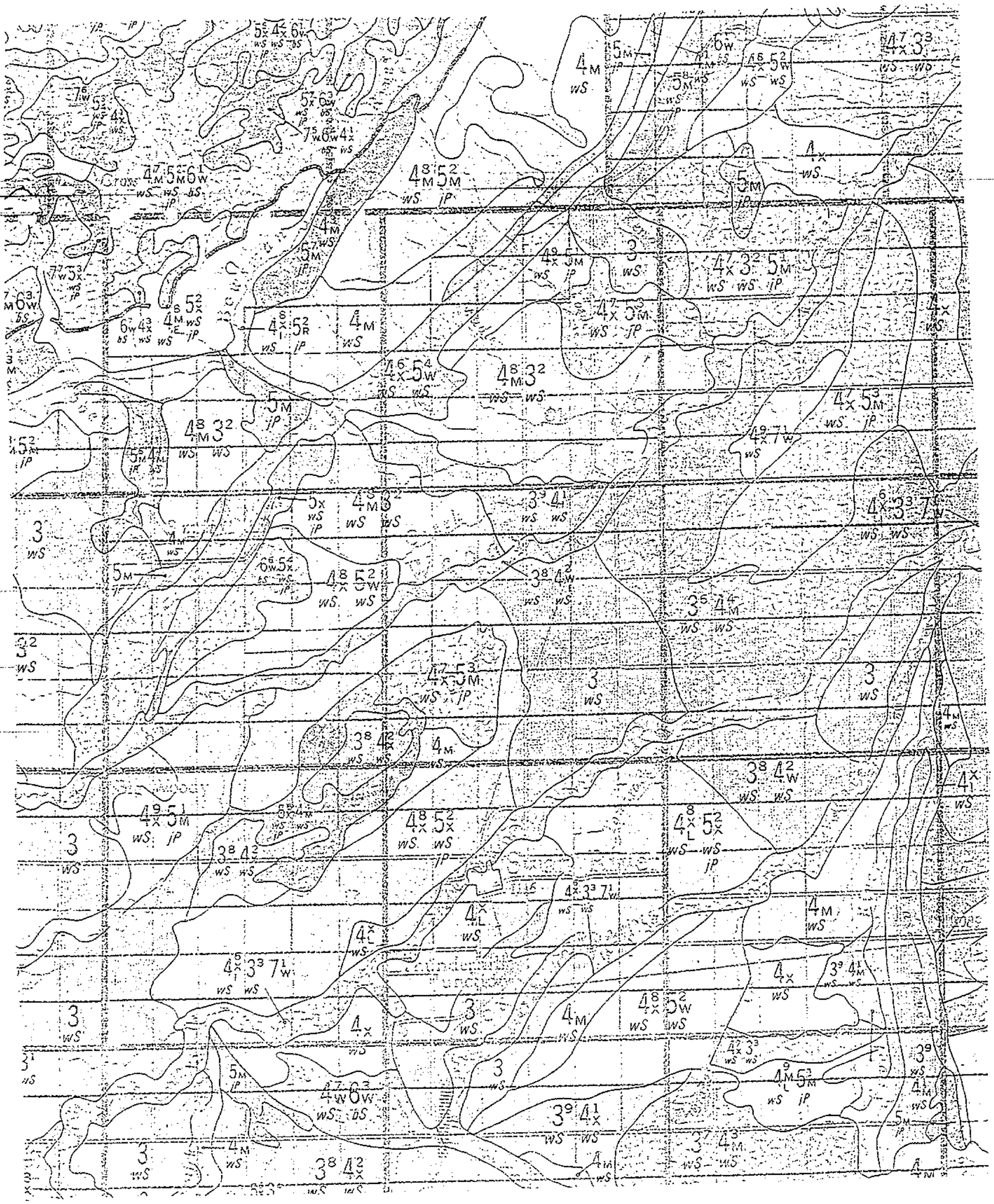
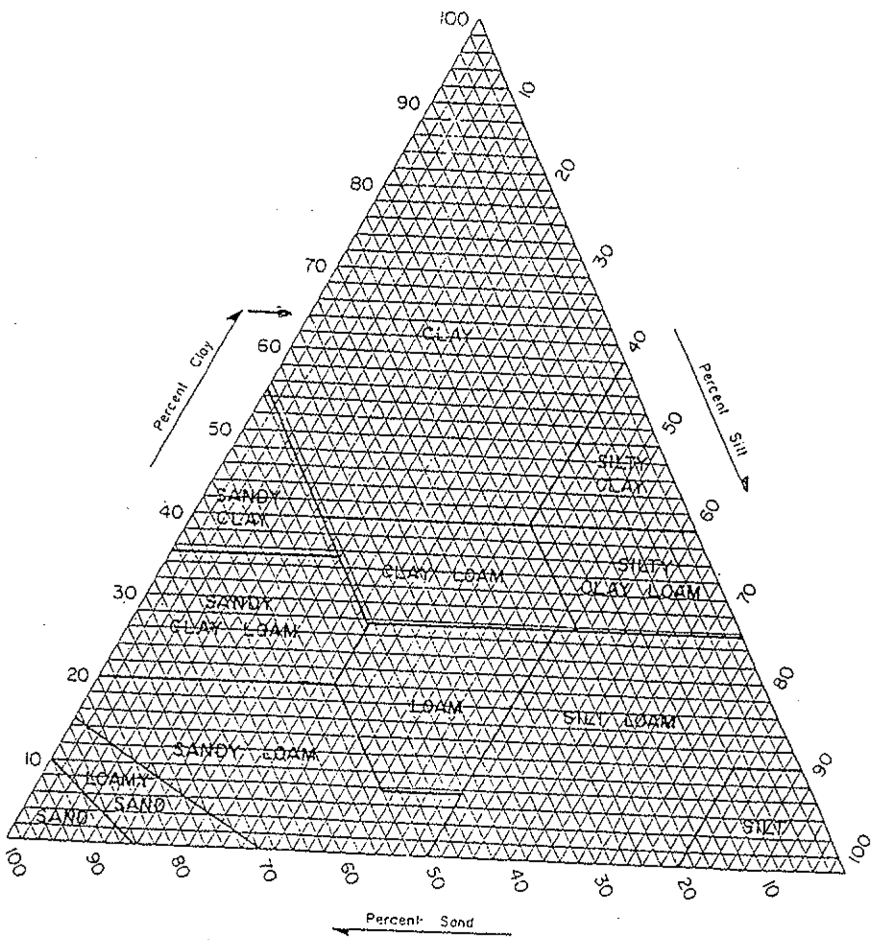


Figure 9. Soil Capability Classes for Forestry - Swan Lake mapping area (63-C).

Soil Texture. Soil texture refers to the distribution sizes of particles in a mineral soils and as can be seen in Figure 10, only four words are used in the description of Textural Calsses, sand, silt, clay and loam. Clay-rich soils are excellent at holding and storing nutrients but management practices must improve drainage. Silts hold less nutrients, and sands hold both less nutrients and little moisture. As Figure 9 suggests, a loam is a combination or mix of particle sizes and loams generally makes for better quality agricultural soils when the mix includes clay with its high nutrient retaining properties, and silt and sand with their imporved drainage properties. For field crops such as wheat sandy soils have limitations on both nutrients and water supply, but with fertilized and irrigated can be greatly improved in terms of vegetable (e.g. carrot) and potato production.



Relationship between the textural class name of a soil sample and its particle size distribution. When using this diagram follow the lines which are parallel to the numbers representing percentages. For example, the textural class for a soil which has 10% sand, 55% silt and 35% clay, is a "silty clay loam".

Figure 10. Mineral particle textural classes.

Soil Structure. Sandy soils low in organic matter are usually structureless i.e. the particles do not aggregate or form clumps or structural aggregates. Sandy topsoils with reasonable organic matter contents can form crumb-like structures which retain both water and nutrients. Crumb aggregates are also typical of loam and clay-rich topsoils, but aggregate size decreases as the organic content decreases. As the larger aggregates are less readily wind eroded, maintaining high organic matter levels can be an important management tool. Even in clay soils, where by themselves clay particles impede drainage, good crumb aggregation allows for the storage of water and nutrients within the aggregates, while drainage of water between aggregates after rain allows for the restoration of a soil atmosphere.

Soil Nutrients Manitoba soils Manitoba vary greatly in their natural ability to provide, retain and deliver soil nutrients to crops, so Capability Classes can vary depending on the degree to which this natural supply occurs. Micronutrients are nutrients needed by plants in small amounts, and many mineral soils are capable of supplying these through natural weathering. Macronutrients are those nutrients needed by plants in large amounts, and examples such as potassium and phosphorus are also released to the soil solution by the weathering of mineral particles. Excessive removal of potassium and phosphorus by crops, however, often means additions as fertilizer may be required. Loams and clays are by far the better natural nutrient delivery soil types in Manitoba. The macronutrient nitrogen is not released by the weathering of minerals but is generally made available in the soils solution as organic matter with nitrogen in it is mineralized/decomposed by soil micro-organisms. In situations where cereal crops are grown every year the demand for nitrogen is higher than the natural supply, so nitrogen fertilizer applications are needed. If the farm operation can accommodate crop rotations with say alfalfa (a species with nitrogen-fixing bacteria living in root nodules) this can greatly help replenish nitrogen supplies. In the case of organic farming (no use of artificially produced chemicals) careful management/recycling of crop residues and crop rotations maintain the natural nutrient balance.

5. Factors influencing soil erosion and sustainability

In theory Capability Class 1 for agriculture are soils optimal for crop production, but in practice some of these may be downgraded if land management/conservation practices are not applied. While optimum productivity also involves aspects of climate, crop type, crop diseases, tillage practices and other factors, the actual soil itself is the "delivery system" which can be maintained in a sustainable way by practicing basic techniques. All too easily topsoils can be washed or blown away, become compacted, waterlogged, acidified and lose some of their vital soil organic matter.

Water Erosion Water erosion results from water flow across a surface. The steeper the slope (gradient) the greater is the potential for water erosion to occur. Likewise, the less surface living plant material and/or plant residues, the greater is the potential for water erosion. Any management practice which encourages water to infiltrate the soil more readily, or be slowed down in its movement can help reduce this problem. As slowing running water on a steep slope

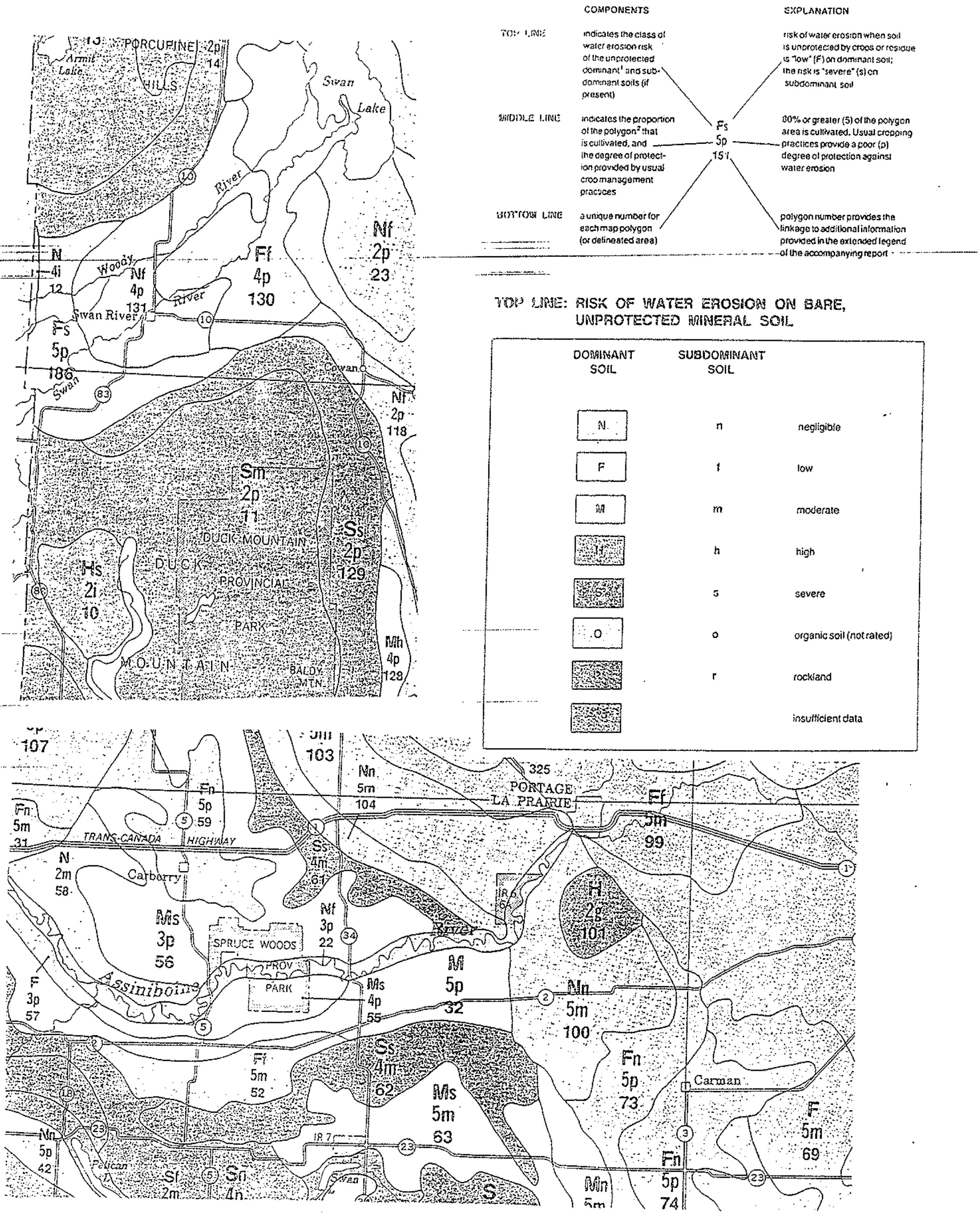


Figure 11. Portions of the "Water Erosion Risk Map: Manitoba" (Agriculture Canada, 1987).

is difficult such areas should be left under natural or permanent cover. Where slopes are gentler techniques such as zero or reduced tillage, and careful residue management must be practiced on a case to case basis. Here too any technique which slows water movement and encourages infiltration helps. Figure 11 shows part of a map of the "Water Erosion Risk Map" for southern Manitoba which is based on the physical characteristics of the soil were it to be bare of vegetation. From this map it can be seen that due to the sandy nature of parent materials around the Fairholme Colony, which encourage water infiltration and little run-off, ratings for water erosion are negligible. In the immediate vicinity of Swan River the sandy soils also discourage erosion, but ratings increase to low on the finer-textured plains not far from the town. Importantly, ratings for the Duck Mountains are high because here slopes are steep, and the finer textured soils reduce infiltration/percolation thereby promoting run-off and erosion.

Wind Erosion Dry, exposed soil surfaces are often very vulnerable to erosion during periods of strong winds, especially in late April to early May, when warm, drying winds from the south impact exposed field surfaces not yet covered by new growth. If the maintenance of a permanent vegetation cover is not practicle, then the maintenance of stubble and/or plant residues (straw from the previous crop) can greatly reduce surface wind speeds and limit this problem. In addition, the planting of shrub or tree shelter belts also slows surface wind speeds, and helps trap snow and reduce soil moisture evaporation. Most vulnerable to wind erosion are particles and aggregates of the size of small sand grains. When these are removed, so is their organic matter and their available plant nutrients. Surprisingly, clay-rich soils, soils where particle sizes are much smaller than fine sand, are often less vulnerable to wind erosion because clay-rich soils tend to have higher organic matter contents that help produce crumb structural aggregates with diameters much larger than fine sand. Clearly, any management practice which encourages large aggregates sizes, or reduces wind speed near the ground will help limit wind erosion. Figure 12 shows part of a map of the "Wind Erosion Risk Map" for southern Manitoba which is based on the physical characteristics of the soil were it to be bare of vegetation. From this map it can be seen that due to the fine sandy nature of parent materials around the Fairholme Colony ratings for wind erosion are high-to-severe, while only along the Assiniboine river, where textures are finer/loamy, is the rating only moderate. The sandy nature of parent materials around Swan River produce high ratings, while away from the town, ratings drop due to the much finer textured/better aggregated topsoils.

Soil Compaction When heavy machinery drives over a filed, some compaction results. Compaction brings aggregates closer together thereby reducing the size of soil pores. As macropores are reduced in size to micropores the speed that water percolates into the soil during and after rainfall is greatly reduced. In turn this limits the entry of air, and promotes conditions more conducive to water erosion.

Soil Acidification As nitrogen fertilizers (e.g. anhydrous ammonia -- NH_3) are altered in the soil by microorganisms to forms more readily useable by crops such as nitrate-nitrogen (N - NO_3), hydrogen is released into the soil solution. This can modestly depress soil pH (increase soil acidity) and in turn slowly limits the availability of other nutrients even though they may be present in sufficient amounts.

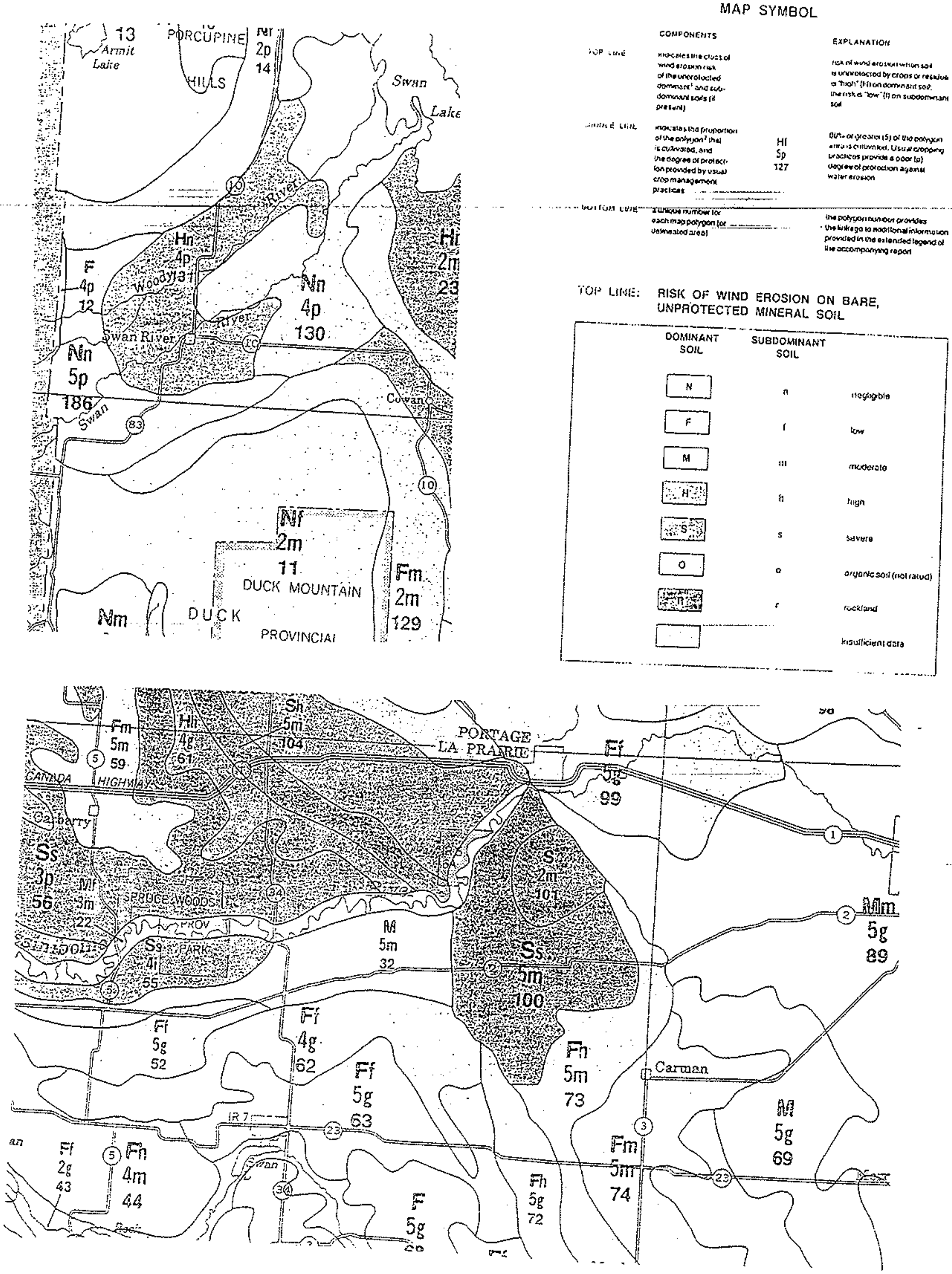


Figure 12. Portions of the "Wind Erosion Risk Map: Manitoba" (Agriculture Canada, 1989).

Loss of Organic Matter The loss of topsoil organic matter is one of the most critical problems in prairie agriculture. Excessive tillage can expose soil organic matter to more rapid decomposition and loss by wind erosion. Any process which halts, or even reverses, this decline is generally considered positive. One practice which is very destructive to soil organic matter content is "*summer fallow*". Summer fallow is a practice where the soil surface is kept bare for at least one full year before replanting. This allows an increase in soil moisture for a subsequent crop, but during the fallow year weeds must be kept down by frequent tillage or by herbiciding because they would use up this water. This soil-moisture storage practice is more critical in the drier prairies but not in Manitoba. Summer fallow also allows for the buildup or available nitrate-nitrogen in the soil solution which greatly assists crop growth the following year. Unfortunately this happens at the expense of organic matter because soil organisms continue to break it down. This breakdown, however, releases the nitrogen in this organic matter, but as there is no crop that year no new organic matter is added - the net result may be extra nitrogen, but slowly the soil organic matter reserves dwindle. In the past many Manitoba farmers practiced this nitrogen-supplying practice, but today extra nitrogen can be added as fertilizer so this practice declining.

6. *Techniques that help promote soil sustainability*

It should be clear from the above comments that agricultural soils can be protected in a sustainable way if there is the desire on the part of the practicioner to do that. Obvious methods to help do this are, where possible, to maintain a permanent vegetation cover, reduce or eliminate soil tillage, plant shelter belts to reduce wind erosion, encourage the recycling of plant resides to the surface and not remove or burn them, and not practice field cropping on steep slopes.

Permanent Cover Having a permanent plant cover is not practical in most agricultural settings because field crops such as wheat can not permit this. On steep slopes, especially where Capability Classes are low, however, it is essential that this be done. One way to approach this concept is to practice a crop rotation pattern which includes perennial herbaceous species such as alfalfa, a species which not only protects the soil from erosion, but adds extra organic material and considerable amounts of nitrogen in a form which soil organisms can make available for subsequent crops. This assumes that the practitioner has a use for such cover crops, but not all farmers have the need for, or can sell, such crops, or the desire to alter their existing practice of say cropping cereals every year. With organic farming, the practice where no artificial fertilizers or artificial biocides are used, the practitioner has already made the decision to practice rotations which include cover crops, till the soil little or not at all, recycle crop residues efficiently, and promote soil organic matter and soil nutrient conservation. Another strategy which helps reduce wind erosion while improving soil moisture conditions is the planting of shelter belts. Long, narrow, rows of tree species such as ash, or shrubs, act to greatly slow ground-level wind speeds, and trap blowing snow.

Residue Management As organic matter inputs are not only critical to the maintenance of many soil properties it is critical that straw, farmyard manure and other residues are returned to the soil as much as possible. This means that for cereal residue burning, and the removal for animal bedding and for strawboard only be done with surplus residue production. Those organic-rich black topsoils so typical of prairie soils only became such due to the in-house recycling of the prairie plant cover, so practices which to a large extent replicate this residue recycling can only help soil. A mulcher on the combine can break up straw sufficiently well that the great majority of it will be incorporated by soil organisms within one year. Figure 14 shows part of a satellite image for the area close to Winnipeg that has suggested ratings for the percentage residue cover that should remain in a field to help greatly reduce erosion before the next crop germinates.

Conservation Tillage (Reduced or Zero Tillage) Conventional tillage requires the disturbance/turning of the topsoil perhaps two or more times a year. In the past this was deemed necessary to kill weeds, incorporate residues, and prepare the seed bed. With the development of new machinary, and the wider use of biocides, the need to till so frequently is greatly reduced, or can be eliminated almost altogether (Zero tillage). While zero or reduced tillage may not necessarily increase local crop productivity, there are benefits for the sustainability/conservation of the soil as organic matter levels stabilize or even increase. This practice also ensures stubble and straw residues remain on the surface to feed soil organisms such as earthworms, recycle nutrients, and protect the soil from erosion. In addition, there may be possible financial benefits as well if the lower tillage-operating expenses are not cancelled out by any higher herbicide costs. Figure 13 indicates that % area of seeded land under zero till in southern Manitoba for 1996 (Senyk, 2002).

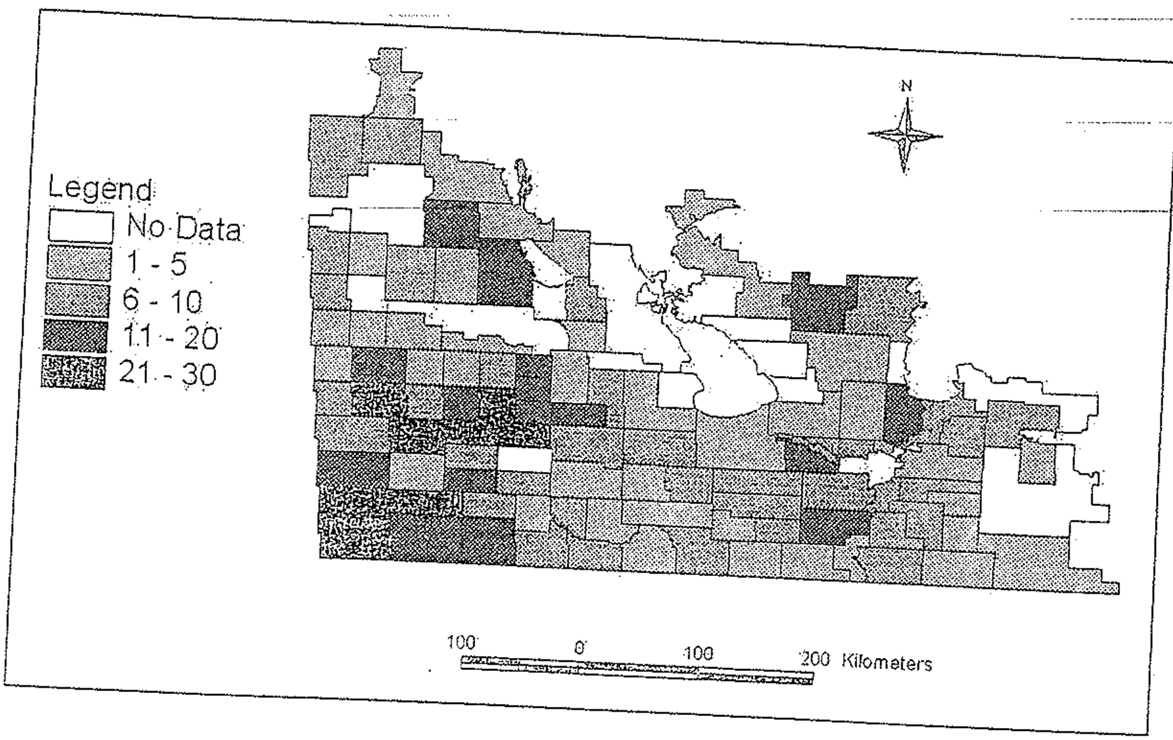


Figure 13. Percentage area of seeded land under zero till in southern Manitoba for 1996 (from Senyk, 2002, using data from Statistics Canada , 1996).

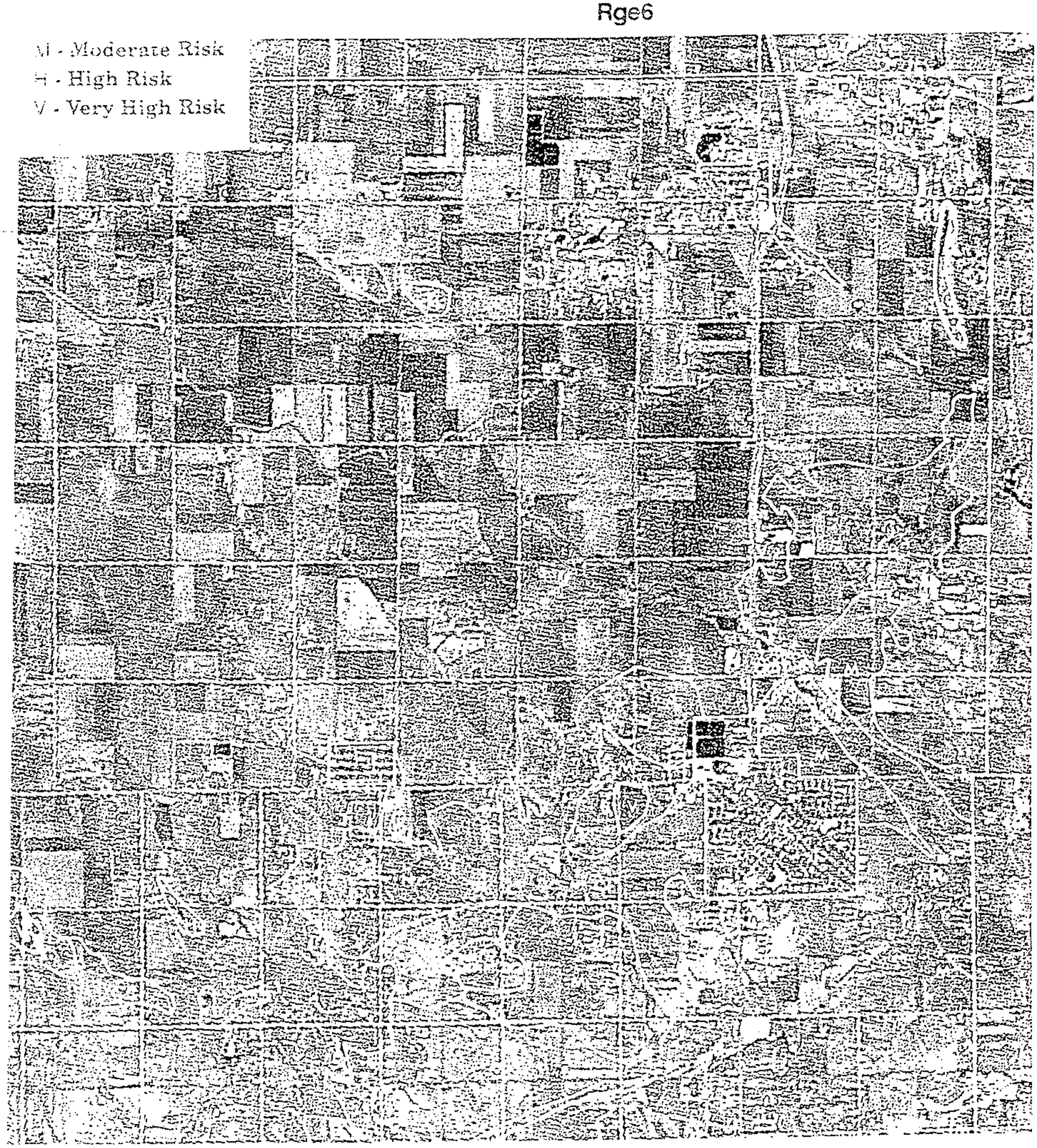


Figure 14. PFRA Residue Ratings for part of the R.M. of Hanover - satellite map for visually assessing the relationship between crop residue to the risk of soil erosion (May, 1986). The City of Steinbach is the square-shaped community on the southeast side of the map. Original is in colour.