# ABSTRACT


Soil survey is a paradigm based science which relies heavily on the application of conceptual soil-landscape models based on tacit expert knowledge. The tacit knowledge is generally acquired by systematic field observation and recording of repeating relationships between soils and landform position. A consistent deficiency of many soil survey databases has been the lack of a mechanism for capturing and recording such tacit expert knowledge. A case in point is the recently completed 1:100,000 scale digital soils database prepared for the province of Alberta (AGRASID). This database provided a list of up to 6 soils that were believed to occur within each mapped soil polygon and a landscape code to identify a type landscape considered to best describe the area enclosed by each polygon. It did not include any mechanism for indicating which portion or portions of the landscape each soil was most likely to occur in or for associating each soil with a specific set of landform conditions such as slope gradient or slope length.

A procedure was developed to facilitate capture and application of local tacit knowledge in order to associate each soil in each AGRASID polygon with its most likely landform position or positions. The procedure, and associated computer programs, were applied to the AGRASID digital soils database which consisted of over 50,000 individual soil polygons which referenced more than 1,500 different named soil series (or non-soils). The procedures capture and codify the essential components of local expert tacit knowledge required to effectively associate each listed soil in any given polygon with its most likely landform position(s).

The concepts on which the procedures were based are simple but effective. They are sufficiently generic as to be applicable to any region in which there is reason to expect consistent and repeating relationships between soils and landform position. They require no special data beyond that which is normally available for any named soil series. The tacit knowledge base, and the procedures used to capture and apply it, may be of as great a potential value as the expanded soil-landform model database created by this specific application of the procedures.


# INTRODUCTION

## Rationale for capturing and applying tacit soil survey knowledge

- A new digital soils database covering the entire agricultural portion of Alberta was completed in 1998.
  - Agricultural Region of Alberta Soil Inventory Database (AGRASID) (CAESA-Soil Inventory Project Working Group, 1998)
  - The database offers consistent, uniform soils information at a scale of 1:100,000.
  - Many applications and assessments of natural resource information are expected to use the AGRASID database
  - It was considered that the utility of the database would be increased if the soils listed as occurring in each polygon were explicitly linked to landform position and associated with landform attributes.

- In common with many jurisdictions, publicly funded operational soil survey activity is no longer supported in Alberta.
  - Soil survey agencies supported by both provincial and federal governments have been disbanded in the last few years.
  - In many ways, the AGRASID digital soils database represents a final legacy for publically funded soil survey in Alberta.
  - A great deal of the soil survey tacit knowledge built up over 65 years of operational soil survey resides in the minds of the individuals who retired or were reassigned with the closures.
  - There was interest in assessing whether a mechanism might be developed to capture, codify & apply some of this tacit knowledge.

## Relevant literature

- In many ways, this project is a response to the challenge posed to soil surveyors by Hudson (1992).
  - Hudson observed that most of the accumulated knowledge and scientific observation associated with soil survey existed primarily in the minds of experienced soil surveyors as "tacit knowledge"
  - Hudson argued that soil survey was deficient in not expressing its scientific knowledge in a more formal, systematic way.
  - Hudson further argued that until the knowledge was expressed semantically and formally it could not be conveyed easily to those not indoctrinated into the discipline and it would need to be relearned by each new generation of surveyors
  - A significant portion of the value of soil survey is lost if the tacit knowledge acquired during mapping is not recorded..

- A fundamental assumption of most soil survey is that the location and distribution of soils in the landscape is predictable (Arnold, 1979, 88).
  - The spatial distribution is widely agreed to be a function of the 5 soil forming factors of Jenny.
  - Topography is widely acknowledged to play a dominant role locally in influencing the distribution of soils at a field or site scale.
  - One school of soil surveyors has argued for formal adoption of soil-landform units as the basic spatial entities for soil survey (Arnold, 1979, 88; Miller et al., 1979, Northcote, 1984; Swanson, 1990 a,b)
  - Local research in Alberta has been successful in automatically defining landform segments that display different soil regimes (MacMillan et al., In press; MacMillan and Pettapiece, 1996, 1997b)

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# OBJECTIVE

**To develop, apply and evaluate a generic set of procedures for capturing local tacit knowledge of soil surveyors to assist with automated allocation of soils to their most likely positions in the landscape.**

# METHODS

**STEP 1.**
Identify and define landform segments with which to associate soils

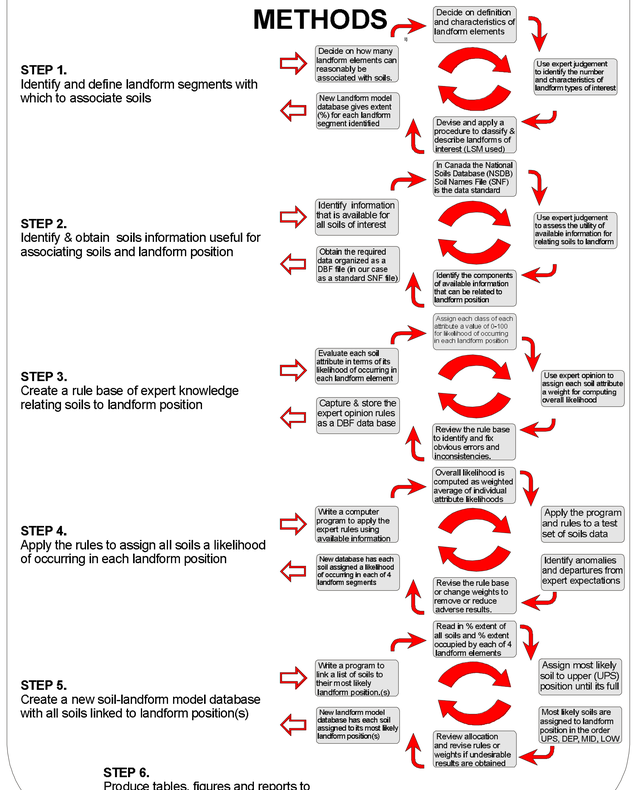
**STEP 2.**
Identify & obtain soils information useful for associating soils and landform position

**STEP 3.**
Create a rule base of expert knowledge relating soils to landform position

**STEP 4.**
Apply the rules to assign all soils a likelihood of occurring in each landform position

**STEP 5.**
Create a new soil-landform model database with all soils linked to landform position(s)

**STEP 6.**
Produce tables, figures and reports to document the new soil-landform models




# RESULTS

**STEP 1.**
Example of 4 simple landform segments defined and described in landform database

| Landform Segment | Upper Slopes | Mid Slopes | Lower Slopes | Depression |
|---|---|---|---|---|
| | UPS | MID | LOW | DEP |
| Landform % | UPS 30% | MID 25% | LOW 25% | DEP 20% |

Figure 1. Illustration of the 4 simple landform segments with which soils are associated using expert tacit knowledge

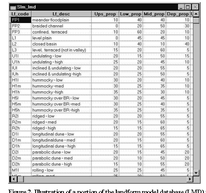


Figure 2. Illustration of a portion of the landform model database (LMD) required to support allocation of soils to landform position

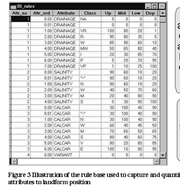
**STEP 2.**
Information contained in Soil Names File (SNF) deemed useful for assigning soils to landforms

Table 1. Structure and content of the standard NSDB Soil Names File (SNF).

| Field Name | Field Type | Field Length | Field Description |
|---|---|---|---|
| NSDB_SERIES | C | 8 | Alpha-numeric code for each SOIL SERIES NAME in the soil names file |
| SERIES | C | 24 | The full name for the Soil Series |
| VERSION | C | 8 | Alpha-numeric code which indicates from which standard source series was derived |
| LU | C | 1 | A code to identify the land use under which the soil was described |
| SCA | N | 2 | A number to identify the soil correlation area in which the soil occurs |
| DRAINAGE | C | 2 | Alpha codes for the CanSIS defined drainage class of the soil |
| CNCSS | C | 2 | Alpha codes for the CanCSS defined subgroup class of the soil |
| PARENT | C | 4 | Alpha codes for the CanSIS defined parent material of the soil |
| PMT_TEX | C | 4 | Alpha codes for the CanSIS texture class of the upper parent material |
| PMT_TYP | C | 4 | Alpha codes for the CanSIS class for type of upper parent material |
| PMZ_TEX | C | 4 | Alpha codes for the CanSIS texture class of the lower parent material |
| PMZ_TYP | C | 4 | Alpha codes for the CanSIS class for type of lower parent material |
| SOIL_ID | C | 8 | Unique alpha-numeric code for each soil in the soil names file |
| REPORT | C | 20 | Text listing of the name of the reports in which the soil was documented |
| ORDER | C | 2 | Alpha codes for the CanSIS symbol for Soil Order in which the soil belongs |
| G_GROUP | C | 4 | Alpha codes for the CanSIS symbol for Sub Group in which the soil belongs |
| G_GROUP | C | 3 | Alpha codes for the CanSIS symbol for Great Group in which the soil belongs |
| MS | C | 8 | Alpha-numeric code for the mapping unit(s) that contain the soil series |
| SG_MOD | C | 8 | Alpha codes for the CanSIS symbol for Sub Group modifier |
| COMMNOTE | C | 254 | A comments field for recording correlation notes about the soil |

Fields deemed useful for allocating soils to landform position are highlighted

**STEP 3.**
Example of rule base of expert knowledge used to relate soil attributes to landform position



Experts have assigned each class of each of the 6 soil attributes a value for likelihood (0 to 100) of occurring in each of the 4 landform positions

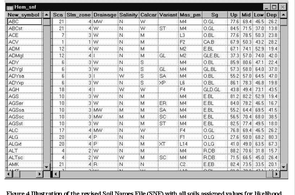
Likelihood values are based on soil surveyors beliefs and expetience and represent "tacit knowledge"

Figure 3 Illustration of the rule base used to capture and quantify expert tacit knowledge relating soil attributes to landform position

**STEP 4.**
Results of calculation used to assign all soils a likelihood of occurring in each landform position

Table 2. Illustration of calculation of a weighted average for overall likelihood of occurrence in the 4 landform positions for 5 example soils

| Soil Attribute | Drainage | Salinity | Calc | Parent Material | Variant | Sub Group | Weighted Mean |
|---|---|---|---|---|---|---|---|
| Attribute Weight | 0.2 | 0.1 | 0.15 | 0.15 | 0.15 | 0.3 | |
| Bistnai (BCC) | P | S | S | L14 | | R3HG | |
| UPS | 5 | 5 | 80 | 30 | 0 | 5 | 18.2 |
| MID | 20 | 30 | 40 | 50 | 0 | 10 | 25.3 |
| LOW | 70 | 90 | 60 | 90 | 0 | 55 | 69.4 |
| DEP | 95 | 100 | 70 | 95 | 0 | 85 | 83.2 |
| Angus Ridge (AGS) | W | N | M | M4 | | E,BL | |
| UPS | 95 | 90 | 70 | 90 | 0 | 75 | 81.2 |
| MID | 90 | 80 | 60 | 80 | 0 | 60 | 62.2 |
| LOW | 60 | 10 | 60 | 40 | 0 | 70 | 52.8 |
| DEP | 10 | 20 | 65 | 20 | 0 | 10 | 19.4 |
| Eroded Angus Ridge (AGSer) | W | N | M | M4 | ER | E,BL | |
| UPS | 95 | 90 | 70 | 90 | 100 | 75 | 84.0 |
| MID | 90 | 80 | 60 | 80 | 55 | 60 | 70.2 |
| LOW | 60 | 10 | 50 | 40 | 10 | 70 | 46.5 |
| DEP | 10 | 20 | 65 | 20 | 1 | 10 | 16.7 |



**STEP 5.**
Illustration of calculation used to assign all soils to their most likely landform position(s)

Table 3. A hypothetical data set illustrating the data required to allocate soils to landform position

| | | Likelihood of Occurring in Each of the 4 Landform Positions | | | |
|---|---|---|---|---|---|
| LF | Percent Extent | 30% | 25% | 25% | 20% |
| Soil | Percent Extent | UP | MID | LOW | DEP |
| A | 20% | 87 | 73 | 48 | 12 |
| B | 20% | 82 | 76 | 52 | 16 |
| C | 15% | 14 | 36 | 81 | 92 |
| D | 15% | 16 | 41 | 86 | 78 |
| E | 30% | 78 | 83 | 71 | 53 |

Allocation fills all UPS with most likely soils then DEP, then MID, then LOW

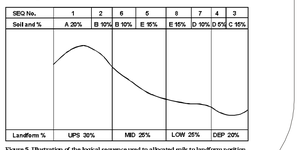


Figure 4 Illustration of the revised Soil Names File (SNF) with all soils assigned values for likelihood of occurring in each of the 4 landform positions

| SEQ No. | 1 | 2 | 6 | 5 | 8 | 7 | 4 | 3 |
|---|---|---|---|---|---|---|---|---|
| Soil and % | A 20% | B 10% | B 10% | E 15% | E 15% | D 10% | D 5% | C 15% |



| Landform % | UPS 30% | MID 25% | LOW 25% | DEP 20% |
|---|---|---|---|---|

Figure 5. Illustration of the logical sequence used to allocated soils to landform position

# RESULTS

**STEP 5.**
Illustration of soil-landform model database with all soils linked to landform position(s)

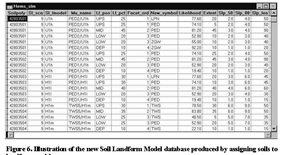


Figure 6. Illustration of the new Soil Landform Model database produced by assigning soils to landform positions

**STEP 6.**
Produce tables, figures and reports to document the new soil-landform models

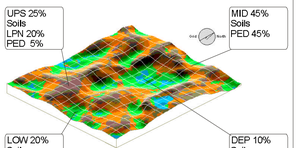



Figure 7. Illustration of a conceptual Soil Landform Model with soils linked to landform positions

# CONCLUSIONS

- The described procedures provide a formal, systematic and reproducible mechanism for capturing, quantifying and applying the local tacit knowledge of expert soil surveyors.
  - This specific application captured tacit knowledge on the locations in the landscape where specific soils were believed to be most likely to be found.
- The concepts on which the procedures are based are simple, but effective.
- The procedures are sufficiently generic as to be applicable to any region in which there is reason to expect consistent and repeating relationships between soils and landform position.
- The procedures require no special data beyond that which is normally available for any named soil series.
- In this particular application of the procedures to the AGRASID digital soils database, all soils in more than 50,000 soil polygons were associated with their most likely landform positions.
  - In almost all cases, the results of allocating soils to landform position for the AGRASID database were in agreement with the expectations and experience of the expert soil surveyors responsible for creating the tacit knowledge rule bases.
- The ability to associate soils with landform positions adds to the value and utility of a digital soil survey database
  - Many models and decision rule algorithms require that data on soil properties be linked to associated attributes of the landform such as slope gradient or slope length.
- The process followed to create the tacit knowledge rule bases required expert soil surveyors to formally express their tacit knowledge
  - The ability to capture and formally express tacit soil surveyor knowledge may be as valuable as the soil-landform models.

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