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DIGITAL MAPPING OF SOIL SURFACE TEXTURE OF THE MONTEREGIE AGRICULTURAL AREA (QC, CANADA) USING ANALYTICAL AND MORPHOLOGICAL SOIL LEGACY DATA

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INTRODUCTION

Soil texture is a basic soil property commonly used in soil classification and mapping. With the organic matter content, it is often used as variable input in many pedotransfer functions. It is also a key factor in many soil survey interpretation and land evaluation systems: soil productivity, capability and suitability rating, vulnerability to soil degradation or risk assessment of surface water and groundwater pollution. Soil texture maps are therefore very useful for most agricultural and agrienvironmental decision making.

Mapping soil texture by traditional soil survey methods is often a slow and expensive process. More precise and reliable maps are needed to modelers and other soil data users. Digital soil mapping technics have been developed for answering these needs (McBratney et al. 2003, Scull et al. 2003). This approach has been proposed by Sanchez et al. (2009) for updating world soil maps (http://www.globalsoilmap.net/) in the next five years (2010-2015). Using morphological and analytical soil data available within many regional and national soil survey databases has been proposed for improving pedotransfer functions and digital soil mapping (Lilly and Lin 2004, Liu et al. 2008, Niang et al. 2010).

OBJECTIVE

The main objective of this study is to assess the usefulness of morphological and analytical soil survey data in digital soil mapping, in terms of reducing the root mean square error (RMSE) of prediction of the sand, silt and clay content, in the context of implementing global soil maps of Canada.

MATERIALS AND METHODS

STUDY AREA : Monteregie (QC, Canada), 11 851 km^2, Fig. 1)

SOIL LEGACY DATA : The morphological soil database (MSDB) of the Monteregie area has been collected by stratified random transects during soil survey works realized in this area by Agriculture and Agri-Food Canada from 1982 to 2009 (44479 soil profiles). In this database, soil texture has been recorded at the subclass level (22) according to the Canadian System of Soil Classification (CSSC) standards. These semi-quantitative data have been converted into percent of sand, silt, and clay content using the median value of each soil textural class (Table 1). The analytical soil database (ASDB) included 3209 soil samples of the surface layer (Fig. 2). Particle-size distribution has been determined by the hydrometer method (Sheldrick and Wang 1993).

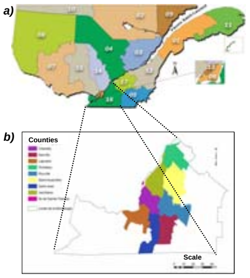


Fig. 1. a) Location of the Monteregie agricultural area (16) in the province of Quebec, Canada; b) counties included in the study area.

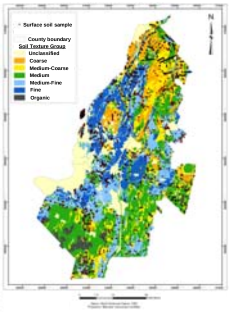
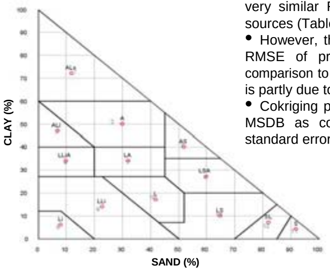


Fig. 2. Soil sampling design used for mapping soil texture of the surface layer.

Table 1. Median value of the sand, clay and silt content (%) of each soil textural class (13)

Textural class	Code	Sand	Clay	Silt
sand	S	92	4	4
loamy sand	SL	82	7	11
sandy loam	LS	65	10	25
loam	L	42	17	41
silt loam	LLi	23	14	63
silt	Li	8	6	86
sandy clay loam	LSA	60	27	13
clay loam	LA	32	34	34
silty clay loam	LLiA	10	34	56
sandy clay	AS	52	40	8
silty clay	ALi	7	47	46
clay	A	30	50	20
heavy clay	ALo	12	72	16

Hydrometer Method



MATERIALS AND METHODS

GEOSTATISTICAL ANALYSIS : Anisotropic and isotropic semivariograms, ordinary block (2 x 2) kriging and cokriging have been computed using ArcGIS Geostatistical Analyst (ESRI) and GS$^+$ (Gamma Design Software). Grid cell size: 90 m.

ANISOTROPY : No significant anisotropy has been detected as shown by the 2-d variogram map (Fig. 3). Isotropic theoritical semivariogram models (exponential) were used (Fig. 4 and Table 2).

SPATIAL STRUCTURE : Evaluated by using the C/C_0+C ratio (Whelan and McBratney 2000). For both data sources (ASDB and MSDB), strong spatial structures were found for surface clay and sand contents as indicated by the relatively high C/C_0+C ratio (>0.7). Moderate spatial structures (C/C_0+C = 0.4-0.6) were observed for surface silt content (Table 2).

CROSS-VALIDATION METHODS (2):

1. Jackknife analysis (n-1)
2. IVD: Independent validation dataset (ASDB) when kriging with MSDB.

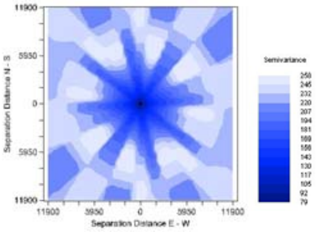


Fig. 3. Variogram map of the clay content calculated with MSDB.
No significant anisotropy (direction-dependent variability) detected.

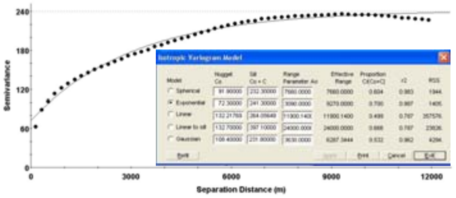


Fig. 4. Isotropic semivariogram of the surface clay content calculated with MSDB using GS$^+$.

Table 2. Statistical and geostatistical parameters for the clay, sand and coarse fragment contents (%) estimated from two data sources (ASDB and MSDB)

Variable	Data	n	Mean	SD	CV	Semivariogram model parameters			
	Source		(%)	(%)	(%)	Model	Range (A_0)	C/C_0+C	R^2_{model}
Clay	ASDB	3209	22.6	14.8	65.5	Exp.	4990 m	0.77	0.96
	MSDB	44479	27.7	15.5	56.0	Exp.	3090 m	0.70	0.99
Sand	ASDB	3209	44.4	24.0	54.2	Exp.	7420 m	0.71	0.97
	MSDB	44479	34.2	25.1	73.4	Exp.	3390 m	0.67	0.98
Silt	ASDB	3209	33.0	14.3	43.3	Exp.	4650 m	0.52	0.94
	MSDB	44479	38.1	14.6	38.2	Exp.	3200 m	0.46	0.98

RESULTS AND DISCUSSION

- Digital maps of the surface clay content (Fig. 5) showed less detailed pattern when kriging with the low density ASDB data source (Fig. 5a) than kriging (Fig. 5b) or cokriging (Fig. 5c) with the MSDB which is based on a higher sampling density.
- The cross-validation procedure using the Jackknife approach showed very similar RMSE of prediction (8-14%) when kriging with both data sources (Table 3).
- However, the Jackknife cross-validation approach under-estimates the RMSE of prediction when kriging with the MSDB data source in comparison to using ASDB as independent validation dataset (Table 3). This is partly due to the estimation error associated to field texture assessment.
- Cokriging particle-size soil surface data using ASDB in combination to MSDB as covariables reduces RMSE (Table 3) and the prediction standard error (Fig. 6), improving the prediction accuracy of digital maps.

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RESULTS AND DISCUSSION

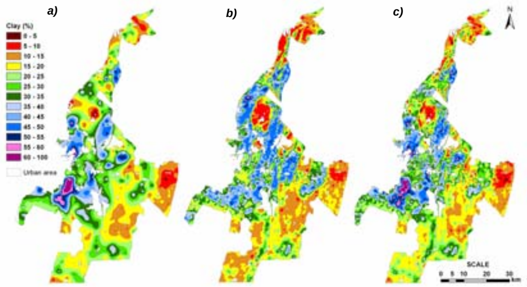

Fig. 5. Digital maps of surface clay content produced by a) kriging with ASDB, b) kriging with MSDB and c) cokriging with ASDB and MSDB using isotropic semivariogram models.

Table 3. Root mean square error (RMSE) of prediction according to soil variables, interpolation methods (kriging and cokriging) and data sources (ASDB and MSDB)

Variable	Interpolation	Data	n	RMSE (%)	
	Method	Source		Jackknife	IVD*
Clay (%)	Kriging	ASDB	3209	8.17	- - -
	Kriging	MSDB	44479	8.38	9.59
	Cokriging	ASDB & MSDB	45173	6.90	- - -
Sand (%)	Kriging	ASDB	3209	13.74	- - -
	Kriging	MSDB	44479	13.76	15.19
	Cokriging	ASDB & MSDB	45173	11.63	- - -
Silt (%)	Kriging	ASDB	3209	9.37	- - -
	Kriging	MSDB	44479	10.30	11.31
	Cokriging	ASDB & MSDB	45173	8.54	- - -

* **IVD** : Independent validation dataset (ASDB).

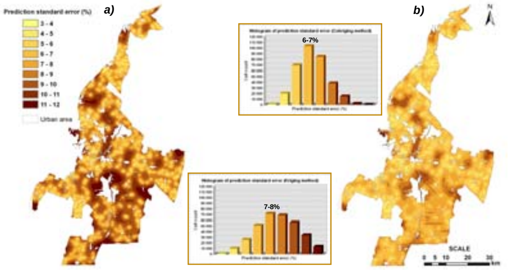

Fig. 6. Distribution of the prediction standard error of surface clay content according to interpolation methods: a) kriging with ASDB and b) cokriging with ASDB and MSDB.

CONCLUSIONS

The considerable volume of morphological data generated within the Monteregie area soil survey program (1982-2009) can be used in combination with sparsely collected analytical data (clay, sand and silt contents) to improve the precision of digital soil surface texture maps. The usefulness of other sources of ancillary variables (remote sensing and digital elevation models) for cokriging soil texture variables will also be tested within this research project.

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