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Refining Soil Organic Matter Determination by Loss-on-Ignition[*1]

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ABSTRACT

Wet oxidation procedure, *i.e.*, Walkley-Black (WB) method, is a routine, relatively accurate, and popular method for the determination of soil organic matter (SOM) but it is time-consuming, costly and also has a high potential to cause environmental pollution because of disposal of chromium and strong acids used in this analysis. Therefore, loss-on-ignition (LOI) procedure, a simple and cheap method for SOM estimation, which also avoids chromic acid wastes, deserves more attention. The aims of this research were to study the statistical relationships between SOM determined with the LOI (SOM_{LOI}) and WB (SOM_{WB}) methods to compare the spatial variability of SOM in two major plains, Shahrekord and Koohrang plains, of Chaharmahal-va-Bakhtiari Province, Iran. Fifty surface soil samples (0–25 cm) were randomly collected in each plain to determine SOM using the WB method and the LOI procedure at 300, 360, 400, 500 and 550 °C for 2 h. The samples covered wide ranges of soil texture and calcium carbonate equivalent (CCE). The general linear form of the regression equation was calculated to estimate SOM_{LOI} from SOM obtained by the WB method for both overall samples and individual plains. Forty soil samples were also randomly selected to compare the SOM and CCE before and after ignition at each temperature. Overall accuracy of the continuous maps generated for the LOI and WB methods was considered to determine the accordance of two procedures. Results showed a significant positive linear relationship between SOM_{LOI} and SOM_{WB}. Coefficients of determination (R^2) of the equations for individual plains were higher than that of the overall equation. Coefficients of determination and line slopes decreased and root mean square error (RMSE) increased with increasing ignition temperature, which may be due to the mineral structural water loss and destruction of carbonates at higher temperatures. A temperature around 360 °C was identified as optimum as it burnt most organic carbon, destroyed less inorganic carbon, caused less clay structural water loss, and used less electrical energy. Although the trends of SOM in the kriged maps by the two procedures accorded well, low overall accuracy was observed for the maps obtained by the two methods. While not suitable for determination where high accuracy is required, determination of organic carbon through LOI is likely suitable for exploratory soil surveys where rough estimation of organic matter is required.

Key Words: calcium carbonate equivalent, ignition temperature, kriged maps, spatial variability, wet oxidation

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INTRODUCTION

Soil organic matter (SOM) is defined as the summation of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and well-decomposed substances (Brady and Weil, 1999). SOM, as one of the most influential of the agricultural soil parameters, is a useful indicator of soil fertility and a crucial factor in the soil dynamics of various agrochemicals (Page, 1974; Krishnan *et al.*, 1981; Pitts *et al.*, 1986). It strongly affects physico-chemical and biological properties of soils like cation exchange capacity, soil structure, water infiltration rate, water holding capacity, soil erodibility and conservation, and pesticide adsorption (Schulte, 1995; Ding *et al.*, 2002).

There are several methods to determine SOM, each method with some advantages and disadvantages regarding convenience, accuracy, and expense (Nelson and Sommers, 1982). For example, wet oxidation procedure, the Walkley-Black (WB) method (Walkley and

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Black, 1934), is a routine, relatively accurate, and cheap popular method for the determination of SOM, but it involves the use of chromate and generates hazardous wastes. Elemental carbon analyzers are accurate but are expensive to purchase and maintain. Another method, loss-on-ignition (LOI), which involves combustion of samples at high temperatures and measuring weight loss after ignition, has been proposed to be an inexpensive and convenient method for estimation of SOM (Cambardella *et al.*, 2001; Konen *et al.*, 2002) which also avoids chromic acid wastes.

The ability of the LOI method to determine SOM content has been considered reliable (Howard and Howard, 1990; Dean, 1999; Abella and Zimmer, 2006; Brunetto *et al.*, 2006; Escosteguy *et al.*, 2007). However, optimal heating temperatures and durations to maximize SOM combustion, while minimizing inorganic carbon combustion, are difficult to determine. Both of these variables can substantially affect LOI results (Ben-Dor and Banin, 1989; Schulte *et al.*, 1991).

Higher temperatures can also drive off structural water from clays and other inorganic constituents. However, the LOI method has been widely used for estimating SOM in a muffle furnace at 360 °C for 2 h (Schulte *et al.*, 1991; Konen *et al.*, 2002; Brunetto *et al.*, 2006; Escosteguy *et al.*, 2007; Yerokun *et al.*, 2007) and at 300, 450, and 600 °C for 2 h (Abella and Zimmer, 2006).

Accurate estimation of within-field SOM is currently an important priority for precision agriculture, given its importance in defining precise fertilizer and pesticide management practices, thus optimizing field productivity and minimizing groundwater contamination risks (Sudduth and Hummel, 1996; Ingleby and Crowe, 2001). The development of SOM field maps is also currently an important aspect of precision agriculture. Although many new techniques are currently being developed, geostatistical methods such as kriging, is most commonly used in mapping SOM levels on a field scale (Chen *et al.*, 2000; Fox and Sabbagh, 2002). The application of geostatistics in soil science ensures a quantitative description of the spatial variation of soils, improves accuracy in the estimation of soil properties for data interpolation and map compilation, and forms the basis for a rational design of soil sampling (Webster, 1985).

The objectives of this study were: 1) to establish the equations between WB and LOI methods in order to determine the optimum temperature for ignition and 2) to compare the spatial variability of SOM determined using both mentioned methods in two major plains of Chaharmahal-va-Bakhtiari Province, Iran.

MATERIALS AND METHODS

Study area and soil sampling

Fifty surface (0–25 cm) soil samples were randomly collected from both the Shahrekord and Koohrang plains (totally 100 samples) in Chaharmahal-va-Bakhtiari Province, Iran (Fig. 1). The positions of all samples were determined by GPS for geostatistical analysis. The Shahrekord Plain (50° 51′ E, 32° 19′ N, 2 060 m above the sea level) is located in a semi-arid region with an annual mean precipitation of 320 mm and an annual mean temperature of 11.8 °C and the Koohrang Plain (50° 07′ E, 32° 26′ N, 2 285 m above the sea level) is located in a semi-humid region with an annual mean precipitation of 1 440 mm and an annual mean temperature of 9.4 °C. Both plains are the most important agricultural lands in the province.

Soil sample analyses

All soil samples were analyzed to determine SOM by the WB method (Nelson and Sommers, 1982) and the LOI procedure (Schulte and Hopkins, 1996). For the LOI analyses, the soil samples were air dried and sieved through a 2-mm sieve. The samples were then oven-dried at 105 °C overnight, cooled in a desiccator, and weighed before they were combusted at 300, 360, 400, 500 and 550 °C for 2 h in a muffle furnace (Model Exation 1200-30 L). After combustion, the samples were cooled in a desiccator and weighed again. An estimation of SOM percentage from the loss-on-ignition method (SOM_{LOI}) was calculated by the following equation (Schulte and Hopkins, 1996):

$$SOM_{LOI} = [(\text{soil weight after combustion} - \text{oven-dry soil weight})/\text{oven-dry soil weight}] \times 100 \quad (1)$$

The soil samples were also analyzed for particle size distribution following the procedure of Gee and Bauder (1986) and for calcium carbonate equivalent (CCE) using the method suggested by Loeppert and Suarez (1996).

Statistical analyses

The general linear form of the regression equation was calculated to estimate SOM_{LOI} after ignition at different temperatures (300, 360, 400, 500 or 550 °C) for 2 h, from SOM obtained by the WB method

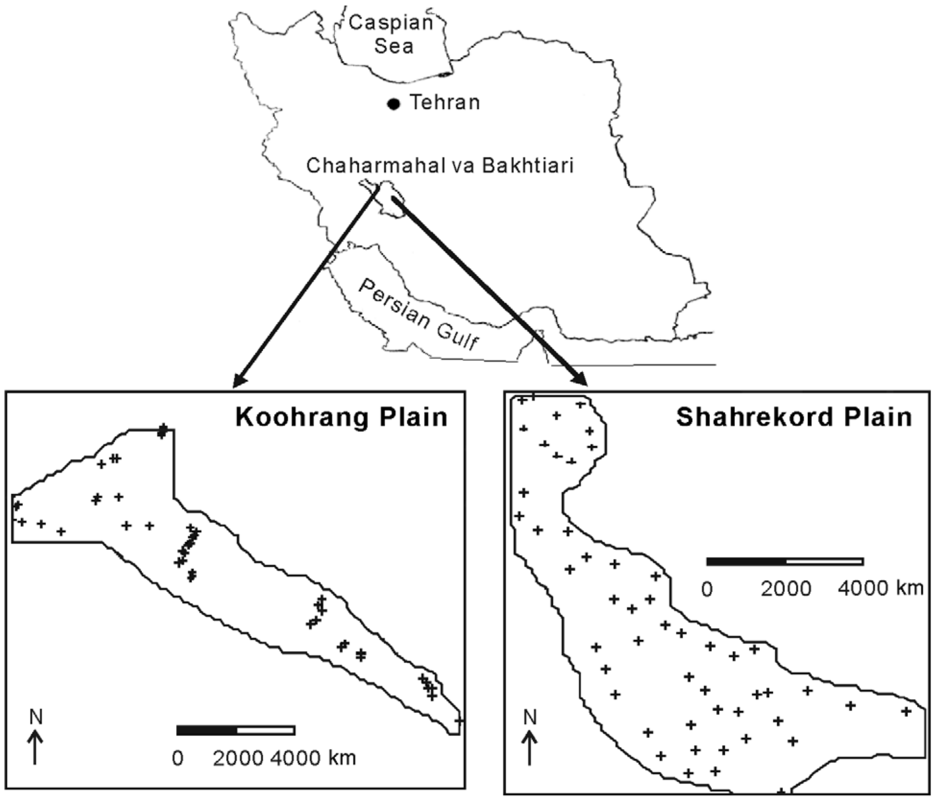

Fig. 1 Location of the study area in central Iran and the sample locations in the plains studied in Chaharmahal-va-Bakhtiari Province.

(SOM_{WB}) for both overall samples and individual plains as follows:

$$SOM_{WB} = b_0 + b_1 SOM_{LOI} \tag{2}$$

where b_0 and b_1 are the intercept and slope in the equation, respectively. Coefficient of determination (R^2) and root mean square error (RMSE) were calculated for Eq. 2. RMSE was calculated using the following equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}[P(x_i) - M(x_i)]^2}{n}} \tag{3}$$

where $P(x_i)$ is the estimation of SOM by the LOI procedure at location x_i, $M(x_i)$ is the measured SOM by the WB method at location x_i (as a based method), and n is the number of samples.

To determine the optimum temperature for ignition, 40 soil samples were randomly selected from the whole data to compare the SOM and CCE before and after ignition for each temperature. Statistica 6.0 software was used for these analyses. In order to study the effects of clay content and CCE values on the accuracy of estimation, regression equations were also calculated for the samples which were partitioned into three arbitrary groups based on clay content and CCE values.

Geostatistical analysis

Geostatistics is based on the theory of a regionalized variable (Matheron, 1971), which is distributed in space (with spatial coordinates) and shows spatial auto-correlation such that samples close together in space are more alike than those that are further apart. Geostatistics uses the technique of variography, *i.e.*, calculating variogram or semivariogram, to measure the spatial variability and dependency of a regionalized variable. Through analysis of the semivariogram, a suitable theory model (*e.g.*, spherical, exponential, or Gaussian) and the parameters for kriging interpolation (*e.g.*, range, nugget, and sill) were obtained. A suitable semivariogram model is expressed as follows (Goovaerts, 1997):

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x_i) - Z(x_i + h)]^2 \tag{4}$$

where $Z(x_i)$ is the value of the variable Z at location x_i, and $N(h)$ is the number of pairs of sample points separated by the lag distance h.

As the variables did not show any anisotropy, omnidirectional semivariograms were used for estimation. First, the minimum distance among the sampling points was considered and then optimum distance was selected for interpolation based on Z score values. An ordinary block kriging, using the nearest maximum 14 sample points and a maximum searching distance almost equal to the range distance of the variable, was chosen to create the spatial distribution maps of SOM for both the LOI and WB methods in the Shahrekord and Koohrang plains.

To define the degree of spatial dependency, the spatial class ratio, the nugget variance (noise) to total variance (sill) ratio multiplied by 100, was adopted, similar to that presented by Cambardella *et al.* (1994). If the ratio of spatial class was less than 25%, then the variable was considered to be strongly spatially dependent; if the ratio was between 25% and 75%, the variable was regarded as moderately spatially dependent; and if the ratio was more than 75%, the variable was considered weakly spatially dependent.

Geostatistical analysis, cross-validation, and kriging were conducted on measured and calculated SOM using the VARIOWIN software version 2.2 (Pannatier, 1996) and the GEOEAS software version 1.2.1 (GEOEAS, 1991), and contour maps were generated using SURFER 8.0 (Golden Software Inc., 2002). As the data showed a normal distribution except for the LOI values at 500 and 550 °C, log transformation was used to normalize these data; but after kriging estimates, the LOI values at 500 and 550 °C were back-transformed to generate final kriged maps.

Overall accuracy calculation

Confusion matrices (Legros, 1996) were obtained to determine the agreement of the kriged estimates. As Walkley-Black (WB) method is a routine method for the determination of SOM, we used the SOM_{WB} map as a reference map, the best possible map (BPM), and SOM_{LOI} maps were considered as the test maps. Based on SOM values in the study area and traditional or usual classification of SOM values for management purposes in our country, we firstly classified the continuous maps of SOM using a same class-group domain (with 0.5% interval bounds) and secondly, we sliced the maps to separate different SOM groups. Then, the classified BPM and the test maps were crossed. Finally, overall accuracy of the crossed maps was measured by the ratio of the number of pixels in the diagonal of the confusion matrix to the total number of pixels by the ILWIS3.4 software. As the SOM values were compared pixel by pixel in the plains, this method was more in agreement with soil reality rather than the straightforward computation of a correlation coefficient.

RESULTS AND DISCUSSION

Descriptive analyses of the measured properties for both plains are given in Tables I and II. The SOM values calculated by the Walkley-Black method (SOM_{WB}) ranged from 0.5 to 38 g kg^{-1} and the CCE values ranged from 1% to 65%. The soil samples also covered a broad range for soil texture: 80–610 g kg^{-1} clay, 20–670 g kg^{-1} sand, and 210–790 g kg^{-1} silt. The means of SOM_{WB} and clay content were significantly higher in the Koohrang Plain than in the Shahrekord Plain ($\alpha = 0.01$), whereas the mean CCE values were significantly lower (data not shown). This can be explained by more precipitation and thereby more vegetation as well as more leaching of carbonates and more weathering in the Koohrang Plain.

A significant linear relationship ($\alpha = 0.05$) was ob-

TABLE I

Descriptive statistics[a)] of some soil properties[b)] in the two plains studied

Property	Shahrekord Plain ($n = 50$)			Koohrang Plain ($n = 50$)			Total ($n = 100$)		
	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum
SOM_{WB} (g kg^{-1})	27	15 ± 6.1	6	35	18 ± 8	6	35	17 ± 7	6
CCE (%)	65	36.0 ± 1.2	15	51	1.7 ± 13.8	1	65	26.0 ± 12.5	1
Clay (g kg^{-1})	400	260 ± 57	140	460	330 ± 63	190	460	290 ± 67	140
Sand (g kg^{-1})	250	110 ± 58	20	210	90 ± 49	20	250	90 ± 54	20
Silt (g kg^{-1})	790	640 ± 71	480	770	580 ± 80	390	790	610 ± 75	390

[a)]SD = standard deviation.; [b)]SOM_{WB} = soil organic matter calculated by the Walkley-Black method; CCE = calcium carbonate equivalent.

TABLE II

Descriptive statistics[a)] of soil organic matter calculated by the loss-on-ignition method at different temperatures for the two plains studied

Temperature	Soil organic matter calculated by the loss-on-ignition method								
	Shahrekord Plain ($n = 50$)			Koohrang Plain ($n = 50$)			Total ($n = 100$)		
	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum
°C	g kg^{-1}								
300	39	21 ± 6.6	10	46	29 ± 9.5	15	46	25 ± 8.1	19
360	47	25 ± 8.2	12	59	34 ± 9.5	18	59	30 ± 8.8	12
400	49	27 ± 8.9	16	65	37 ± 10	19	65	32 ± 9.5	16
500	96	47 ± 13	26	85	51 ± 12	31	96	49 ± 13	26
550	97	51 ± 14	26	85	56 ± 11	38	97	54 ± 13	26

[a)]SD = standard deviation.

served between SOM_{LOI} at all temperatures and SOM_{WB}. Coefficients of determination (R^2) of the equations were higher and their RMSE values were lower for individual plains (particularly Shahrekord) than those of the overall equations (Table III). This showed the positive effect of sample partitioning on the increase of the accuracy of estimation and also indicated that a unique equation should be used for each region to estimate SOM by the LOI method. Numerous researchers have also suggested that SOM_{LOI} equations be developed separately for different soil depths and types (Spain *et al.*, 1982; David, 1988; Konan *et al.*, 2002).

Coefficients of determination decreased and RMSE increased with increasing ignition temperature, as was also reported by Abella and Zimmer (2007). The slope of the equations also showed a decreasing trend with increasing temperature, clay content, and CCE (Tables IV and V). It seemed that this decrease occurred to prevent the overestimation of SOM at higher temperatures. At 500 and 550 °C, R^2 decreases and RMSE increases with increasing ignition temperature were more noticeable. Significant positive correlations ($\alpha = 0.01$) between soil clay content and SOM_{LOI} values in the Koohrang Plain (data not shown) also confirmed that increasing clay content may cause overestimation of SOM by the LOI method. Yerokun *et al.* (2007) also reported that SOM_{LOI} had positive correlations with clay content ($R^2 = 0.44$*) in Zambian soils. Some researchers also showed that the LOI estimation is improved where clay content as an independent variable is included in multiple regressions (Konen *et al.*, 2002; Abella and Zimmer, 2007; Fullen *et al.*, 2007; Yerokun *et al.*, 2007). Konen *et al.* (2002) also reported that the LOI method overestimates SOM in high clay content soils. Another possible reason for the observed trends may be the clay mineral structural water loss and destruction of carbonates at higher temperatures.

TABLE III

Regression parameters[a)] between the soil organic matter calculated by the Walkley-Black method and that calculated by the loss-on-ignition method at different temperatures for all samples and for the two plains studied

Temperature	All samples ($n = 100$)				Shahrekord Plain ($n = 50$)				Koohrang Plain ($n = 50$)			
	Intercept	Slope	R^2	RMSE	Intercept	Slope	R^2	RMSE	Intercept	Slope	R^2	RMSE
°C												
300	−0.15*	0.72	0.71*	0.33	−0.15*	0.78	0.81*	0.33	−0.81*	0.88	0.76*	0.45
360	−0.17	0.62	0.73*	0.33	−0.12	0.64	0.82*	0.33	−0.69*	0.74	0.75*	0.45
400	−0.17	0.62	0.73*	0.33	−0.03	0.56	0.81*	0.33	−0.66*	0.67	0.77*	0.39
500	−0.48	0.43	0.67*	0.42	−0.29	0.39	0.70*	0.42	−0.91*	0.53	0.67*	0.47
550	−0.65*	0.43	0.70*	0.40	−0.37*	0.38	0.73*	0.40	−1.36*	0.57	0.72*	0.43

*Significant at the 5% probability level.

[a)]R^2 = coefficient of determination; RMSE = root mean square error.

TABLE IV

Effect of clay content on the regression parameters[a)] between the soil organic matter calculated by the Walkley-Black method and that calculated by the loss-on-ignition method at different temperatures for all samples studied (n = 100)

Temperature	Clay content								
	> 400 g kg^{-1}			200–400 g kg^{-1}			< 200 g kg^{-1}		
	Intercept	Slope	R^2	Intercept	Slope	R^2	Intercept	Slope	R^2
°C									
300	−0.69	0.87	0.84	−0.24	0.75	0.70	−0.02	0.67	0.86
360	−0.49	0.69	0.82	−0.31	0.68	0.71	0.00	0.59	0.86
400	−0.61	0.60	0.60	−0.12	0.54	0.69	−0.06	0.50	0.84
500	−1.75	0.62	0.92	−0.60	0.45	0.64	−0.19	0.38	0.77
550	−1.92	0.59	0.74	−0.37	0.36	0.57	−0.32	0.36	0.74

a) R^2 = coefficient of determination.

TABLE V

Effect of calcium carbonate equivalent (CCE) on the regression parameters[a)] between the soil organic matter calculated by the Walkley-Black method and that calculated by the loss-on-ignition method at different temperatures for all samples studied (n = 100)

Temperature	CCE								
	> 40%			20%–40%			< 20%		
	Intercept	Slope	R^2	Intercept	Slope	R^2	Intercept	Slope	R^2
°C									
300	−0.17	0.81	0.78	−0.24	0.78	0.76	−0.40	0.75	0.78
360	−0.07	0.67	0.79	−0.20	0.66	0.72	−0.50	0.68	0.83
400	−0.31	0.42	0.60	−0.08	0.55	0.69	−0.27	0.52	0.69
500	0.03	0.33	0.68	−0.46	0.44	0.66	−0.94	0.50	0.82
550	0.14	0.27	0.61	−0.50	0.40	0.66	−0.99	0.46	0.73

a) R^2 = coefficients of determination.

Loss of structural water in illite, smectite, and vermiculite is a relatively gradual process and can occur at any temperature level. For chlorite and kaolinite, however, the loss of structural water occurs largely in the range of 450–600 °C (Sun *et al.*, 2007). Smectite has been reported as the dominant clay mineral in the Koohrang Plain (with formation of Vertisols), whereas a mixed clay mineralogy including mica, chlorite, kaolinite, and smectite was reported for the Shahrekord Plain (Salehi *et al.*, 2003).

Destruction of CCE was been observed with increasing temperature (Fig. 2). According to the results obtained, the percentage of overestimation of SOM at 300 and 360 °C would be 1.37% because 0.4% (29.2% minus 28.8%) decrease of CCE occurred at 330 and 360 °C. Mean CCE values after ignition at 500 and 550 °C

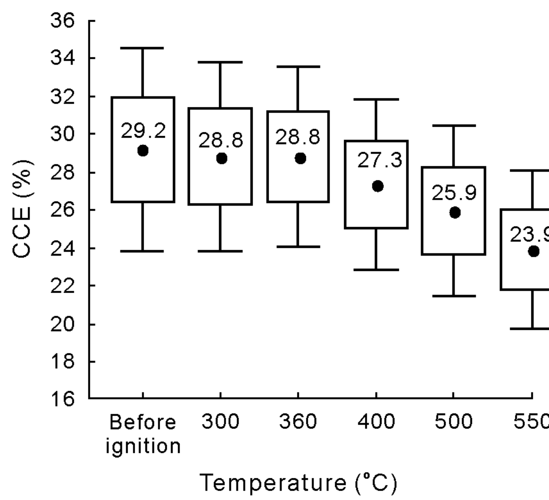

Fig. 2 Means of calcium carbonate equivalent (CCE) before and after ignition at different temperatures.

showed a significant difference ($\alpha = 0.01$) in comparison with those at lower temperatures. On the other hand, no organic matter could be detected for the samples burned at 400 °C and higher temperatures by the WB method (Fig. 3). Therefore, a temperature around 360 °C seemed to be optimum because it burnt most organic carbon, destroyed less inorganic carbon (CCE), caused less clay structural water loss, and used less electrical energy.

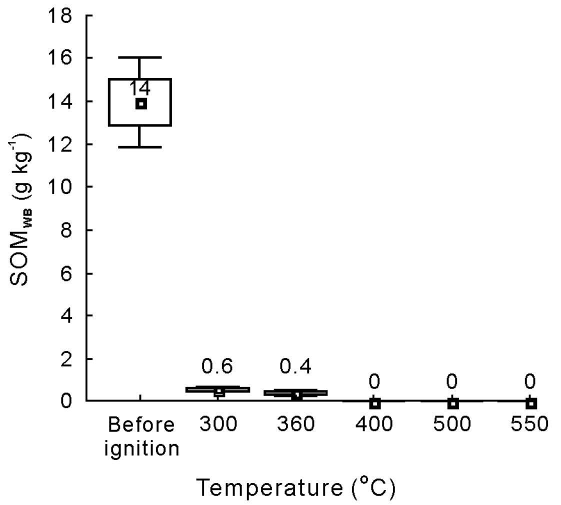

Fig. 3 Means of soil organic matter determined by the Walkley-Black method (SOM_{WB}) before and after ignition at different temperatures.

Semivariograms and related continuous maps were generated and compared for SOM_{WB} and SOM_{LOI}. The semivariogram parameters (Table VI) showed considerable differences. All variograms of SOM_{WB} and SOM_{LOI} were exponential and their ranges were from 2 676 to 4 310 and 1 820 to 2 917 m for the Koohrang and Shahrekord plains, respectively. Although the ranges were different, a mean sampling distance more or less equal to 3 500 and 2 400 m was reasonable to study the SOM in the Koohrang and Shahrekord plains, respectively. This finding can be used as a good indicator for future monitoring of the SOM. The nugget/sill ratios as the characteristic of the strength in spatial dependency were classified based on Cambardella *et al.* (1994). Both SOM_{WB} and SOM_{LOI} exhibited moderate to strong spatial dependency for the two plains. Cambardella and Karlen (1999) hypothesized that intrinsic variations may control the strongly spatially dependent soil variables such as SOM.

Based on visual interpretation, the kriged map of SOM_{LOI} at 300 °C showed higher accordance with the map of organic matter determined by the wet oxidation method for both plains (Figs. 4 and 5). Higher overall accuracy for SOM_{LOI} at 300 °C (Table VII) seemed to be related to overestimation of SOM at higher temperatures. These suggested that the maps of SOM_{LOI} at 300 °C can be used to get a good idea of the SOM trend in the study area. Although the trends of SOM in the kriged maps by the two procedures accorded well, low overall accuracy was calculated for the kriged maps obtained by the two methods even for SOM_{LOI} at 300 °C. This can be explained by considerable differences of SOM values in the maps obtained by both methods. Therefore, LOI maps seemed not to be reliable where high accuracy for spatial information of SOM was needed. Determination of organic carbon through

TABLE VI

Characteristics of variograms for the soil organic matter (SOM) calculated by the Walkley-Black method (SOM_{WB}) and that calculated by the loss-on-ignition method (SOM_{LOI}) for the two plains studied

Plain	SOM	Model	Nugget	Sill	Range	Spatial dependency	Class of spatial dependency
					m	%	
Koohrang	SOM_{WB}	Exponential	0.3137	0.656 7	4 169	47.8	Moderate
	SOM_{LOI} at 300 °C	Exponential	0.166 7	0.695 2	3 490	24.0	Strong
	SOM_{LOI} at 360 °C	Exponential	0.288 5	0.939 0	3 673	30.7	Moderate
	SOM_{LOI} at 400 °C	Exponential	0.165 0	1.022 8	2 676	16.1	Strong
	SOM_{LOI} at 500 °C	Exponential	0.278 5	1.589 3	3 983	17.5	Strong
	SOM_{LOI} at 550 °C	Exponential	0.336 0	1.569 4	4 310	21.4	Strong
Shahrekord	SOM_{WB}	Exponential	0.210 0	0.562 5	2 335	37.3	Moderate
	SOM_{LOI} at 300 °C	Exponential	0.192 0	0.816 0	2 917	23.5	Strong
	SOM_{LOI} at 360 °C	Exponential	0.180 0	1.248 0	2 701	14.4	Strong
	SOM_{LOI} at 400 °C	Exponential	0.090 0	1.545 9	1 955	5.8	Strong
	Logarithmic SOM_{LOI} at 500 °C	Exponential	0.007 5	0.016 0	1 820	46.5	Moderate
	Logarithmic SOM_{LOI} at 550 °C	Exponential	0.008 8	0.017 6	2 057	49.8	Moderate

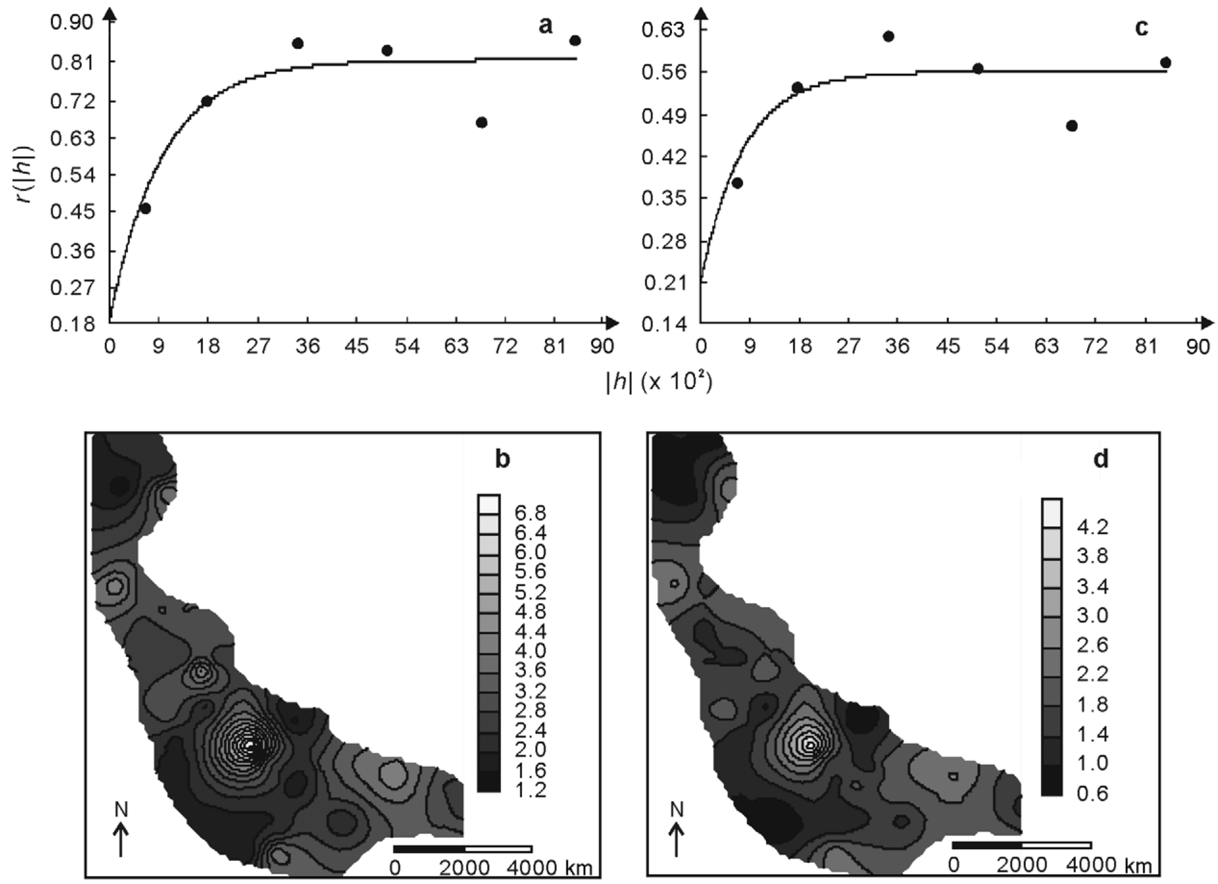

Fig. 4 Semivariograms ($\gamma(h)$, where h is the lag distance) and kriged maps for soil organic matter determined by the Walkley-Black method (a and b) and the loss-on-ignition method at 300 °C (c and d) for the Shahrekord Plain.

TABLE VII

Accordance of the maps (overall accuracy) of soil organic matter determined by the loss-on-ignition (SOM_{LOI}) with that of the Walkley-Black method (SOM_{WB}) for the two plains studied

Plain	Temperature	Accordance of SOM_{LOI} with SOM_{WB}
	°C	%
Shahrekord	300	35.95
	360	7.84
	400	5.74
	500	0.00
	550	0.00
Koohrang	300	0.88
	360	0.15
	400	0.00
	500	0.00
	550	0.00

LOI is likely suitable for exploratory soil surveys where rough estimation of SOM is required.

CONCLUSIONS

A significant linear relationship was observed between SOM_{LOI} at all temperatures and SOM_{WB}. A temperature around 360 °C was identified as optimum for the LOI method. According to overall accuracy investigations, the map of SOM_{LOI} at 300 °C showed higher accordance with that of SOM_{WB}, which was probably due to the overestimation of SOM at higher temperatures. Determination of organic carbon through the LOI method is suitable for exploratory soil surveys where rough estimation of organic matter is required. Although our results indicated that selected temperatures were not accurate enough to show the spatial variability of organic matter in semi-arid and semi-humid regions, the efficiency of the LOI method should be investigated for arid soils with lower organic matter. We also recommended such a study to be done at temperatures from 300 to 400 °C with different duration of ignition.

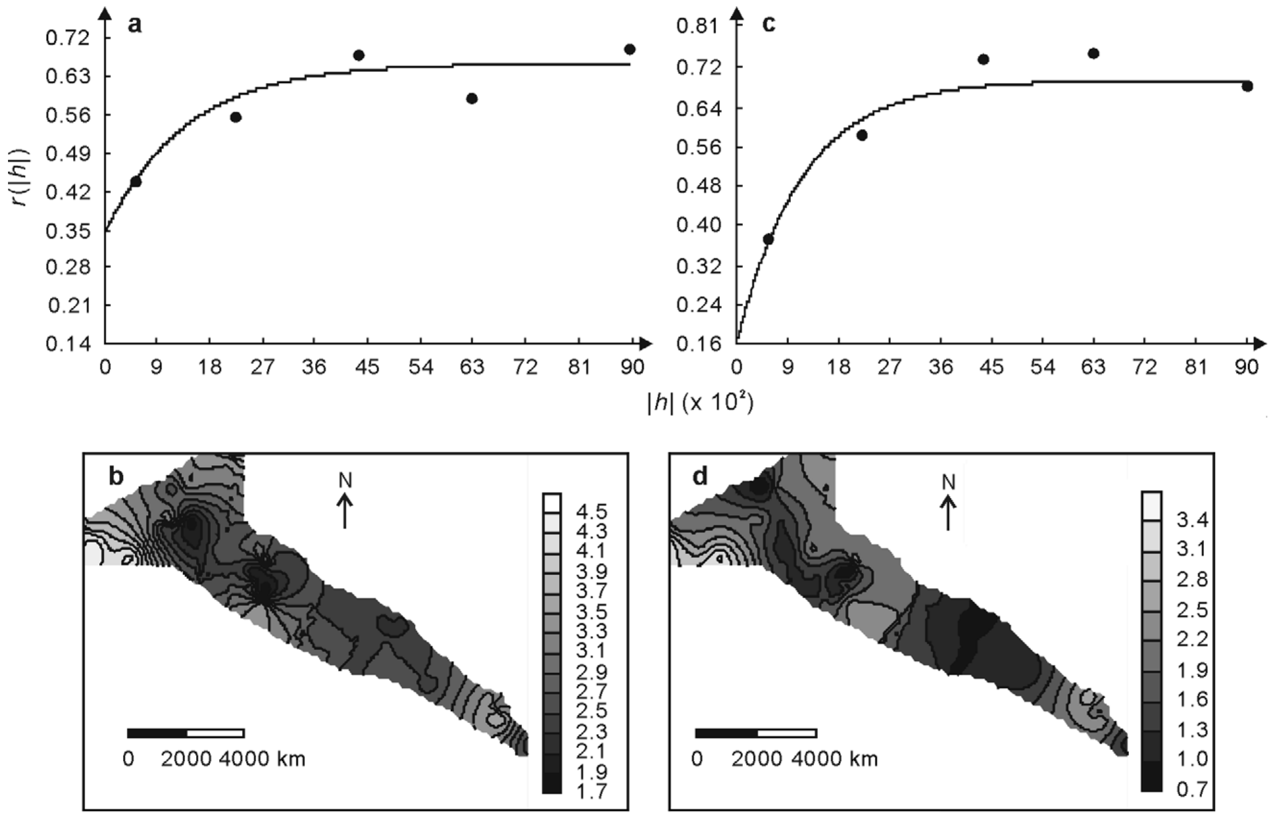

Fig. 5 Semivariograms ($\gamma(h)$, where h is the lag distance) and kriged maps for soil organic matter determined by the Walkley-Black method (a and b) and loss-on-ignition method at 300 °C (c and d) for the Koohrang Plain.

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