A comparison of soil maps, kriging and a combined method for spatially predicting bulk density and field capacity of ferralsols in the Havana–Matanzas Plain

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Abstract

Predictions of soil bulk density and field capacity at 0–10, 10–20 and 20–30 cm depths in Rhodic and Xhantic Ferralsols at the Havana–Matanzas plain are validated at a number of measured sites. It was done in order to compare the prediction accuracy under the constraint of a small data set by the following three procedures: (1) soil maps, (2) kriging, considering Xhantic and Rhodic Ferralsols as different soil types, as well as Ferralsols as a combined single soil type and (3) combined kriging–soil map predictions. The results show a considerable bias in the predictions made with the soil map, which is not found in kriging predictions. Generally, soil map predictions are also less accurate. However, the use of soil maps in Xhantic Ferralsols field-capacity predictions was the most reliable approach. The use of semivariograms for each soil type in kriging predictions only yields more accurate results for Rhodic Ferralsols, where enough data is available. The combined kriging–soil map procedure yields the smallest bias. Predictions of the combined procedure are more accurate, although accuracy differences found with the other two

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1. Introduction

Predictions of a specific soil property are commonly performed by using detailed soil maps. Nevertheless, soil properties change from place to place, even for the same soil type (Warrick and Nielsen, 1980). Thus, point estimations using soil maps are often very inaccurate. Consequently, in the last two decades, interpolation techniques such as kriging (Journel and Huijbregts, 1978; Burgess and Webster, 1980) have been extensively used. In studies made by Van Kuilemberg et al. (1982) and Voltz and Webster (1990), kriging yields better point estimates of soil properties than other interpolation techniques. However, kriging interpolations require the determination of semivariograms, which must be calculated with 100 or more data points (Webster and Oliver, 1992). In addition, Stein et al. (1988) showed that kriging predictions over a region with several soil types are more accurate when semivariograms are calculated for each soil type. It follows that more than 100 measurements must be available at each soil type, which is not generally the case (Stein et al., 1988). Heuvelink and Bierkens (1992) suggested a combined kriging–soil map estimator, which yields better predictions than kriging or soil maps alone. This method reduces the need of separate semivariograms for each soil. Hence, the combined soil map–kriging procedure is especially recommended when a small number of observation points per soil type are available (Heuvelink and Bierkens, 1992). A similar combined procedure was also followed by Voltz et al. (1997). They showed that soil-type information could be useful in interpolating soil property values by kriging.

The objective of this paper is to compare predictions of soil properties by using soil maps alone, kriging and a kriging–soil map combination, under the constraint of small data sets. The effects of considering separated semivariograms for each particular soil type and a global semivariogram for the whole zone were also compared.

2. Materials and methods

The experiment was conducted on the Havana–Matanzas plain. It is located in the west of Cuba, from Artemisa (22°53′N, 83°14′E) to Aguada de Pasajeros
Fig. 1 shows a general scheme of the zone. As can be seen in the figure, the shape of Havana–Matanzas plain is relatively long and narrow. The plain consists of Miocene limestone (National Direction of Soil and Fertilizers, 1992). The soils at Havana–Matanzas plain are mostly Ferralsols. Rhodic Ferralsol is most extensive, although Xhantic Ferralsol is also found.

Xhantic Ferralsols are relatively bad-drained soils as compared to Rhodic Ferralsols (Institute of Soils, 1980) and they are usually found in lowest lands. Field capacity in these soils is usually higher than in Rhodic Ferralsols (Simeon, 1979).

Measurements of bulk density and field capacity in 41 sites for Xhantic Ferralsols and 92 sites for Rhodic Ferralsols were made at 0–10, 10–20, and 20–30 cm depths in the last 20 years. The 133 measurements are distributed over the whole Havana–Matanzas plain and they are contained in a soil database (Simeon, 1979). The sampling sites are shown in Fig. 1. Bulk density measurements were made from undisturbed soil samples taken at each site and depth.

Fig. 1. Experimental sites for semivariogram calculation, spatial prediction and prediction validation on the Havana-Matanzas plain.
Field capacity was obtained from periodical measurements of soil water content, after 8 h of continued infiltration (Simeon, 1979). The soil water content approaches to an asymptotic value, which was assumed as the field capacity for each measurement (Israelsen and Hansen, 1965; Simeon, 1979). This procedure agrees with the field capacity definition (Israelsen and Hansen, 1965) and was very used in Cuba for field capacity determinations with irrigation purposes (Irrigation and Drainage Research Institute (IDRI), 1989).

Predictions of bulk density and field capacity were also made at each location according to the reported values of these properties for each soil type (Simeon, 1979), which is very often used as practical-routine predictions (Irrigation and Drainage Research Institute (IDRI), 1989). These predictions were made according to the soil type using the 1:25,000 soil map of the zone (National Direction of Soil and Fertilizers (NDSF), 1992).

Semivariances were calculated at each depth for lags of 10 km, 20 km, 30 km, up to 100 km. Allowable theoretical semivariograms models (Journel and Huijbregts, 1978; Mc Bratney and Webster, 1986) were automatically fitted to the estimated semivariograms through the weighted least-squares procedure recommended by Mc Bratney and Webster (1986). The model selection was made by considering Akaike’s criterion (Mc Bratney and Webster, 1986).

Two-dimensional semivariograms were determined at each depth for Rhodic and Xhantic Ferralsols, separately, with the 92 and 41 measurements and also for Ferralsols as a single soil, by considering all the 133 measurements. Only isotropic semivariograms were determined. Myers (1991) pointed out that an anisotropy analysis is not useful when the data is directionally oriented. The narrow shape of Havana–Matanzas plain does not allow any directional analysis, even though a topographically based anisotropy behavior could be expected. Moreover, determinations of directional semivariograms require more experimental data (Webster and Oliver, 1992).

Voltz and Webster (1990) pointed out that the same data must not be used for semivariogram determination and validation analysis. Therefore, an independent data set was designed for such analysis. According to the coordinates of each location and the 1:25,000 soil map, 30 measurements of bulk density and field capacity corresponds to Rhodic Ferralsols and 20 measurements were made at Xhantic Ferralsols. The locations of these validation values are also shown in Fig. 1. These measurements were made in the last 10 years over the whole Havana–Matanzas plain and they are contained in an independent data set (NDSF, 1992). Bulk density and field capacity values of this data set were determined by the same procedure described above, hence differences among the measured values are not due to any experimental disagreement.

Kriging predictions were performed at each site of the separated data set, by using the corresponding soil semivariogram, as well as that of all Ferralsols. Simple punctual kriging was used in all the cases. Between four to eight neighbours were considered for kriging calculations. The semivariogram range
was selected as the maximum allowable distance between the kriging estimation point and the measured neighbour point.

Combined kriging–soil map predictions were made through the weighting procedure proposed by Heuvelink and Bierkens (1992). The estimation value, \( Z^* \), is calculated from the linear combination of the kriging estimate, \( Z_K \), and the soil map estimate, \( Z_s \), by the equation:

\[
Z^* = \omega_K Z_K + \omega_s Z_s
\]  

(1)

The weights \( \omega_K \) and \( \omega_s \) are calculated according to:

\[
\begin{align*}
\omega_K &= \frac{\sigma_K^2 - \rho_{sk} \sigma_s \sigma_K}{\sigma_s^2 + \sigma_K^2 - 2 \rho_{sk} \sigma_s \sigma_K} \\
\omega_s &= \frac{\sigma_s^2 - \rho_{sk} \sigma_s \sigma_K}{\sigma_s^2 + \sigma_K^2 - 2 \rho_{sk} \sigma_s \sigma_K}
\end{align*}
\]  

(2)

and

\[
\begin{align*}
\omega_K &= \frac{\sigma_K^2 - \rho_{sk} \sigma_s \sigma_K}{\sigma_s^2 + \sigma_K^2 - 2 \rho_{sk} \sigma_s \sigma_K} \\
\omega_s &= \frac{\sigma_s^2 - \rho_{sk} \sigma_s \sigma_K}{\sigma_s^2 + \sigma_K^2 - 2 \rho_{sk} \sigma_s \sigma_K}
\end{align*}
\]  

(3)

where \( \sigma_s^2 \) and \( \sigma_K^2 \) are the soil map and kriging prediction variances at the location and \( \rho_{sk} \) is the correlation coefficient between the prediction errors.

The kriging variances were obtained at each estimation site, whereas the soil map variance was calculated from all the reported values for each depth provided by Simeon (1979) for Rhodic and Xhantic Ferralsols and assumed as the same for all the estimation sites. The correlation coefficients between soil map and kriging prediction errors were calculated from the differences between predicted and actual values, at each case.

Mean absolute error (MAE) and mean square error (MSE) were used as comparison criteria between predicted and actual values. They were calculated as:

\[
\text{MAE} = \frac{\sum_{i=1}^{n} \theta_i - \theta_m}{n}
\]  

(4)

and

\[
\text{MSE} = \frac{\sum_{i=1}^{n} (\theta_i - \theta_m)^2}{n}
\]  

(5)

where \( \theta_i \) are the prediction values, \( \theta_m \) are the mean values and \( n \) is the total number of predictions for each validation case.

The MAE gives the bias and the MSE the prediction accuracy.
3. Results

3.1. Spatial variability of bulk density and field capacity

Mean values, standard deviations and coefficients of variation (CV) of bulk density and field capacity at each depth are shown in Table 1 for Rhodic and Xhantic Ferralsols, as well as for all Ferralsols together. Field capacity CVs are about 10%–30%. They are considerably larger than those found for bulk density, which is generally considered a less variable soil-physical property (Warrick and Nielsen, 1980). The CVs found in Rhodic Ferralsols are smaller than those corresponding to Xhantic Ferralsols, which indicates a larger internal variability in this soil type.

Fig. 2A shows the experimental semivariograms of soil bulk density in Rhodic Ferralsols and Fig. 2B shows field capacity semivariograms for this soil. Fig. 3A and 3B show Xhantic Ferralsols bulk density and field capacity semivariograms, respectively, and Fig. 4A and 4B show bulk density and field capacity semivariograms for all Ferralsols. The parameters of the theoretical model (nugget, sill and range) fitted to the calculated semivariograms are shown in Table 2. The fraction of variation explained by the semivariogram model, calculated as \((\text{sill} - \text{nugget})/\text{sill}\) is also shown in Table 2 as the parameter \(s\) of the table.

There is a correspondence between the reported CV of Table 1 and the semivariogram nuggets of Table 2. It agrees with the nugget causes pointed out in Table 1.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Density ((d))</th>
<th>Field capacity ((\text{FC}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(d) (g/cm(^3))</td>
<td>(\sigma) (g/cm(^3))</td>
</tr>
<tr>
<td>Rhodic Ferralsols</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.24</td>
<td>0.12</td>
</tr>
<tr>
<td>20</td>
<td>1.23</td>
<td>0.09</td>
</tr>
<tr>
<td>30</td>
<td>1.23</td>
<td>0.09</td>
</tr>
<tr>
<td>Xhantic Ferralsols</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.24</td>
<td>0.15</td>
</tr>
<tr>
<td>20</td>
<td>1.22</td>
<td>0.15</td>
</tr>
<tr>
<td>30</td>
<td>1.22</td>
<td>0.15</td>
</tr>
<tr>
<td>Ferralsols</td>
<td></td>
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</tr>
<tr>
<td>10</td>
<td>1.23</td>
<td>0.09</td>
</tr>
<tr>
<td>20</td>
<td>1.22</td>
<td>0.11</td>
</tr>
<tr>
<td>30</td>
<td>1.23</td>
<td>0.12</td>
</tr>
</tbody>
</table>
A. Bulk density.

B. Field Capacity.

Fig. 2. Rhodic Ferralsol semivariograms.

by Burgess and Webster (1980). The bulk density $s$ values are lesser than those corresponding to field capacity. According to the considered scale (see Fig. 1), the spatial structures of the measured properties should be related to topography and soil types rather than to soil use, irrigation management or tillage. Therefore, as soil density shows little variations for the same soil type (Warrick and Nielsen, 1980), its $s$ values are lesser than those of field capacity, which is a more variable soil property. The fraction of variations explained by the all Ferralsols semivariograms of field capacity are lesser than those corresponding to each soil type for this property. In this case the CV are also lesser than for the particular case of each soil. According to these results, the spatial structure of field capacity is weaker when a pooled semivariogram is considered. The same conclusion can be achieved comparing Figs. 2–4.
Fig. 3. Xhantic Ferralsol semivariograms.

A. Bulk density.

B. Field Capacity.

Larger semivariances were found for both properties at 0–10 cm depth in Rodthic Ferralsols, as compared to deeper depths. This soil layer shows a considerable variability in this soil type (see Table 1). However, the semivariograms shown in Fig. 2 have very similar spatial structures. Semivariograms of bulk density and field capacity of Xhantic Ferralsols show considerably erratic behavior. Due to this erratic behavior, no differences can be seen among semivariograms at each depth in Xhantic Ferralsols. On the other hand, semivariograms of both soil properties considering all Ferralsol data (Fig. 4A and 4B) also show little differences among depths. The Ferralsol profiles are very deep and homogeneous (Institute of Soils, 1980). Thus, no great differences can be expected among the spatial structures at the measured depths.
Linear unbounded models were fitted to semivariograms of bulk density for all Ferralsols. Either transitive or unbounded models were fitted to semivariograms of both properties for Xhantic and Rhodic Ferralsols. Particularly, for the semivariograms of field capacity of Rhodic Ferralsols, the linear behavior was not observed. This means that the spatial correlation of bulk density and field capacity is smaller when separated soils are considered, which also agrees with the differences in the $s$ values shown in Table 2.

3.2. Comparison between kriging, soil map and combined predictions

Table 3 shows the MAE and the MSE obtained for each property by soil maps, kriging interpolations using Xhantic, Rhodic and all Ferralsols semivariograms.
Table 2
Nugget ($C_n$), sill ($C_o + C$), range ($r$), fraction of the variation explained by the spatial model ($s$) and fitted model obtained for semivariograms of Rhodic Ferralsols, Xhantic Ferralsols and all Ferralsols at each depth

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Density (g/cm$^2$)</th>
<th>$C_o$ (g$^2$/cm$^6$)</th>
<th>$C_o + C$ (g$^2$/cm$^6$)</th>
<th>$r$ (km)</th>
<th>$s$</th>
<th>Model</th>
<th>Field capacity (cm$^3$/cm$^2$)</th>
<th>$C_o$ (cm$^6$/cm$^2$)</th>
<th>$C_o + C$ (cm$^6$/cm$^2$)</th>
<th>$r$ (km)</th>
<th>$s$</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.0044</td>
<td>0.019$^a$</td>
<td>0.019</td>
<td>–</td>
<td>0.76</td>
<td>1</td>
<td>16.7</td>
<td>36.0</td>
<td>38.8</td>
<td>0.54</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.0058</td>
<td>0.012$^a$</td>
<td>0.012</td>
<td>–</td>
<td>0.52</td>
<td>1</td>
<td>1.5</td>
<td>34.1</td>
<td>17.0</td>
<td>0.95</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.0048</td>
<td>0.011$^a$</td>
<td>0.011</td>
<td>–</td>
<td>0.56</td>
<td>1</td>
<td>1.3</td>
<td>28.8</td>
<td>16.2</td>
<td>0.95</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.0077</td>
<td>0.022$^a$</td>
<td>0.022</td>
<td>–</td>
<td>0.65</td>
<td>1</td>
<td>25.6</td>
<td>148.2</td>
<td>–</td>
<td>0.83</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.0054</td>
<td>0.016</td>
<td>0.016</td>
<td>35.4</td>
<td>0.66</td>
<td>3</td>
<td>26.6</td>
<td>109.4</td>
<td>85.1</td>
<td>0.76</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.0054</td>
<td>0.019</td>
<td>0.019</td>
<td>35.7</td>
<td>0.72</td>
<td>3</td>
<td>44.5</td>
<td>151.5</td>
<td>–</td>
<td>0.71</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.0057</td>
<td>0.016$^a$</td>
<td>0.016</td>
<td>–</td>
<td>0.64</td>
<td>1</td>
<td>30.7</td>
<td>82.7</td>
<td>–</td>
<td>0.63</td>
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<tr>
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<td>0.017</td>
<td>–</td>
<td>0.63</td>
<td>1</td>
<td>33.6</td>
<td>79.5</td>
<td>–</td>
<td>0.58</td>
<td>1</td>
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</tr>
<tr>
<td>30</td>
<td>0.0048</td>
<td>0.017$^a$</td>
<td>0.017</td>
<td>–</td>
<td>0.72</td>
<td>1</td>
<td>37.2</td>
<td>77.3</td>
<td>–</td>
<td>0.52</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

1. Linear model: $\gamma(h) = C_o + bh$.
2. Spherical model: $\gamma(h) = C_o + C$, $h > r$; and $\gamma(h) = C_o + C[(3h/2r) - (h^3/2r^3)]$, $h \leq r$.
3. Gaussian model: $\gamma(h) = C_o + C[1 + \exp(-h^2/r^2)]$.

*s = (sill – nugget)/sill.
Table 3
Mean absolute errors (MAE) and mean square errors (MSE) for soil maps predictions, kriging interpolations and combined kriging–soil maps — predictions of bulk density and field capacity. SD = Soil depth, RFS = Rhodic Ferralsols semivariogram, XFS = Xhantic Ferralsols semivariogram, AFS = All Ferralsols semivariogram.

<table>
<thead>
<tr>
<th>SD (cm)</th>
<th>Kriging RFS</th>
<th>Kriging AFS</th>
<th>Soil maps</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAE</td>
<td>MSE</td>
<td>MAE</td>
<td>MSE</td>
</tr>
<tr>
<td>Bulk density of Rhodic Ferralsols</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.0256</td>
<td>0.0126</td>
<td>0.0260</td>
<td>0.0133</td>
</tr>
<tr>
<td>20</td>
<td>0.0260</td>
<td>0.0141</td>
<td>0.0247</td>
<td>0.0141</td>
</tr>
<tr>
<td>30</td>
<td>0.0393</td>
<td>0.0254</td>
<td>0.0335</td>
<td>0.0311</td>
</tr>
<tr>
<td>Bulk density of Xhantic Ferralsols</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.0173</td>
<td>0.0141</td>
<td>0.0125</td>
<td>0.0141</td>
</tr>
<tr>
<td>20</td>
<td>0.0173</td>
<td>0.0147</td>
<td>0.0127</td>
<td>0.0142</td>
</tr>
<tr>
<td>30</td>
<td>0.0118</td>
<td>0.0326</td>
<td>0.0086</td>
<td>0.0373</td>
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<tr>
<td>Field capacity of Rhodic Ferralsols</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.1873</td>
<td>13.152</td>
<td>0.5442</td>
<td>18.244</td>
</tr>
<tr>
<td>30</td>
<td>0.1583</td>
<td>8.402</td>
<td>0.1677</td>
<td>9.959</td>
</tr>
<tr>
<td>Field capacity of Xhantic Ferralsols</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.1488</td>
<td>28.484</td>
<td>0.1871</td>
<td>27.881</td>
</tr>
<tr>
<td>20</td>
<td>0.0678</td>
<td>22.983</td>
<td>0.0196</td>
<td>23.636</td>
</tr>
<tr>
<td>30</td>
<td>0.1300</td>
<td>24.649</td>
<td>0.1301</td>
<td>24.650</td>
</tr>
</tbody>
</table>

As can be seen in Table 3 and in Fig. 5, the MAE is considerably larger for map predictions in both properties and soils. Hence, the use of soil maps produces a bias, which is not observed in kriging interpolations. The obtained bias is related to the extremely restricted supposition that bulk density and field capacity have a constant value for each soil type. However, kriging estimates take into account the spatial variation and hence the bias is reduced through this procedure.

According to Table 3 and Fig. 6, in many cases, the use of soil maps also yields less accurate predictions. However, MSE for soil map predictions of field capacity in Rhodic Ferralsols are very close to those found with kriging using all Ferralsols semivariograms. Moreover, the best predictions of field capacity in Xhantic Ferralsols are obtained using soil maps. On the other hand, kriging predictions of bulk density, by using both separated and all Ferralsols semivariograms, are considerably more precise than those obtained through soil maps.

The results show a correspondence between the soil variation that is not explained by semivariograms (see Table 2) and the MSE results. Field capacity...
Fig. 5. AMEs of the average 0–30 cm depth for kriging interpolations by separated semivariograms for each soil or by an all Ferralsol semivariogram, as well as predictions by soil maps and by the combined procedure.

is more variable than bulk density and hence its prediction by using soil maps is still more accurate when compared to kriging. Conversely, kriging estimates of bulk density are considerably more precise than those obtained through soil maps. This property has the lowest CV, according to Table 1. In addition, the lowest MSE for both properties were found in Rhodic Ferralsols, which has lower CV than Xhantic Ferralsols.

As can be seen in Table 3 and in Fig. 5, MAE is higher when separated Rhodic Ferralsols semivariograms are used than when considering an all Ferral-
Fig. 6. MSEs of the average 0–30 cm depth for kriging interpolations by separated semivariograms for each soil or by an all Ferralsol semivariogram, as well as predictions by soil maps and by the combined procedure.

Kriging predictions of bulk density and field capacity in Xhantic Ferralsols, using all Ferralsols or Xhantic Ferralsols semivariograms, are equally accurate (see MSE in Table 3 and Fig. 6). Conversely, the prediction accuracy using Rhodic Ferralsols semivariograms is higher than using an all Ferralsols semivariogram in most of the cases. Rhodic Ferralsols semivariograms are able to explain the spatial variation of field capacity particularly better than a more
global all Ferralsols semivariograms. Stein et al. (1988) already showed this. The same ability was not found in Xhantic Ferralsols semivariograms cause the specific semivariograms for this soil type were made with a reduced amount of soil data. Moreover, both bulk density and field capacity are more variable in Xhantic Ferralsols than in Rhodic Ferralsols. As was already pointed out, kriging is not a good predictor in those cases and accuracy differences using semivariograms for each soil type or a pooled semivariogram are negligible. Therefore, the use of specific Xhantic Ferralsols semivariograms in this case produces no obvious improvement in bulk density and field capacity predictions.

Based on the above results, in the combined kriging–soil map approach, only semivariograms for each soil type were considered in kriging interpolations. As can be seen in Table 3 and in Fig. 5, MAE of combined kriging–soil maps predictions are considerably smaller than those obtained with soil map predictions alone, but very similar to the ME obtained with kriging predictions either considering separated or all Ferralsols semivariograms. It therefore follows that through the combined procedure the bias obtained by the soil map method is removed.

In addition, through the combined procedure the resulting MSE are quite similar, or even lower, than those achieved by performing kriging or soil maps predictions alone. Once again, the resulting MSE are related to the CV of each corresponding property, soil or depth. Less accurate predictions are those obtained for field capacity at Xhantic Ferralsols and the highest accuracy was found for bulk density predictions in Rhodic Ferralsols.

4. Conclusions

Predictions of bulk density and field capacity in Ferralsols at the Havana–Matanzas plain using the available soil maps show a considerable bias. Predictions by using kriging interpolation show little bias. Predictions of these properties using soil maps are also less accurate than those obtained by kriging. There is a direct relationship between the semivariogram’s unexplained soil variation, related to CV and semivariogram’s nugget, and the kriging prediction accuracy. Field Capacity in Xhantic Ferralsols has a large CV (higher than 30%) and hence a prediction of this property by using soil maps seems to be the more reliable approach. As expected, kriging predictions in Rhodic Ferralsols are more accurate when a soil-separated semivariogram is used. Nevertheless, no improvement is obtained when using a soil-separated semivariogram in kriging predictions in Xhantic Ferralsols. This seems to be related to the higher variability of these soils, as expressed in the larger CV, as well as the small data set provided for semivariogram calculations. The use of the combined kriging–soil map procedure effectively reduces the bias found in soil map predictions.
This procedure generally yields more accurate results than soil map or kriging predictions alone, although the accuracy increment is not very large.

References


