

## Interpolators in predicting the estimated population density of *Oebalus* spp.

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**ABSTRACT:** The objective of this study was to compare interpolation methods of ordinary kriging and inverse distance weighted applied to the spatial distribution of *Oebalus poecilus* and *Oebalus ypsilongriseus* population densities in irrigated rice. In two crops, it was generated a grid of 30 x 30 m sampling, termed Area 1 and Area 2 with 39 and 192 sampling units (1 m<sup>2</sup>, corresponding to 200 rice plants), respectively. Seven evaluations were carried out from sowing to harvesting. In these areas, *O. poecilus* and *O. ypsilongriseus* adults were quantified and the sum of each species was used for analysis. Values were submitted to the ordinary kriging interpolation and inverse distance weighted for different semivariogram models, in which the cross-validation technique was used for defining the best interpolator. The ordinary kriging interpolation method showed a better performance than the method of inverse distance weighted applied in the spatial distribution of population density of *O. poecilus* in rice cultivation. *O. ypsilongriseus* could not generate estimates for comparison.

**Key words:** dispersion; kriging; *Oryza sativa*; spatial distribution

## Interpoladores na previsão da densidade populacional estimada de *Oebalus* spp.

**RESUMO:** O objetivo do estudo foi comparar métodos de interpolação de krigagem ordinária e inverso da distância ponderada aplicada à distribuição espacial da densidade populacional de *Oebalus poecilus* e *Oebalus ypsilongriseus* em arroz irrigado. Em duas safras foi gerada uma grade de 30 x 30 m de amostragem, denominada Área 1 e Área 2 com 39 e 192 unidades amostrais (1 m<sup>2</sup>, correspondentes a 200 plantas de arroz), respectivamente. Da semeadura até a colheita foram realizadas sete avaliações. Nessas áreas, os adultos de *O. poecilus* e *O. ypsilongriseus* foram quantificados e a soma de cada espécie foi utilizada para análise. Os valores foram submetidos à krigagem ordinária e distância inversa ponderada para diferentes modelos de semivariogramas, sendo utilizada a técnica de validação cruzada para definir o melhor interpolador. O método de krigagem ordinária apresentou melhor desempenho do que o método de distância inversa ponderada aplicada na distribuição espacial da densidade populacional de *O. poecilus* no cultivo de arroz. *O. ypsilongriseus* não pôde gerar estimativas para comparação.

**Palavras-chave:** dispersão; krigagem; *Oryza sativa*; distribuição espacial

## Introduction

Rice (*Oryza sativa* L.) is one of the most produced and consumed grain in the world. It is characterized as staple food for over half of the world's population. In addition, Brazil is the ninth largest producer, holding 2% of rice production worldwide and the state of Rio Grande do Sul is the largest rice producer in Brazil, producing over 60% of the national production in more than million hectares (Sosbai, 2014).

The attack of insect pests that economically damage the irrigated rice, includes *Oebalus poecilus* and *Oebalus ypsilon* (Hemiptera: Pentatomidae), which are referred to as rice grain stink bug. Such insects occur sporadically in rice production areas (Oliveira et al., 2010; Sosbai, 2014). The damage to the crop occurs from the grain formation until its maturity, affecting quality and quantity of the final product (Walzer et al., 2009). According to Oliveira et al. (2010), grains damaged by these insect pests present lower germination power, less weight, become brittle during processing and display dark spots after it. The same authors also claim that for each insect m<sup>2</sup>, a reduction by 1% occurs in yield grain.

Insect populations in croplands can be estimated with the use of interpolation procedures, which are able to generate continuous surfaces by single point sampling units (Soares et al., 2008). Among the kriging interpolation methods, the inverse of the weighted distance is more used (Coelho et al., 2009; Souza et al., 2010; Silva et al., 2010; Dinardo-Miranda et al., 2011; Pasini et al., 2014; Pasini et al., 2015; Pazini et al., 2015). The ordinary kriging (OK) method uses the spatial dependence among neighboring samples, expressed in the semivariogram to estimate values at any position in the field not using trend and with minimum variance (Mello et al., 2003). In the inverse distance weighted (IDW) method, the weighting factor is the inverse of the Euclidean distance to the raised power. This method is considered easy to be applied but with less accuracy than the kriging method because it does not consider the spatial dependence structure (Mello et al., 2003).

There are many works that were carried out which applied this methodology in many areas of knowledge. Kanegae Júnior et al. (2006) observed a greater reduction in the mean and variance of the sampling error with the IDW from the OK in the stratification of eucalypt. Soares et al. (2008) found minimum benefits obtained from OK method to the IDW. Silva et al. (2011) evaluated interpolating monthly precipitation in the State of Espírito Santo, where OK method showed the best estimates. By evaluating geostatistical interpolation analysis of the spatial distribution of annual precipitation, Carvalho et al. (2012) obtained more accurate estimates for the OK interpolation, however, Sajid et al. (2013) evaluated the performance of two widely used interpolators, OK and IDW, for spatial interpolation of measured soil bulk density, where the best performance for the IDW were obtained.

Interpolation procedures are important tools for monitoring insect pests and other harmful organisms. From the understanding of the behavior of the target pest, it is

possible to define management zones in order to optimize the use of pesticides besides helping in the prediction of the emergence of harmful species to cultivated plants (Sciarreta & Trematerra, 2014; Pasini et al., 2018).

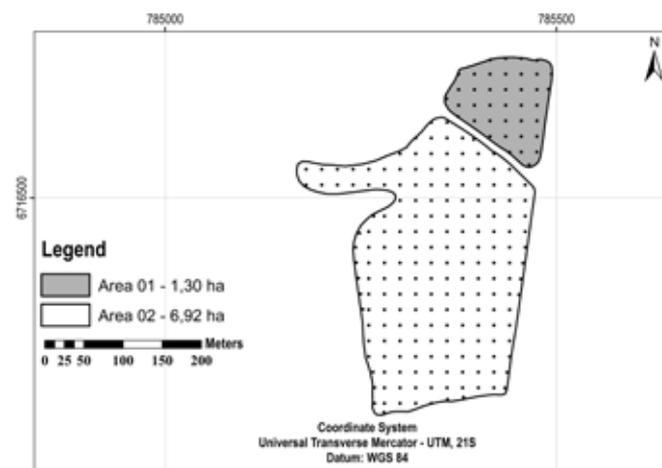
Not much information regarding the comparison of interpolation in pest insects is found in the literature and there is no information for the species *O. poecilus* and *O. ypsilon*. The selection of an appropriate method of interpolation is essential to obtain reliable spatial maps (Mello et al., 2003; Silva et al., 011; Sajid et al., 2013). Thus, the objective of this study was to identify the interpolation method with the best performance in the spatial distribution of population density of *O. poecilus* and *O. ypsilon* in irrigated rice.

## Materials and Methods

The study area is located in Parada Link in Santa Maria, state of Rio Grande do Sul, Brazil (Latitude 29° 38' S and Longitude 54° 03' W), divided into two growing areas, the first area of 1.3 ha, termed Area 1 (L01) and the second, 6.92 ha, Area 2 (L02), cultivated with irrigated rice crop following the technical recommendations for the crop (Sosbai, 2014). This area is surrounded by scrub vegetation, trees and fields. The local climate, according to the Köppen classification is Cfa (Heldwein et al., 2009). During the execution of the research, no pesticides were applied.

From each field, a grid of 30 x 30 m was generated for the sampling of insect pests, resulting in 39 sampling units in L01, and 192 sampling units in L02 (Figure 1). At each sampling unit, 200 rice plants were sampled, totaling 1 m<sup>2</sup> (50 able plants per linear meter and line spacing of 0.20 m). In each rice plant, a direct count of the number of *Oebalus poecilus* and *Oebalus ypsilon* individuals was performed.

From sowing, seven evaluations were performed for each field: the first evaluation (A1) in the corresponding stage V3, corresponding to the collar formed at leaf 3 on the main stem; the second evaluation (A2) was at the V6 stadium,



**Figure 1.** Study area by respective sampling grid. Santa Maria, Rio Grande do Sul, Brazil.

corresponding to collar formed at leaf 6 on the main stem; the third evaluation (A3) was performed at V9 (R0) stage, corresponding to panicle initiation; the fourth evaluation (A4) at V13 (R2) stage corresponding to collar formation on the flag leaf (booting); the fifth evaluation (A5) at the R4 stage at anthesis; the sixth evaluation (A6) at the R6 stage, corresponding to elongation of one or more grains in the shell, and the seventh and last evaluation (A7) at the R9 stage, corresponding to full maturity of the grains in the panicle (Counce et al., 2013).

Regarding statistical analysis, the total number of individuals per m<sup>2</sup> (200 plants) of each species was used. Values of *O. poecilus* and *O. ypsilongriseus* adults per evaluation were analyzed by applying descriptive and interpolation techniques analysis. At OK interpolating, the data normality hypothesis was tested by using the Shapiro-Wilk test ( $p > 0.05$ ); if not satisfied, the data that showed a positive asymmetry were submitted to Box-Cox transformation. Species were individually analyzed.

Next, the data were submitted to geostatistical analysis in order to verify the existence of spatial dependence and, if so, to quantify its degree by comparing the models to the isotropic experimental semivariogram, estimated by (Eq. 1):

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

in which the semivariance and  $N(h)$  are the number of pairs of the measured values  $Z(x_i)$  and  $Z(x_i+h)$ , separated by an  $h$  vector. From the experimental semivariograms, 11 theoretical models of semivariograms, Circular, Spherical, Tetraspherical, Pentaspherical, Exponential, Gaussian, Rational quadratic, Hole effect, K-Bessel, J-Bessel and Stable, were adjusted according to Johnson et al. (2001) and Pasini et al. (2014). By using the algorithm of weighted least squares, these models were adjusted to the experimental semivariogram, and the model parameters were defined: nugget effect ( $C_0$ ), sill ( $C_0+C_1$ ), and range ( $a$ ). In order to verify the existence of spatial dependence, the spatial dependence index (SDI) was applied. This index is the ratio representing the percentage of data variability explained by spatial dependence (Pasini et al., 2014).

After confirmation of spatial dependence, inferences were performed by ordinary kriging (OK) according to Johnson et al. (2001). The method allowed for the estimation of values at not measured locations. For OK, non-biased estimates, with minimum deviation from the known values, are interpolated by considering the spatial variability structure of the attribute (Webster & Oliver, 2007).

The semivariogram model was selected according to the cross-validation technique of Webster & Oliver (2007). Linear regression was used as a first indicator of cross-validation, where the estimated values (dependent variable) were crossed with the sampled values (independent variable). The

best adjustments are obtained when the estimation of the intercept “ $a$ ” approaches zero, and the linear “ $b$ ” and the determination “ $R^2$ ” coefficients approach 1. As a second, third, fourth and fifth indicator were the mean prediction error ( $E$ ), mean absolute prediction error ( $EA$ ), standard deviation prediction error ( $SD$ ) and root-mean-square prediction errors ( $RMS$ ), respectively. For these parameters, the closer to zero, the best the adjustment of the model. In addition, as a sixth indicator, the root-mean-square standardized prediction error ( $RMSS$ ). For this parameter, the best adjustments is obtained when it approaches 1. The cross-validation grades for the indicators varied from 1 to 10, according to the selected criterion of each indicator: for  $b$ ,  $R^2$  and  $RMSS$ , values closer to 1 received score 10, whereas the most distant values received score 1; for the estimative  $E$ ,  $EA$ ,  $SD$  and  $RMS$ , values closer or equal to zero received score 10, and the most distant values received score 1. The model with the greatest sum of grades was chosen.

The IDW is a univariate deterministic interpolator with weighted averages (Eq. 2):

$$\hat{Z}_i = \frac{\sum_{i=1}^n \left( \frac{1}{d_i^\lambda} \times Z_i \right)}{\sum_{i=1}^n \left( \frac{1}{d_i^\lambda} \right)} \quad (2)$$

in which  $Z_i$  is the interpolated value,  $Z_i$  is the sampled value,  $d_i$  is the Euclidean distance between the sampled point and the estimated,  $n$  is the number of neighboring points used in interpolation and  $\lambda$  is the weight exponent of the Euclidean distance applied to the weights 2, 3, 4, 5 and 6.

Regarding selection, the best weight cross-validation was applied across the indicators  $a$ ,  $b$ ,  $R^2$ ,  $E$ ,  $SD$ ,  $EA$  and  $RMS$ . From the estimated indicators of cross-validation, scores 1-5 were assigned according to the selection criteria for each indicator: for estimates of  $b$ ,  $R^2$  the value closest to or equal to 1, score 5 was assigned and for the furthest value of 1, score 1 was assigned, respectively; for estimates  $a$ ,  $b$ ,  $E$ ,  $SD$ ,  $EA$  and  $RMS$ , the closest or equal to 0, score 5 was applied and to the furthest value of 0, score 1 was assigned, respectively. After the assignment of the scores, their sum was carried out within each weight and the situation was evaluated by adopting the criterion of choosing the model with the highest score sum.

To choose the best interpolating between OK and IDW, cross validation was applied between the best theoretical semivariogram model and the best weight was applied across the indicators  $a$ ,  $b$ ,  $R^2$ ,  $E$ ,  $SD$ ,  $EA$  and  $RMS$ . From the estimated indicators of cross-validation, scores 1-2 were assigned according the selection criterion for each indicator. After score assignment, their sum was carried out within each interpolator by adopting the criterion to choose the method with the highest score sum.

## Results and Discussion

For this study, 4477 *Oebalus poecilus* adults, corresponding to an average of 3.03 adults m<sup>-2</sup> farming<sup>-1</sup> evaluation<sup>-1</sup>, were evaluated. Area 2 (L02) had the largest number of adults (3.537), with an average number of adults per sample of 2.62 adults m<sup>-2</sup> farming<sup>-1</sup> evaluation<sup>-1</sup>, lower than the mean value found in Area 1 (L01), a smaller area, 3.44 adults m<sup>-2</sup> farming<sup>-1</sup> evaluation<sup>-1</sup> (Table 1). The species *O. ypsilongriseus* presented values smaller than those of *O. poecilus* collected and identified with 133 subjects, with an average of 0.12 adults m<sup>-2</sup> farming<sup>-1</sup> evaluation<sup>-1</sup>. Similar to *O. poecilus*, L02 had the largest number of adults and L01m, the highest average number of adults per sample (0.52 adults m<sup>-2</sup> farming<sup>-1</sup> evaluation<sup>-1</sup>). However, their averages were below those of *O. poecilus*. The asymmetry values reveal that the evaluations for species in crop data was positive (Table 1). The difference between the farming in the average values of adults per m<sup>2</sup> (Table 1) reflects the dispersal ability of the species because a smaller crop area have a tendency to have higher population densities than most farming areas (Pasini et al., 2014). Such observation was possible since the cropped areas present similar host plants along their surroundings in their constitution.

Unlike Lepidoptera, Pentatomid stink bugs have limited dispersal ability, which reflects in areas infested with insect pests. When crops are located in larger areas, the insect pest has to go through a greater distance to reach its center. This feature appears as a benefit to the insect pest because there is a lower energy cost to be dispersed in the farming regions near the aggregation sites situated on the edges of crop fields (these sites are used in the cold seasons, mainly represented by host plants) (Kim & Sappington, 2013). However, for the crops in smaller areas, the opposite occurs as they do not offer large distances for the dispersal of insect pests, with a greater possibility of finding individuals in the internal areas of cultivation.

The lack of records on bugs species in the first evaluations reflects their behaviors, which are motivated by the availability of food source from the grain formation and filling (Table 1). Yet, the record of the species from booting stage (A4) may be derived from the presence of weeds in the attractive phase for the species of insect pests. During evaluations, a gradual increase of the populations was observed, motivated by the development of rice plants and fecundity of insect pests.

**Table 1.** Descriptive statistics of the number of *Oebalus poecilus* and *Oebalus ypsilongriseus* (Hemiptera: Pentatomidae) per m<sup>2</sup> sampled in evaluations from irrigated rice. Santa Maria, RS, Brazil, 2014.

Statistics	Farming													
	Area 01							Area 02						
	A1	A2	A3	A4	A5	A6	A7	A1	A2	A3	A4	A5	A6	A7
<i>Oebalus poecilus</i>														
Samples	39	39	39	39	39	39	39	192	192	192	192	192	192	192
Average	0	0	0	0.43	2.9	7.8	13.0	0	0	0	0.87	2.5	6.5	8.5
Standard deviation	0	0	0	0.94	4.9	7.6	6.8	0	0	0	2.33	5.1	6.3	5.5
Coefficient of variation	0	0	0	2.18	1.68	0.97	0.52	0	0	0	2.67	2.04	0.96	0.64
Interval	0	0	0	4	16	26	31	0	0	0	14	23	25	29
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	4	16	26	31	0	0	0	14	23	25	29
Sum	0	0	0	17	113	304	506	0	0	0	167	486	1256	1628
Sum farming	940							3,537						
Asymmetry	-	-	-	2.40	1.51	0.96	-0.37	-	-	-	2.45	2.01	0.70	1.34
Kurtosis	-	-	-	5.58	0.90	0.07	0.38	-	-	-	12.39	3.00	-0.56	2.50
p-value	-	-	-	0.00	0.01	0.02	0.01	-	-	-	0.00	0.00	0.02	0.01
$\lambda$ (Box-Cox)	-	-	-	-2.5	-0.78	0.27	0.98	-	-	-	-2.1	-1.1	0	0.47
p-value	-	-	-	0.05	0.07	0.1	0.09	-	-	-	0.06	0.06	0.08	0.09
<i>Oebalus ypsilongriseus</i>														
Samples	39	39	39	39	39	39	39	192	192	192	192	192	192	192
Average	0	0	0	0	0.2	0.2	0.9	0	0	0	0	0.1	0.2	0.1
Standard deviation	0	0	0	0	0.5	0.4	1.2	0	0	0	0	0.4	0.7	0.4
Coefficient of variation	0	0	0	0	2.50	2.00	1.33	0	0	0	0	4.00	3.50	4.00
Interval	0	0	0	0	2	2	4	0	0	0	0	2	4	2
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	2	2	4	0	0	0	0	2	4	2
Sum	0	0	0	0	6	6	35	0	0	0	0	17	46	23
Sum farming	47							86						
Asymmetry	-	-	-	-	4.25	4.97	4.24	-	-	-	-	4.25	3.39	3.24
Kurtosis	-	-	-	-	9.86	8.91	0.56	-	-	-	-	18.24	11.70	10.6
p-value	-	-	-	-	0.00	0.00	0.00	-	-	-	-	0.00	0.00	0.00
$\lambda$ (Box-Cox)	-	-	-	-	-2.5	-2.5	-0.6	-	-	-	-	-2.5	-2.5	-2.5
p-value	-	-	-	-	0.00	0.00	0.00	-	-	-	-	0.00	0.00	0.00

\* The data presented adherence to normality by the Shapiro-Wilk test at 5% significance.

Positive values of asymmetry and the absence of a normal distribution are particularly linked to the large number of sample units of crops without the presence of individuals or species with low values, featuring a lognormal distribution, in some cases (Table 1). However, after data processing for *O. poecilus* species, a normal distribution was identified. Nevertheless, after data processing *O. poecilus* species, a normal distribution was identified. As for the species *O. ypsilongriseus*, because normal distribution was not identified, the continuation of geostatistical procedure as well as the comparison between the interpolators were not possible. According to Yamamoto & Landim (2013), if the distribution is a positive asymmetry, some data processing need to avoid the influence of a few great values in the estimation of neighborhood points, characterized by low values. Due to the small number of *O. ypsilongriseus* individuals present in

the area, it was not possible to establish the best interpolator because the assumptions of the model were not met. Hence, it was possible to compare the interpolators for *O. poecilus* species.

In both crops and at the seven evaluations, a spatial dependence was observed with an SDI greater than 75% in theoretical models for *O. poecilus*, showing that the use of OK interpolator (Table 2) was feasible. In relation to OK method, eight models of semivariograms from the choice criterion were selected in Area 1 and 2 (Table 3 and 4). In L01, the Circular model showed greater sum of scores between the models in the A4 evaluation, the model K-Bessel in A5 evaluation, the model Hole effect in evaluation A6 and Gaussian model in A7 evaluation. In L02, the model J-Bessel in A4 evaluation, the model K-Bessel in A5 evaluation, the model Pentaspherical in A6 evaluation and the model Circular in A7 evaluation.

**Table 2.** Nugget effect ( $C_0$ ), structural variable ( $C_1$ ), range (a), gamma function ( $\Gamma$ ) and spatial dependence index (SDI) estimated for the semivariograms theoretical models Circular (C), Spherical (E), Tetraspherical (T), Pentaspherical (P), Exponential (Ex), Gaussian (G), Rational quadratic (RQ), Hole effect (SC), K-Bessel (KB), J-Bessel (JB) and Stable (Es) evaluations in the different fields L01 and L02. Santa Maria, RS, Brazil, 2014.

Models	Estimative														
	$C_0$	$C_1$	a	$\Gamma$	IDE	$C_0$	$C_1$	a	$\Gamma$	IDE	$C_0$	$C_1$	a	$\Gamma$	IDE
	L01 A4					L01 A5					L01 A6				
C	0.000	0.924	60.5		100	0.000	15.177	48.2		100	12.628	69.726	119.0		85
E	0.000	0.665	72.4		100	0.000	14.641	52.2		100	10.309	70.326	127.4		87
T	0.000	0.678	81.7		100	0.000	16.558	65.5		100	7.665	69.999	127.4		90
P	0.000	0.702	89.3		100	0.000	16.352	67.9		100	5.462	69.480	127.4		93
Ex	0.000	1.090	147.8		100	0.000	17.969	48.5		100	0.000	57.218	58.4		100
G	0.088	1.062	87.9		92	5.105	36.214	127.4		88	23.268	60.917	119.0		72
RQ	0.000	0.966	129.4		100	0.021	21.880	88.3		100	0.057	56.573	87.6		100
SC	0.242	0.434	59.5		64	15.774	3.950	59.5		20	8.813	44.842	131.1		83
KB	0.094	1.126	99.8	10.0	92	0.000	13.933	36.5	10.0	100	4.823	78.302	82.2	10.0	94
JB	0.000	0.537	66.6	4.5	100	0.000	16.196	45.3	4.2	100	18.851	45.948	130.3	0.7	71
Es	0.088	1.062	97.1	2.0	92	5.105	36.214	128.7	2.0	88	19.353	57.446	97.9	2.0	75
	L01 A7					L02 A4					L02 A5				
C	0.000	44.205	38.4		100	0.299	7.253	241.9		96	0.000	9.009	46.9		100
E	0.000	43.404	43.8		100	0.109	7.059	294.5		98	0.000	38.029	295.0		100
T	0.000	44.339	50.1		100	0.000	7.131	257.3		100	0.000	36.969	314.7		100
P	0.000	33.317	54.9		100	0.000	7.256	352.1		100	0.000	35.052	314.7		100
Ex	0.000	50.807	68.1		100	0.000	7.380	384.2		100	0.000	34.211	314.7		100
G	0.063	46.701	38.4		100	0.891	1.836	72.3		67	0.000	9.409	43.0		100
RQ	0.054	54.645	89.1		100	0.000	5.796	200.4		100	0.000	19.420	178.3		100
SC	21.008	23.088	74.9		52	1.128	4.962	241.2		81	1.225	12.282	144.6		91
KB	0.000	46.792	40.3	10.0	100	0.000	2.580	60.3	1.1	100	0.000	9.289	44.4	10.0	100
JB	0.000	45.397	49.0	3.8	100	0.181	2.391	66.4	6.5	93	0.000	15.432	105.1	5.1	100
Es	0.000	46.415	38.4	2.0	100	0.000	2.742	66.5	1.3	100	0.000	9.410	43.0	2.0	100
	L02 A6					L02 A7									
C	1.550	35.554	145.9		96	0.000	18.678	65.4		100					
E	0.000	15.809	45.4		100	0.000	19.326	72.6		100					
T	0.000	15.506	49.1		100	0.000	21.192	85.3		100					
P	0.000	15.329	52.1		100	0.000	20.872	85.3		100					
Ex	0.000	23.145	94.3		100	0.000	38.756	255.2		100					
G	4.556	14.343	52.2		76	0.000	13.903	44.4		100					
RQ	0.021	21.066	65.9		100	0.000	24.928	153.3		100					
SC	15.894	7.703	120.9		33	4.377	15.450	133.2		78					
KB	3.677	15.218	52.2	10.0	81	0.000	13.730	45.8	10.0	100					
JB	0.000	15.120	55.9	10.0	100	0.000	22.670	109.4	4.8	100					
Es	4.573	14.323	54.8	2.0	76	0.000	13.903	44.4	2.0	100					

**Table 3.** Cross-validation indicators and assigned scores (in brackets), obtained from ordinary kriging for the following semivariogram models: C, Circular; S, Spherical; T, Tetraspherical; P, Pentaspherical; E, Exponential; G, Gaussian; R, Rational quadratic; H, Hole effect; K, K-Bessel; J, J-Bessel; and St, Stable. Area O1. Santa Maria, RS, Brazil, 2014.

Indicator	C	E	T	P	Ex	G	RQ	SC	KB	JB	Es
Evaluation 04											
<i>b</i>	0.868(6)	0.854(5)	0.850(3)	0.847(2)	0.805(1)	0.892(9)	0.915(10)	0.852(4)	0.881(8)	0.971(11)	0.877(7)
<i>a</i>	0.064(9)	0.072(6)	0.074(5)	0.075(4)	0.100(1)	0.059(11)	0.077(3)	0.086(2)	0.066(8)	0.069(7)	0.063(10)
<i>R</i> <sup>2</sup>	0.865(6)	0.865(8)	0.866(9)	0.867(10)	0.860(5)	0.857(11)	0.815(2)	0.865(7)	0.856(4)	0.669(1)	0.852(3)
<i>E</i>	0.006(11)	0.008(8)	0.008(8)	0.008(8)	0.015(4)	0.011(6)	0.040(2)	0.022(3)	0.014(5)	0.056(1)	0.009(7)
<i>EA</i>	0.166(8)	0.161(9)	0.159(10)	0.158(11)	0.171(7)	0.176(6)	0.244(2)	0.190(3)	0.179(5)	0.423(1)	0.182(4)
<i>SD</i>	0.345(8)	0.345(8)	0.344(11)	0.344(11)	0.356(6)	0.358(4)	0.417(2)	0.346(7)	0.358(4)	0.643(1)	0.362(3)
<i>RMS</i>	0.341(8)	0.341(8)	0.340(10)	0.339(11)	0.352(6)	0.353(4)	0.413(2)	0.342(7)	0.354(4)	0.637(1)	0.358(3)
<i>RMSS</i>	0.767(7)	0.740(6)	0.727(5)	0.709(4)	0.620(3)	0.948(9)	0.997(11)	0.506(2)	0.921(8)	3.216(1)	0.989(10)
$\Sigma$	63	58	61	61	33	60	34	35	46	24	47
Evaluation 05											
<i>B</i>	0.763(11)	0.747(9)	0.732(8)	0.727(6)	0.652(2)	0.698(4)	0.725(5)	-(1)	0.747(9)	0.731(7)	0.697(3)
<i>A</i>	0.721(11)	0.775(7)	0.817(6)	0.851(5)	1.048(2)	0.768(9)	0.908(4)	-(1)	0.741(10)	0.986(3)	0.770(8)
<i>R</i> <sup>2</sup>	0.645(2)	0.665(3)	0.668(4)	0.671(5)	0.701(10)	0.675(6)	0.690(9)	-(1)	0.684(8)	0.720(11)	0.676(7)
<i>E</i>	0.033(10)	0.042(7)	0.040(9)	0.059(6)	0.041(8)	-0.106(5)	0.110(3)	-(1)	0.008(11)	0.205(2)	-0.108(4)
<i>EA</i>	1.778(2)	1.683(8)	1.700(5)	1.685(7)	1.647(10)	1.762(3)	1.640(11)	-(1)	1.663(9)	1.692(6)	1.759(4)
<i>SD</i>	3.023(2)	2.891(3)	2.864(4)	2.843(5)	2.708(10)	2.810(6)	2.751(9)	-(1)	2.796(8)	2.604(11)	2.807(7)
<i>RMS</i>	2.984(2)	2.854(3)	2.828(4)	2.807(5)	2.673(10)	2.776(6)	2.718(9)	-(1)	2.760(8)	2.579(11)	2.773(7)
<i>RMSS</i>	1.186(4)	1.067(8)	1.044(9)	1.004(11)	0.716(2)	1.069(7)	0.886(5)	-(1)	0.986(10)	0.787(3)	1.070(6)
$\Sigma$	44	48	49	50	64	46	55	8	73	54	46
Evaluation 06											
<i>B</i>	0.578(3)	0.593(4)	0.609(8)	0.621(9)	0.572(2)	0.557(1)	0.630(10)	0.601(6)	0.700(11)	0.602(7)	0.596(5)
<i>A</i>	3.272(3)	3.166(4)	3.057(6)	2.975(10)	3.373(1)	3.348(2)	3.027(7)	3.003(8)	2.449(11)	3.000(9)	3.073(5)
<i>R</i> <sup>2</sup>	0.581(7)	0.579(6)	0.576(5)	0.573(4)	0.570(3)	0.587(11)	0.548(2)	0.587(11)	0.541(1)	0.586(9)	0.581(7)
<i>E</i>	-0.017(9)	-0.009(10)	0.007(11)	0.024(8)	0.036(7)	-0.108(3)	0.144(1)	-0.105(4)	0.110(2)	-0.101(5)	-0.076(6)
<i>EA</i>	3.289(5)	3.265(7)	3.242(8)	3.234(9)	3.350(1)	3.347(2)	3.265(11)	3.297(3)	3.556(10)	3.293(4)	3.286(6)
<i>SD</i>	4.896(8)	4.912(6)	4.939(5)	4.970(3)	4.959(4)	4.870(9)	5.156(2)	4.864(11)	5.375(1)	4.867(10)	4.897(7)
<i>RMS</i>	4.841(8)	4.856(6)	4.882(5)	4.912(3)	4.904(4)	4.819(9)	5.094(2)	4.814(11)	5.308(1)	4.817(10)	4.845(7)
<i>RMSS</i>	0.924(4)	0.950(5)	0.984(7)	1.013(8)	0.785(2)	0.905(3)	1.006(11)	0.988(10)	1.752(1)	0.986(9)	0.967(6)
$\Sigma$	47	48	55	54	24	40	46	64	38	63	49
Evaluation 07											
<i>B</i>	0.529(7)	0.498(5)	0.482(4)	0.479(3)	0.406(2)	0.625(11)	0.502(6)	0.402(1)	0.592(8)	0.608(9)	0.614(10)
<i>A</i>	6.018(7)	6.545(5)	6.799(4)	6.865(3)	7.814(2)	4.727(11)	6.587(6)	7.834(1)	5.311(8)	5.276(9)	4.886(10)
<i>R</i> <sup>2</sup>	0.535(7)	0.484(5)	0.470(3)	0.474(4)	0.442(2)	0.589(10)	0.522(6)	0.352(1)	0.558(8)	0.657(11)	0.586(9)
<i>E</i>	-0.099(7)	0.028(10)	0.078(9)	0.102(6)	0.111(5)	-0.133(2)	0.124(4)	0.081(8)	0.017(11)	0.188(1)	-0.123(3)
<i>EA</i>	3.531(8)	3.734(5)	3.791(2)	3.762(4)	3.861(1)	3.468(9)	3.567(6)	4.193(7)	3.531(3)	3.001(11)	3.461(10)
<i>SD</i>	4.646(8)	4.892(5)	4.960(2)	4.941(4)	5.100(1)	4.378(10)	4.715(6)	5.513(7)	4.541(3)	4.011(11)	4.388(9)
<i>RMS</i>	4.590(8)	5.054(5)	5.142(2)	5.053(4)	5.038(1)	4.327(10)	4.806(6)	5.782(7)	4.828(3)	4.090(11)	4.336(9)
<i>RMSS</i>	0.874(2)	0.916(5)	0.924(7)	0.916(5)	0.885(3)	0.942(9)	0.914(4)	0.968(11)	0.950(10)	0.792(1)	0.928(8)
$\Sigma$	54	45	33	33	17	72	44	43	54	64	68

(<sup>1</sup>) Angular coefficient (*b*); Intersection (*a*); Determination coefficient (*R*<sup>2</sup>), Mean Prediction Errors (*E*); Standard Deviation Prediction Errors (*SD*); Mean Prediction Absolute Errors (*EA*); Root-Mean-Square Prediction Errors (*RMS*); Root-Mean-Square Standardized Prediction Errors (*RMSS*).

From the selected semivariograms, there was no presence of nugget effect in the A4 and A5 evaluation in L01 and A5, A6 and A7 in L02 (Table 2). The range estimative varied from 36.5 to 131.1 m.

In all evaluations, the presence of spatial dependence was confirmed in the tested models (Table 2). This result indicates that the spatial dependence greatly contributes to the variability of the data inferences by OK for theoretical models of semivariograms performed in evaluations and crops (Pasini et al., 2014; Pasini et al., 2015). In cross validation (Table 3 and 4), most models with the largest sum of scores did not achieve the highest score for all indicators, revealing a discrepancy among the estimated

values. This behavior underestimate the importance of using a larger number of indicators for decision making. By using this procedure, there is the possibility of a better fit of the theoretical model to the experimental semivariograms, a better representation of the spatial variability and estimates with smaller errors. In areas and evaluations, selection was different in semivariograms models, which is in agreement with the hypothesis of Gundogdu and Guney (2007), where each data set has a different spatial structure, therefore, it is necessary to define a semivariogram model with the best fit for the experiment.

In the selected semivariogram models, although effects of random variance had been shown in these three situations,

**Table 4.** Cross-validation indicators and assigned scores (in brackets) obtained from ordinary kriging for the following semivariogram models: C, Circular; S, Spherical; T, Tetraspherical; P, Pentaspherical; E, Exponential; G, Gaussian; R, Rational quadratic; H, Hole effect; K, K-Bessel; J, J-Bessel; and St, Stable. Area O2. Santa Maria, RS, Brazil, 2014.

Indicator	C	E	T	P	Ex	G	RQ	SC	KB	JB	Es
Evaluation 04											
<i>B</i>	0.676(5)	0.696(7)	0.710(9)	0.710(9)	0.693(6)	0.647(2)	0.799(11)	0.646(1)	0.647(2)	0.699(8)	0.658(4)
<i>A</i>	0.256(2)	0.235(5)	0.218(8)	0.218(8)	0.226(7)	0.248(3)	0.119(11)	0.334(1)	0.238(4)	0.195(10)	0.233(6)
<i>R</i> <sup>2</sup>	0.740(5)	0.756(4)	0.767(8)	0.768(9)	0.758(3)	0.712(2)	0.834(11)	0.683(1)	0.741(6)	0.785(10)	0.743(7)
<i>E</i>	-0.025(11)	-0.030(9)	-0.035(7)	-0.034(8)	-0.040(6)	-0.059(4)	-0.056(5)	0.026(10)	-0.069(1)	-0.067(2)	-0.064(3)
<i>EA</i>	0.498(5)	0.489(8)	0.484(9)	0.484(9)	0.490(7)	0.518(2)	0.467(11)	0.584(1)	0.501(4)	0.498(5)	0.502(3)
<i>SD</i>	1.212(5)	1.174(6)	1.146(8)	1.144(9)	1.172(7)	1.275(2)	0.964(11)	1.329(1)	1.225(3)	1.115(10)	1.216(4)
<i>RMS</i>	1.209(5)	1.171(6)	1.143(8)	1.141(9)	1.169(7)	1.273(2)	0.963(11)	1.326(1)	1.223(3)	1.114(10)	1.214(4)
<i>RMSS</i>	1.143(5)	1.288(3)	1.210(4)	1.334(2)	1.126(6)	1.076(8)	1.718(1)	1.126(7)	1.010(11)	1.060(9)	1.018(10)
$\Sigma$	43	48	61	63	49	25	61	23	34	64	41
Evaluation 05											
<i>b</i>	0.796(2)	0.805(4)	0.805(4)	0.804(3)	0.791(1)	0.843(8)	0.862(11)	0.814(6)	0.826(7)	0.860(10)	0.843(8)
<i>a</i>	0.357(6)	0.451(2)	0.450(3)	0.449(4)	0.465(1)	0.291(9)	0.308(8)	0.375(5)	0.328(7)	0.287(11)	0.291(9)
<i>R</i> <sup>2</sup>	0.798(2)	0.819(6)	0.818(4)	0.818(4)	0.816(3)	0.830(8)	0.823(7)	0.777(1)	0.830(8)	0.828(11)	0.830(8)
<i>E</i>	-0.160(1)	-0.043(8)	-0.044(7)	-0.046(6)	-0.063(5)	-0.108(10)	-0.041(9)	-0.097(4)	-0.113(2)	-0.067(11)	-0.108(3)
<i>EA</i>	1.174(3)	1.086(8)	1.086(8)	1.086(8)	1.094(7)	1.096(5)	1.184(2)	1.297(1)	1.081(11)	1.139(4)	1.096(5)
<i>SD</i>	2.274(2)	2.155(5)	2.155(5)	2.156(4)	2.172(3)	2.086(9)	2.139(7)	2.398(1)	2.085(11)	2.104(8)	2.086(9)
<i>RMS</i>	2.274(2)	2.150(5)	2.150(5)	2.151(4)	2.167(3)	2.083(9)	2.134(7)	2.393(1)	2.083(11)	2.100(8)	2.083(9)
<i>RMSS</i>	1.080(11)	1.141(6)	1.123(7)	1.097(9)	0.892(8)	1.210(4)	1.881(2)	1.788(3)	1.092(10)	2.976(1)	1.210(4)
$\Sigma$	29	44	43	42	31	63	43	22	67	64	55
Evaluation 06											
<i>b</i>	0.743(4)	0.763(8)	0.756(6)	0.749(5)	0.738(3)	0.766(9)	0.721(2)	-(1)	0.769(11)	0.758(7)	0.766(9)
<i>a</i>	1.671(4)	1.555(8)	1.601(6)	1.641(4)	1.716(3)	1.532(9)	1.859(2)	-(1)	1.522(11)	1.654(7)	1.533(9)
<i>R</i> <sup>2</sup>	0.719(4)	0.719(4)	0.722(6)	0.723(7)	0.726(8)	0.719(10)	0.727(9)	-(1)	0.718(11)	0.657(2)	0.718(3)
<i>E</i>	-0.011(4)	0.005(6)	0.002(9)	0.000(11)	-0.001(10)	0.004(7)	0.032(3)	-(1)	0.010(5)	0.074(2)	0.003(8)
<i>EA</i>	2.337(4)	2.327(6)	2.304(8)	2.296(10)	2.297(9)	2.331(5)	2.289(11)	-(1)	2.327(6)	2.630(2)	2.341(3)
<i>SD</i>	3.329(7)	3.342(5)	3.317(8)	3.305(9)	3.282(10)	3.341(6)	3.276(11)	-(1)	3.349(3)	3.754(2)	3.346(4)
<i>RMS</i>	3.320(7)	3.333(5)	3.308(8)	3.296(9)	3.274(10)	3.332(6)	3.268(11)	-(1)	3.341(3)	3.744(2)	3.337(4)
<i>RMSS</i>	1.228(2)	1.079(8)	1.047(9)	1.025(11)	0.972(10)	1.105(7)	0.854(3)	-(1)	1.120(5)	1.319	1.133(4)
$\Sigma$	36	50	62	66	63	59	52	8	55	24	44
Evaluation 07											
<i>b</i>	0.841(6)	0.834(5)	0.828(4)	0.826(3)	0.812(2)	0.905(11)	0.887(8)	0.809(1)	0.860(7)	0.892(9)	0.905(11)
<i>a</i>	1.324(6)	1.395(5)	1.448(4)	1.464(3)	1.591(2)	0.805(11)	0.999(8)	1.613(1)	1.196(7)	0.954(9)	0.805(11)
<i>R</i> <sup>2</sup>	0.833(11)	0.831(7)	0.832(8)	0.832(8)	0.826(4)	0.827(5)	0.825(3)	0.812(1)	0.817(2)	0.833(11)	0.827(5)
<i>E</i>	-0.021(3)	-0.013(5)	-0.012(6)	-0.016(4)	-0.006(8)	0.002(11)	0.042(1)	-0.006(8)	0.011(7)	0.034(2)	0.002(11)
<i>EA</i>	1.736(11)	1.742(8)	1.740(10)	1.742(8)	1.759(4)	1.754(6)	1.758(5)	1.833(1)	1.800(2)	1.765(3)	1.754(6)
<i>SD</i>	2.257(11)	2.269(8)	2.263(9)	2.263(9)	2.303(6)	2.345(4)	2.338(5)	2.391(1)	2.375(2)	2.280(7)	2.345(3)
<i>RMS</i>	2.252(11)	2.263(8)	2.257(9)	2.257(9)	2.297(6)	2.338(4)	2.333(5)	2.385(1)	2.369(2)	2.274(7)	2.338(3)
<i>RMSS</i>	0.908(10)	0.863(9)	0.835(7)	0.797(6)	0.835(7)	1.309(3)	1.423(2)	0.991(11)	1.217(5)	2.357(1)	1.309(3)
$\Sigma$	69	55	57	50	37	50	39	25	34	49	53

<sup>(1)</sup> Angular coefficient (*b*); Intersection (*a*); Determination coefficient (*R*<sup>2</sup>), Mean Prediction Errors (*E*); Standard Deviation Prediction Errors (*SD*); Mean Prediction Absolute Errors (*EA*); Root-Mean-Square Prediction Errors (*RMS*); Root-Mean-Square Standardized Prediction Errors (*RMSS*).

the nugget effect was not representative, not influencing the SDI, for all evaluations considered strong ( $\geq 75\%$ ), pointing out that the spatial distribution of *O. poecilus* population had a strong spatial dependence (Souza et al., 2008). The presence of the nugget effect indicates sampling errors and/or error in the size of the grid used for sampling (Yamamoto & Landim, 2013). The range values were appropriate to the sampling grid used in the study. According to Yamamoto & Landim (2013), the range value determines the number of values used in the interpolation, the greater its value, the greater the reliability of estimates. According to Silva et al. (2011), the range values can influence the quality of the estimates since it determines

the number of values used in interpolation, and estimates with OK interpolation using values greater than the range tend to be more reliable.

In the IDW method, eight weights were selected according to the criterion of choice (Table 5). In L01, weight 4 showed greater sum of scores among the evaluation A4, the weight 3 in evaluation A5 and the weight 6 in evaluations A6 and A7. In L02, the weight 6 was selected for all evaluations. In scores selected from IDW cross validation, for most assessments, weights with greater value were selected, indicating that for *O. poecilus*, the smaller the influence of more distant points, the better

**Table 5.** Estimates of cross-validation and assigned scores (in brackets) from the inverse distance weighted interpolation of different weights in evaluations. Area 01 and Area 02. Santa Maria, RS, Brazil, 2014.

Indicator <sup>1</sup>	Farming									
	Area 01					Area 02				
	Weight					Weight				
	2	3	4	5	6	2	3	4	5	6
Evaluation 04										
<i>b</i>	0.673(1)	0.750(2)	0.804(3)	0.840(4)	0.863(5)	0.499(1)	0.540(2)	0.564(3)	0.578(4)	0.587(5)
<i>a</i>	0.150(1)	0.132(2)	0.120(3)	0.113(4)	0.108(5)	0.301(1)	0.285(2)	0.272(3)	0.262(4)	0.255(5)
<i>R</i> <sup>2</sup>	0.795(3)	0.805(5)	0.801(4)	0.793(2)	0.784(1)	0.623(1)	0.646(2)	0.661(3)	0.670(4)	0.675(5)
$\bar{E}$	0.007(5)	0.023(4)	0.035(3)	0.043(2)	0.048(1)	-0.134(1)	-0.115(2)	-0.107(3)	-0.104(5)	-0.104(5)
$\bar{EA}$	0.212(1)	0.192(2)	0.183(4)	0.181(5)	0.184(3)	0.574(1)	0.548(2)	0.531(3)	0.520(4)	0.514(5)
<i>SD</i>	0.445(1)	0.419(5)	0.419(5)	0.431(3)	0.445(1)	1.491(1)	1.434(2)	1.398(3)	1.377(4)	1.365(5)
<i>RMS</i>	0.439(2)	0.414(5)	0.415(4)	0.428(3)	0.441(1)	1.493(1)	1.435(2)	1.399(3)	1.378(4)	1.366(5)
$\Sigma$	14	25	26	23	17	7	14	21	29	35
Evaluation 05										
<i>b</i>	0.615(1)	0.658(2)	0.687(3)	0.705(4)	0.715(5)	0.643(1)	0.686(2)	0.714(3)	0.731(4)	0.742(5)
<i>a</i>	1.102(1)	1.020(2)	0.961(3)	0.923(4)	0.899(5)	0.632(1)	0.583(2)	0.546(3)	0.519(4)	0.501(5)
<i>R</i> <sup>2</sup>	0.686(5)	0.685(4)	0.680(3)	0.675(2)	0.671(1)	0.761(1)	0.784(2)	0.799(3)	0.809(4)	0.816(5)
$\bar{E}$	-0.012(5)	0.030(4)	0.054(3)	0.068(2)	0.074(1)	-0.273(1)	-0.213(2)	-0.179(3)	-0.161(4)	-0.152(5)
$\bar{EA}$	1.744(1)	1.685(2)	1.641(3)	1.610(4)	1.588(5)	1.248(1)	1.169(2)	1.117(3)	1.087(4)	1.066(5)
<i>SD</i>	2.792(3)	2.770(5)	2.785(4)	2.811(2)	2.836(1)	2.563(1)	2.416(2)	2.318(3)	2.253(4)	2.210(5)
<i>RMS</i>	2.756(3)	2.734(5)	2.750(4)	2.776(2)	2.801(1)	2.571(1)	2.419(2)	2.319(3)	2.253(4)	2.209(5)
$\Sigma$	19	28	23	20	19	7	14	21	28	35
Evaluation 06										
<i>b</i>	0.525(1)	0.564(2)	0.592(3)	0.610(4)	0.621(5)	0.674(1)	0.699(2)	0.716(3)	0.727(4)	0.735(5)
<i>a</i>	3.732(1)	3.490(2)	3.310(3)	3.187(4)	3.102(5)	2.061(1)	1.937(2)	1.849(3)	1.790(4)	1.751(5)
<i>R</i> <sup>2</sup>	0.554(1)	0.550(2)	0.542(3)	0.535(4)	0.530(5)	0.713(1)	0.720(2)	0.723(3)	0.724(4)	0.725(5)
$\bar{E}$	0.026(5)	0.092(4)	0.128(3)	0.143(2)	0.148(1)	-0.071(1)	-0.030(2)	-0.006(5)	0.007(4)	0.014(3)
$\bar{EA}$	3.603(1)	3.584(2)	3.578(3)	3.576(4)	3.574(5)	2.408(1)	2.347(2)	2.319(3)	2.304(4)	2.293(5)
<i>SD</i>	5.058(5)	5.078(4)	5.144(3)	5.213(2)	5.268(1)	3.373(1)	3.323(2)	3.301(3)	3.292(4)	3.289(5)
<i>RMS</i>	5.027(5)	5.041(4)	5.102(3)	5.166(2)	5.218(1)	3.365(1)	3.314(2)	3.292(3)	3.284(4)	3.281(5)
$\Sigma$	18	20	21	22	23	7	14	23	28	33
Evaluation 07										
<i>b</i>	0.311(1)	0.363(2)	0.406(3)	0.437(4)	0.460(5)	0.674(1)	0.715(2)	0.744(3)	0.762(4)	0.774(5)
<i>a</i>	9.099(1)	8.374(2)	7.825(3)	7.438(4)	7.173(5)	2.678(1)	2.350(2)	2.123(3)	1.977(4)	1.886(5)
<i>R</i> <sup>2</sup>	0.377(5)	0.433(4)	0.473(3)	0.499(2)	0.516(1)	0.774(5)	0.793(4)	0.805(3)	0.811(2)	0.816(1)
$\bar{E}$	0.157(2)	0.113(5)	0.114(4)	0.137(3)	0.167(1)	-0.090(1)	-0.064(2)	-0.047(3)	-0.038(4)	-0.033(5)
$\bar{EA}$	4.143(1)	3.911(2)	3.727(3)	3.596(4)	3.494(5)	1.996(1)	1.907(2)	1.851(3)	1.819(4)	1.798(5)
<i>SD</i>	5.427(1)	5.178(2)	4.990(3)	4.858(4)	4.770(5)	2.700(1)	2.555(2)	2.467(3)	2.415(4)	2.384(5)
<i>RMS</i>	5.365(1)	5.112(2)	4.927(3)	4.796(4)	4.710(5)	2.694(1)	2.549(2)	2.461(3)	2.409(4)	2.378(5)
$\Sigma$	12	19	25	25	27	11	16	21	26	31

<sup>(1)</sup> Angular coefficient (*b*); Intersection (*a*); Determination coefficient (*R*<sup>2</sup>), Mean Prediction Errors ( $\bar{E}$ ); Standard Deviation Prediction Errors (*SD*); Mean Prediction Absolute Errors ( $\bar{EA}$ ); Root-Mean-Square Prediction Errors (*RMS*).

the estimates, which may be a reflection of the behavior of the data distribution (Table 5). However, the choice of the weights did not evidence any direct or inverse relationship with the descriptive statistics.

The results of cross-validation for comparison between interpolation of OK and IDW indicated that for almost all the evaluations, interpolator OK (87.5%) was greater than IDW (12.5%) (Table 6). Out of the eight performed assessments, only one interpolator KO was below the IDP, which was assessment A7 in L01. The maps of the spatial distribution of *O. poecilus* (adults m<sup>-2</sup>) interpolated by OK and IDW for different evaluations revealed a better delimitation of areas with population densities for OK interpolating, where lines had an organic behavior, different from that found for IDW interpolating, with straight lines (Figure 2).

The superiority of OK interpolator obtained in cross validation meets the works of Mello et al. (2003), Soares et al. (2008), Silva et al. (2011) and Carvalho et al. (2012) (Table 6), resulting in the recommendation of its use in estimating values in unsampled points. Among all estimates, the exception was the evaluation A7 in L01. According to Soares et al. (2008), the superiority of OK interpolation is due to non-tendentiousness of the estimator and the minimum variance of the estimates is considered a great interpolator. Such superiority was also evidenced by the plotting with more reliable variability of *O. poecilus* special isolines (Figure 2). According to Alves & Vecchia (2011), a negative characteristic of the inverse weighted distance of the interpolation method is the generation effect observed around the crosshair points.

**Table 6.** Estimates of cross-validation and assigned scores (in brackets) from the best semivariogram model in ordinary kriging (OK) and the best weight in inverse distance weighted (IDW) evaluation interpolation. Area 01 and Area 02. Santa Maria, RS, Brazil, 2014.

Indicator <sup>1</sup>	Farming			
	Area 01		Area 02	
	OK	IDW	OK	IDW
Evaluation 04				
<i>B</i>	0.868(2)	0.804(1)	0.699(2)	0.587(1)
<i>A</i>	0.064(2)	0.120(1)	0.195(2)	0.255(1)
<i>R</i> <sup>2</sup>	0.865(2)	0.801(1)	0.785(2)	0.675(1)
$\bar{E}$	0.006(2)	0.035(1)	-0.067(2)	-0.104(1)
$\bar{E}A$	0.166(2)	0.183(1)	0.498(2)	0.514(1)
<i>SD</i>	0.345(2)	0.419(1)	1.115(2)	1.365(1)
<i>RMS</i>	0.341(2)	0.415(1)	1.114(2)	1.366(1)
$\Sigma$	14	7	14	7
Evaluation 05				
<i>B</i>	0.747(2)	0.658(1)	0.826(2)	0.742(1)
<i>A</i>	0.741(2)	1.020(1)	0.328(2)	0.501(1)
<i>R</i> <sup>2</sup>	0.684(1)	0.685(2)	0.830(2)	0.816(1)
$\bar{E}$	0.008(2)	0.030(1)	-0.113(2)	-0.152(1)
$\bar{E}A$	1.663(2)	1.685(2)	1.081(1)	1.066(2)
<i>SD</i>	2.796(1)	2.770(1)	2.085(2)	2.210(1)
<i>RMS</i>	2.760(1)	2.734(1)	2.083(2)	2.209(1)
$\Sigma$	11	10	13	8
Evaluation 06				
<i>B</i>	0.601(1)	0.621(2)	0.749(2)	0.735(1)
<i>A</i>	3.003(2)	3.102(1)	1.641(2)	1.751(1)
<i>R</i> <sup>2</sup>	0.587(2)	0.530(1)	0.723(2)	0.725(1)
$\bar{E}$	-0.105(2)	0.148(1)	0.000(2)	0.014(1)
$\bar{E}A$	3.297(2)	3.574(1)	2.296(1)	2.293(2)
<i>SD</i>	4.864(2)	5.268(1)	3.305(1)	3.289(2)
<i>RMS</i>	4.814(2)	5.218(1)	3.296(1)	3.281(2)
$\Sigma$	13	8	11	10
Evaluation 07				
<i>B</i>	0.625(1)	0.716(2)	0.841(2)	0.774(1)
<i>A</i>	4.727(1)	1.190(2)	1.324(2)	1.886(1)
<i>R</i> <sup>2</sup>	0.589(2)	0.766(1)	0.833(2)	0.816(1)
$\bar{E}$	-0.133(2)	-0.238(1)	-0.021(2)	-0.033(1)
$\bar{E}A$	3.468(1)	1.928(2)	1.736(2)	1.798(1)
<i>SD</i>	4.378(1)	3.046(2)	2.257(2)	2.384(1)
<i>RMS</i>	4.327(1)	3.044(2)	2.252(2)	2.378(1)
$\Sigma$	9	12	14	7

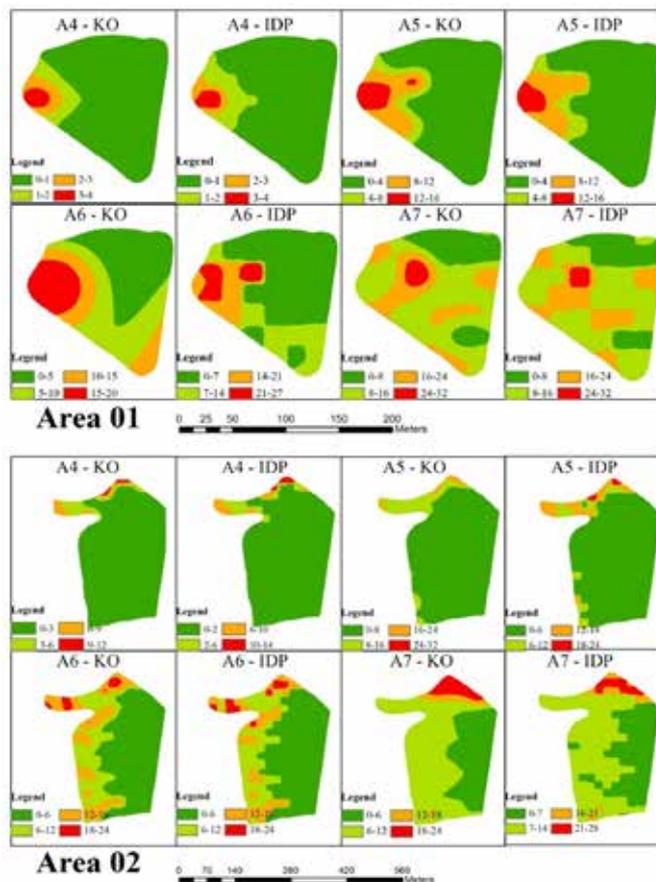
<sup>(1)</sup> Angular coefficient (b); Intersection (a); Determination coefficient (*R*<sup>2</sup>), Mean Prediction Errors (*E*); Standard Deviation Prediction Errors (*SD*); Mean Prediction Absolute Errors (*EA*); Root-Mean-Square Prediction Errors (*RMS*).

## Conclusion

The ordinary kriging interpolation method performs better than the method of inverse distance weighted applied in the spatial distribution of the population density of *Oeobalus poecilus* in irrigated rice.

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**Figure 2.** Spatial distribution maps of *Oeobalus poecilus* adults (Hemiptera: Pentatomidae) respectively interpolated by ordinary kriging (OK) and inverse distance weighted (IDW) by different evaluation in Area 01 and 02. Santa Maria, RS, Brazil, 2014.

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