

## Draft

### Spatial patterns analyses of daily rainfall in Sumberjaya, Lampung, Sumatra, Indonesia

#### 1. Objectives

- To characterize spatial patterns in daily rainfall based on degrees of spatial correlation, either horizontally (based on distance) or vertically (based on absolute elevation difference in elevation).

#### 2. Methods

- Semivariance is used to characterize daily rainfall patterns and identify degrees of spatial correlation between station pairs, either horizontally or vertically. Here, semivariance is calculated as half of mean square difference in daily rainfall from a number of station pairs. For horizontal semivariance, station pairs are sampled from stations with the same horizontal lag (distance). For vertical semivariance, station pairs are sampled from stations with the same vertical lag (absolute difference in elevation). Procedure to sample station pairs from each station is done within specified directions (Figure 1). A pair of stations with barrier (*e.g.* hill) in between can be dropped from the sampling (Figure 2). In this study, barriers are not excluded due to limited number of data for sampling purpose (see Table 1). All calculation procedures for this analysis are programmed using NetLogo. The program is called “SpatRain Tool Box”.
- Correlation between semivariance and horizontal lag or vertical lag is calculated based on non-linear fitting model, *i.e.* general asymptotic function:  $y = \max * (1 - \exp(-a * x)^b)$ . Fitting procedures are done using SigmaPlot. Semivariogram is characterized based on its slope, calculated from  $y_{\max}$  relative divided by range to reach  $y_{\max}$ . Semivariograms with relatively low slopes indicate low variability of rainfall in space. Semivariograms with relatively high slopes indicate high variability of rainfall in space.
- Daily rainfall data from the year 2005 recorded by 17 manual stations and 21 automatic stations in Sumberjaya, Lampung, Sumatra, Indonesia, were used for the analyses (Figure 3). Summary on data available for this analyses are listed in Table 1.

#### 3. Results

- Horizontal semivariograms are shown in Figures 4-7. Non-linear correlation ( $R^2$ ) between semivariance and horizontal lag within specified sampling directions are listed in Table 2. Horizontal semivariograms with significant correlations ( $R^2 \geq 0.60$ ) are found in all months, mostly within north-south, northeast-southwest and east-west directions. Only data from May resulted significant correlation within southeast-northwest direction. At significant correlations, slopes of semivariograms are relatively low in general (about 89% of the semivariograms have the slopes below the average of about 15.37), with relatively high slopes found in June and November (Table 3).
- Vertical semivariograms are shown in Figures 8-11. Non-linear correlation ( $R^2$ ) between semivariance and vertical lag within specified sampling directions are listed in Table 4. Vertical semivariograms with significant correlations ( $R^2 \geq 0.60$ ) are only found in February, March, June, July, November and December, mostly within north-south direction. Only data

from February resulted significant correlation within southeast-northwest direction and only data from July resulted significant correlation within east-west direction. At significant correlations, slopes of semivariograms are about the average in general (about 63% of the semivariograms have the slopes below the average of about 51.10), with relatively high slopes found in June, March and November (Table 5).

**Table 1.** Data availability.

Month	Number of days	Number of stations		
		Manual	Automatic	Total
Jan	N/A	N/A	N/A	N/A
Feb	15	13	0	13
Mar	30	20	0	20
Apr	29	20	0	20
May	31	13	0	13
Jun	30	12	0	12
Jul	26	11	0	11
Aug	31	11	0	11
Sep	25	12	17	29
Oct	31	11	0	11
Nov	30	11	0	11
Dec	29	11	0	11

**Table 2.** Non-linear correlation ( $R^2$ ) between semivariance and horizontal lag (km) within specified sampling directions, based on fitting model  $y=\max*(1-\exp(-a*x)^b)$ .

Month	N-S	NE-SW	E-W	SE-NW
Jan	N/A	N/A	N/A	N/A
Feb	0.32	0.41	<b>0.62</b>	0.20
Mar	<b>0.86</b>	<b>0.82</b>	<b>0.71</b>	0.50
Apr	<b>0.78</b>	<b>0.68</b>	<b>0.76</b>	0.22
May	0.42	0.44	0.39	<b>0.65</b>
Jun	<b>0.68</b>	0.50	0.30	0.27
Jul	<b>0.78</b>	<b>0.62</b>	<b>0.63</b>	0.59
Aug	<b>0.73</b>	0.59	0.35	0.16
Sep	0.26	<b>0.83</b>	<b>0.73</b>	0.35
Oct	<b>0.77</b>	0.35	<b>0.62</b>	0.16
Nov	<b>0.85</b>	0.51	0.58	0.51
Dec	<b>0.90</b>	0.24	0.20	0.16

**Table 3.** Slope of horizontal semivariogram, calculated from  $y_{\max}$  divided by range to reach  $y_{\max}$ , based on fitting model  $y=\max*(1-\exp(-a*x)^b)$ .

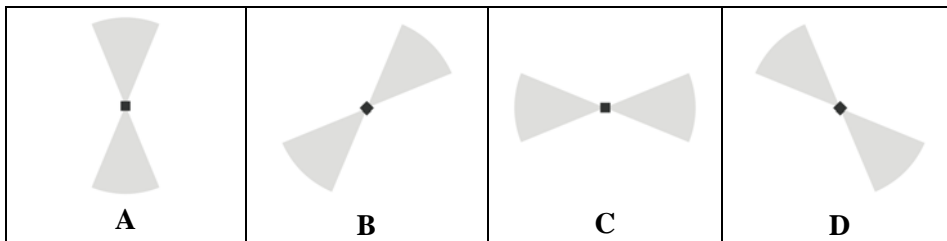
Month	N-S	NE-SW	E-W	SE-NW
Jan	N/A	N/A	N/A	N/A
Feb	187.12	5.51	<b>11.61</b>	5.79
Mar	<b>2.10</b>	<b>1.78</b>	<b>2.86</b>	6.38
Apr	<b>0.38</b>	<b>0.56</b>	<b>0.81</b>	4.53
May	82.29	2.47	1.34	<b>3.91</b>
Jun	<b>157.87</b>	4.70	182.41	4.62
Jul	<b>0.16</b>	<b>0.29</b>	<b>0.55</b>	1.53
Aug	<b>0.63</b>	1.14	85.17	123.28
Sep	4.22	<b>1.49</b>	<b>1.24</b>	3.76
Oct	<b>0.72</b>	2.40	<b>3.02</b>	202.51
Nov	<b>100.70</b>	6.56	2.73	8.84
Dec	<b>1.30</b>	8.70	164.48	5.51

**Table 4.** Non-linear correlation ( $R^2$ ) between semivariance and vertical lag (m) within specified sampling directions, based on fitting model  $y=\max*(1-\exp(-a*x)^b)$ .

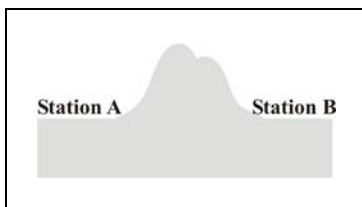
Month	N-S	NE-SW	E-W	SE-NW
Jan	N/A	N/A	N/A	N/A
Feb	<b>0.75</b>	0.41	0.53	<b>0.64</b>
Mar	<b>0.72</b>	0.42	0.50	0.17
Apr	0.49	0.39	0.35	0.15
May	0.53	0.45	0.31	0.37
Jun	<b>0.68</b>	0.35	0.46	0.38
Jul	<b>0.62</b>	0.30	<b>0.70</b>	0.40
Aug	0.55	0.23	0.46	0.20
Sep	0.00	0.41	N/A	0.04
Oct	0.50	0.43	0.55	0.14
Nov	<b>0.95</b>	0.46	0.56	0.48
Dec	<b>0.70</b>	0.19	0.34	0.09

**Table 5.** Slope of vertical semivariogram, calculated from  $y_{\max}$  divided by range to reach  $y_{\max}$ , based on fitting model  $y=\max*(1-\exp(-a*x)^b)$ .

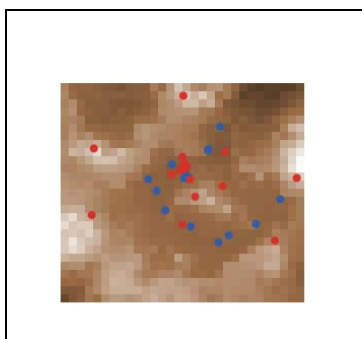
Month	N-S	NE-SW	E-W	SE-NW
Jan	N/A	N/A	N/A	N/A
Feb	<b>0.62</b>	0.57	1.43	<b>0.94</b>
Mar	<b>190.59</b>	2.87	2.21	0.93
Apr	60.20	0.39	1.11	59.55
May	0.42	0.50	2.89	109.54
Jun	<b>78.27</b>	3.11	0.92	0.56
Jul	<b>26.73</b>	0.68	<b>0.48</b>	26.51
Aug	17.36	1.00	1.73	51.32
Sep	0.44	0.76	N/A	100.41
Oct	66.30	0.83	8.61	159.73
Nov	<b>0.56</b>	2.29	2.25	138.59
Dec	<b>110.59</b>	3.57	0.76	0.75



**Figure 1.** Procedure to sample station pairs from each station is done within specified direction (grey area): (A) north-south ( $337.5^{\circ}$ - $22.5^{\circ}$  or  $157.5^{\circ}$ - $202.5^{\circ}$ ), (B) northeast-southwest ( $22.5^{\circ}$ - $67.5^{\circ}$  or  $202.5^{\circ}$ - $247.5^{\circ}$ ), (C) east-west ( $67.5^{\circ}$ - $112.5^{\circ}$  or  $247.5^{\circ}$ - $292.5^{\circ}$ ), (D) southeast-northwest ( $112.5^{\circ}$ - $157.5^{\circ}$  or  $292.5^{\circ}$ - $337.5^{\circ}$ ).

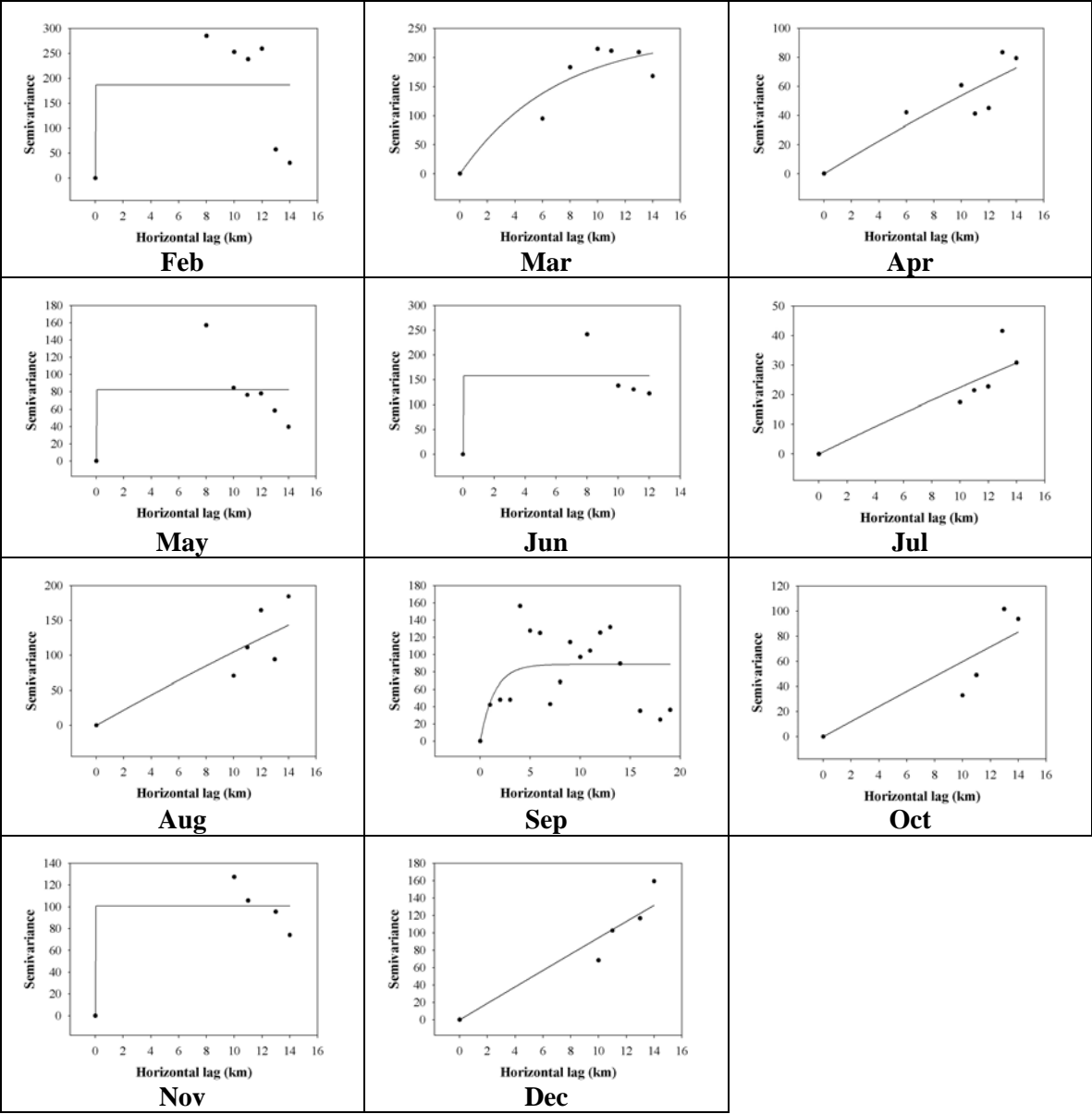


**Figure 2.** Pair of station A and station B, can be dropped from the sampling due to barrier in between.

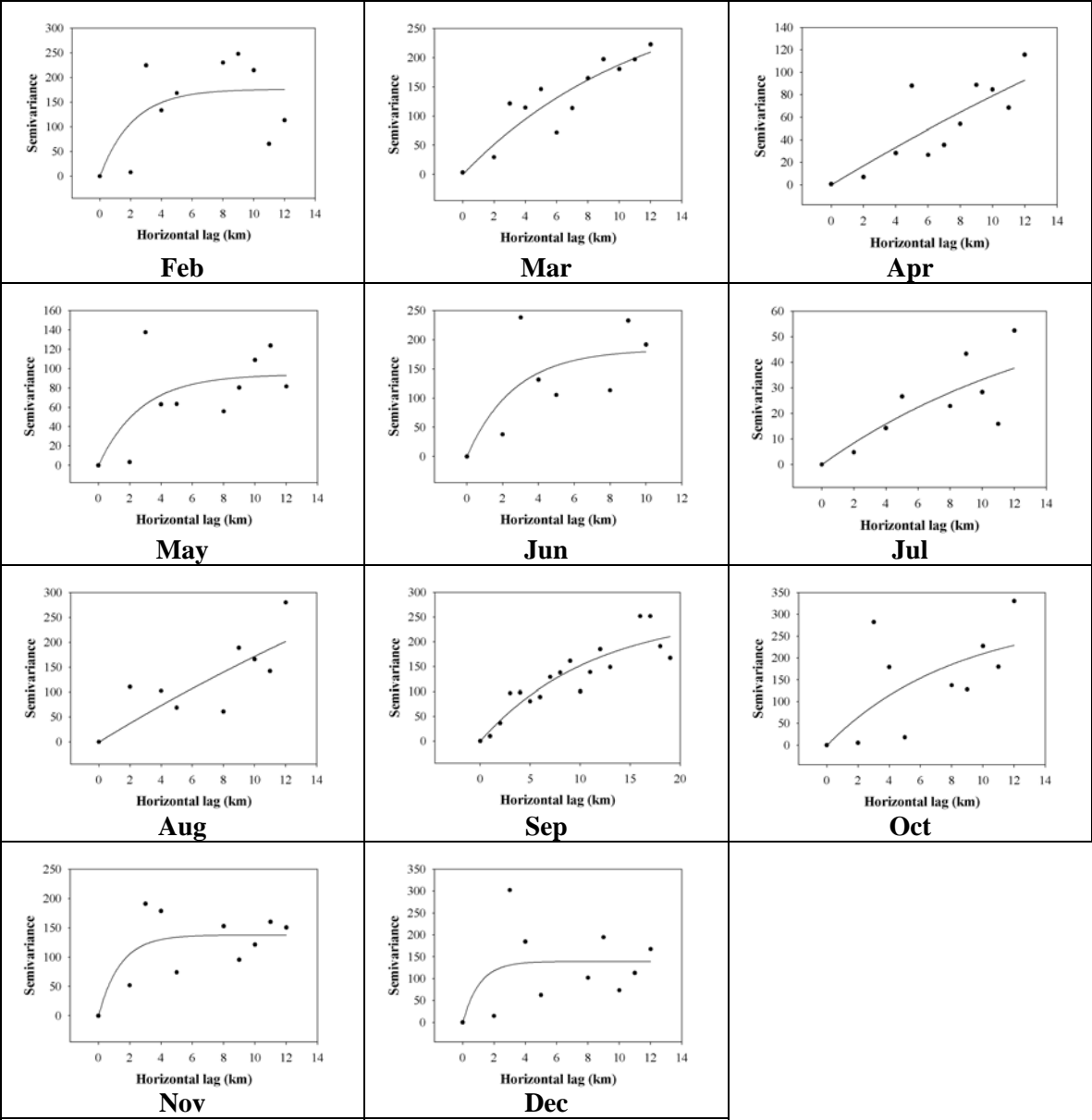


**Figure 3.** Rainfall stations in Sumberjaya used for the analyses, consisting of 17 manual stations (blue dots) and 21 automatic stations (red dots).

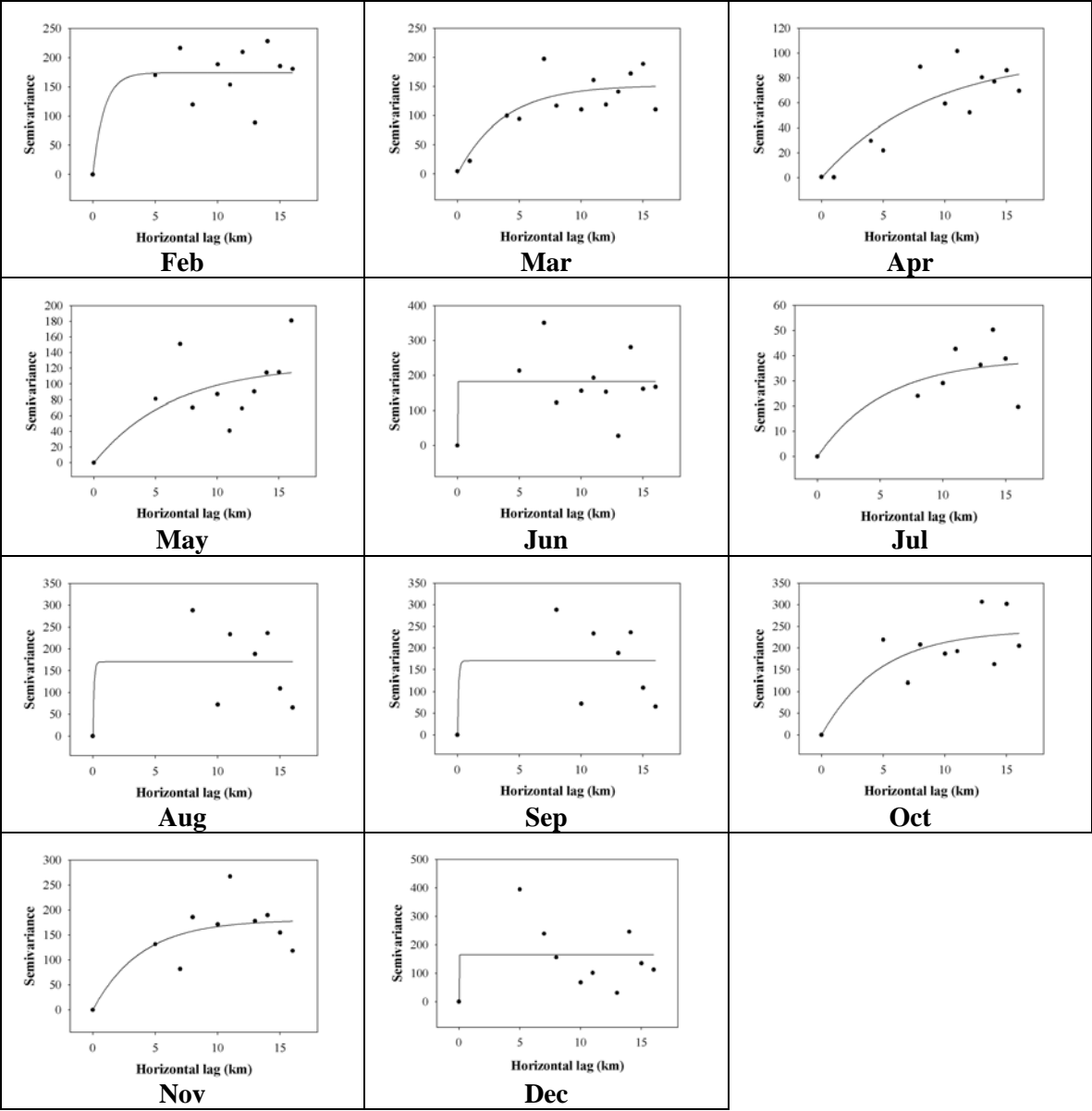
**Figure 4.** Horizontal semivariogram and non-linear regression line  $y=\max*(1-\exp(-a*x)^b)$ , in north-south direction.



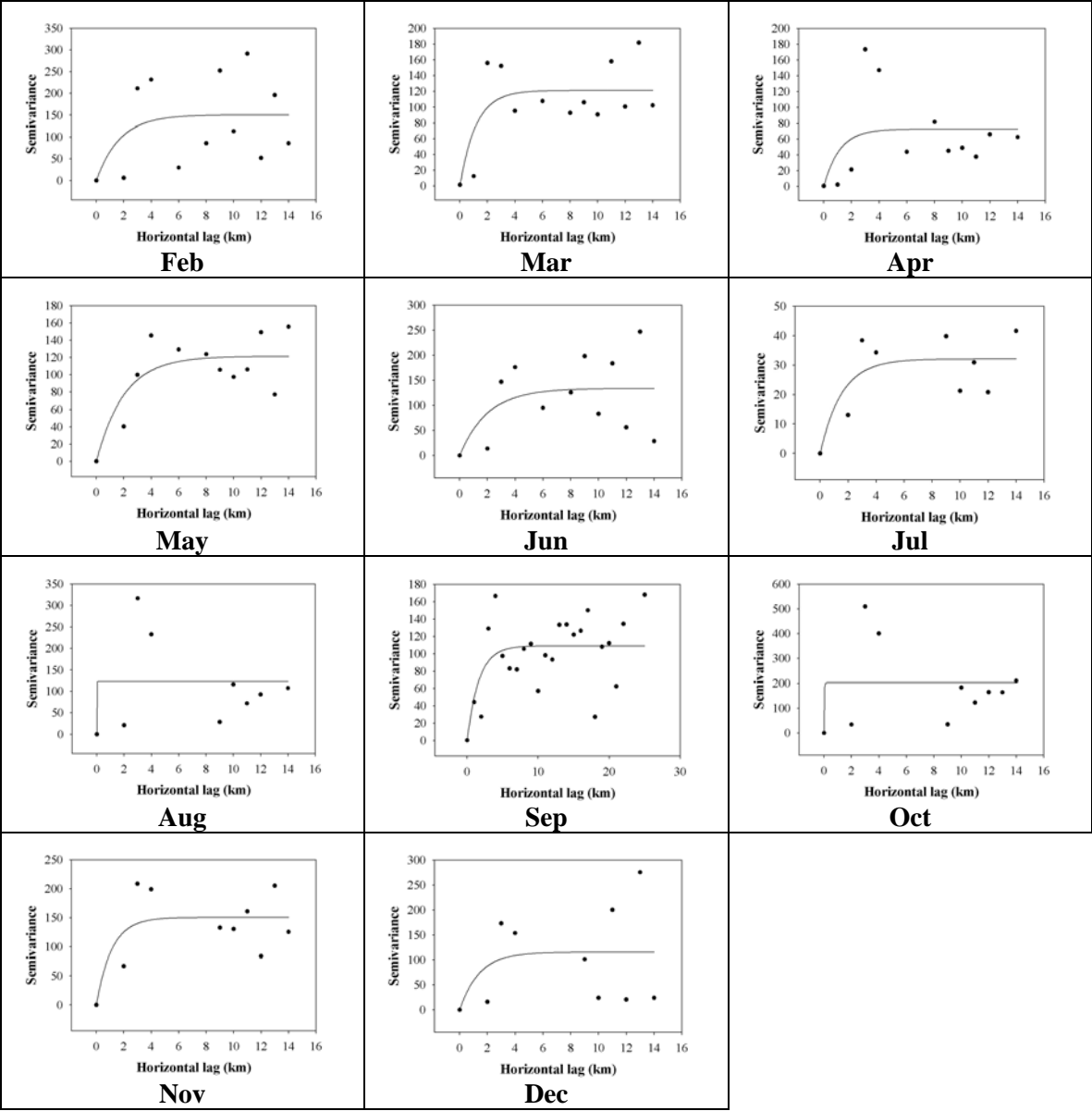
**Figure 5.** Horizontal semivariogram and non-linear regression line  $y=\max*(1-\exp(-a*x)^b)$ , in northeast-southwest direction.



**Figure 6.** Horizontal semivariogram and non-linear regression line  $y=\max*(1-\exp(-a*x)^b)$ , in east-west direction.

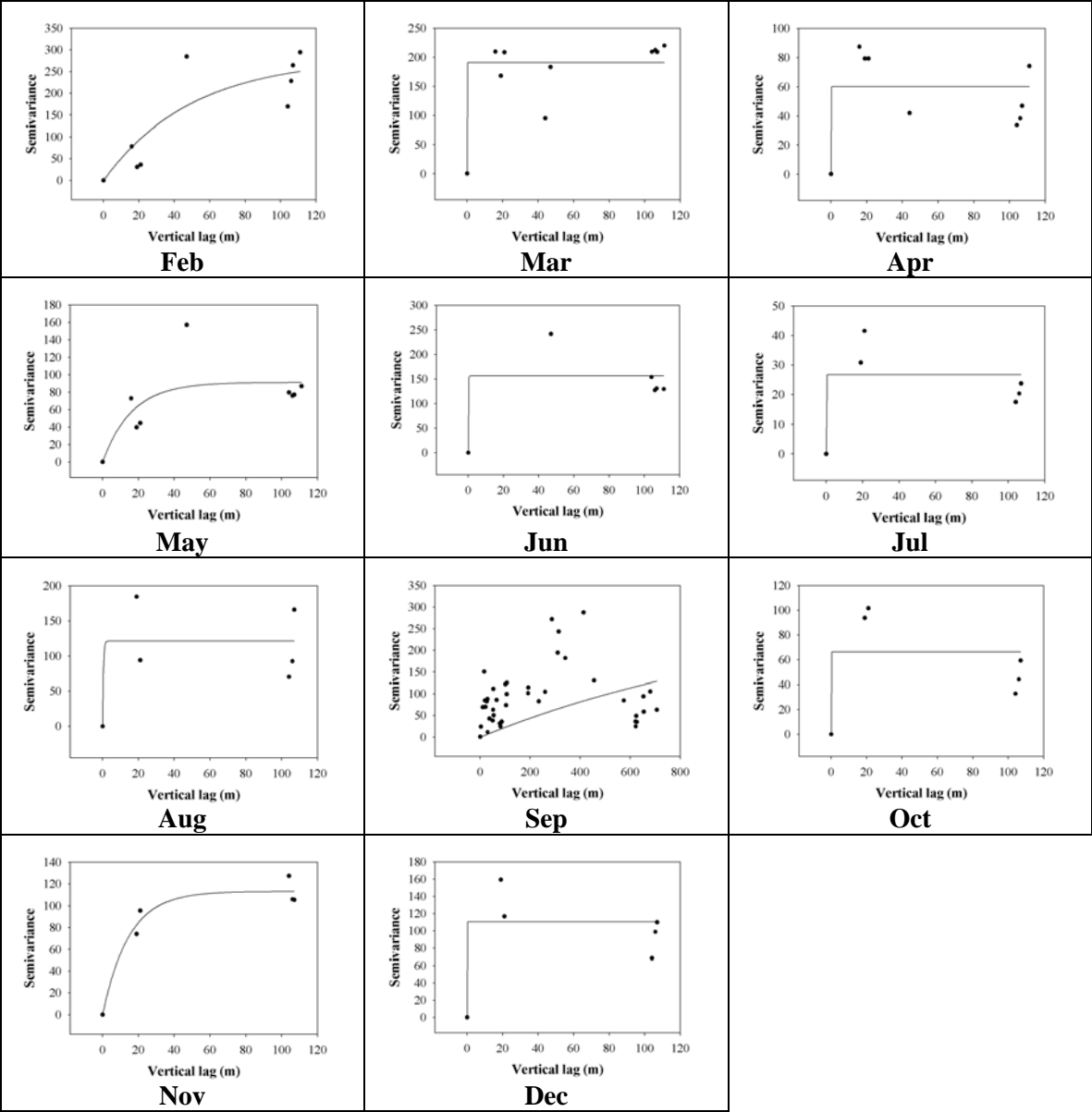


**Figure 7.** Horizontal semivariogram and non-linear regression line  $y=\max*(1-\exp(-a*x)^b)$ , in southeast-northwest direction.

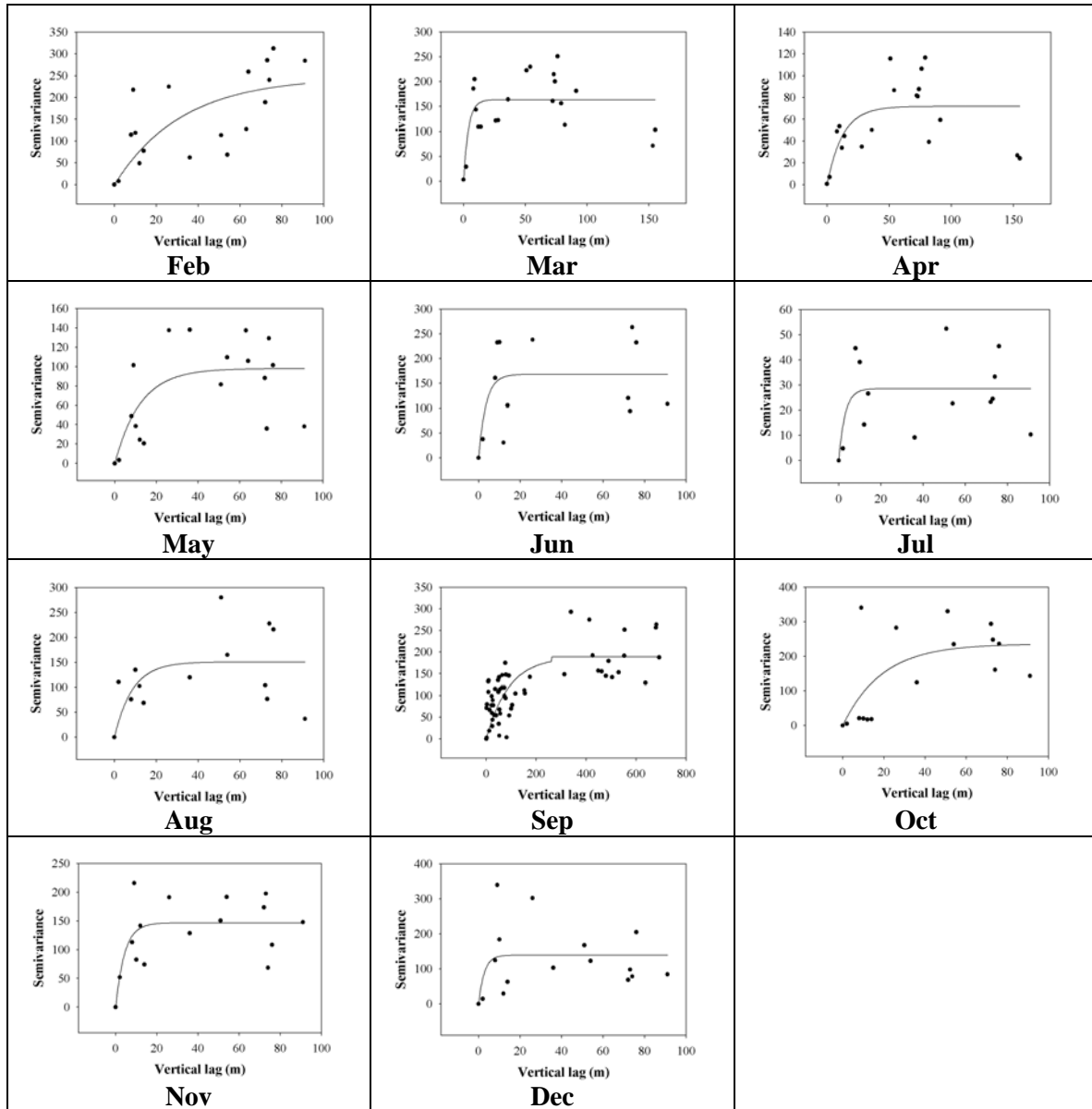




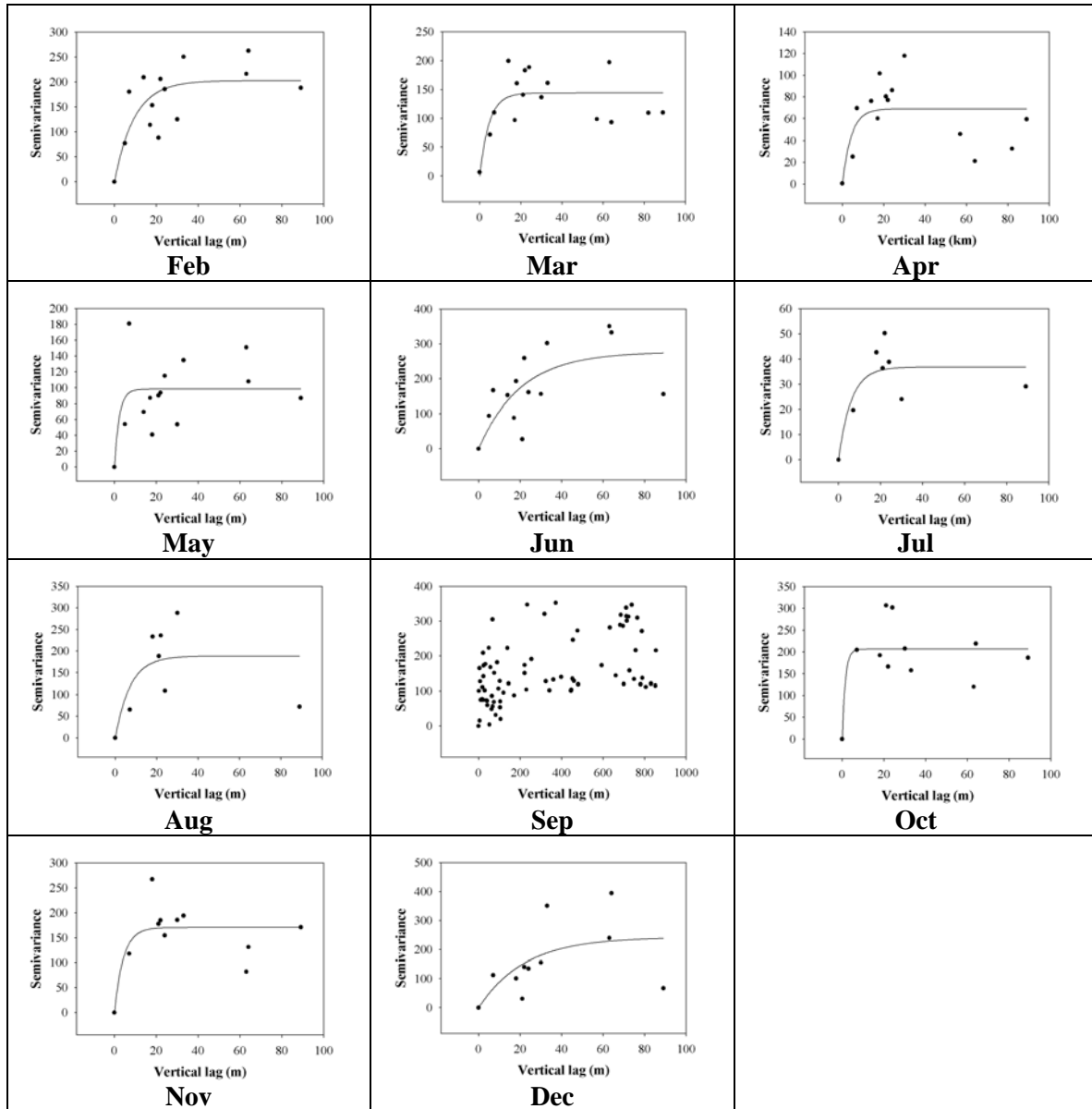
**Figure 8.** Vertical semivariogram and non-linear regression line  $y=\max*(1-\exp(-a*x)^b)$ , in north-south direction.



**Figure 9.** Vertical semivariogram and non-linear regression line  $y=\max*(1-\exp(-a*x)^b)$ , in northeast-southwest direction.



**Figure 10.** Vertical semivariogram and non-linear regression line  $y=\max*(1-\exp(-a*x)^b)$ , in east-west direction.



**Figure 11.** Vertical semivariogram and non-linear regression line  $y=\max*(1-\exp(-a*x))^b$ , in southeast-northwest direction.

