

## Introduction

Leaf wetness is basically defined as the presence of free water over plant tissues and its duration is commonly named leaf wetness duration (LWD) (Figure 1). LWD is recognized as a very important conditioner of crops and forests diseases.

Among the LWD empirical models, the number of hours with relative humidity (RH) above a specific threshold is the most common and easy to apply. As for large scales, e.g. in a country level, the availability of weather data for estimating LWD is very restricted, the use of hours of RH ≥ 90% appears as the only alternative to assess the temporal and spatial LWD variability.

The objective of this study was to develop monthly LWD models based on the relationship between hours of RH ≥ 90% and average RH for Brazil, and based on these models to characterize the temporal and spatial LWD variability across the country, in order to support crop and forest diseases control strategic plans.

## Material and methods

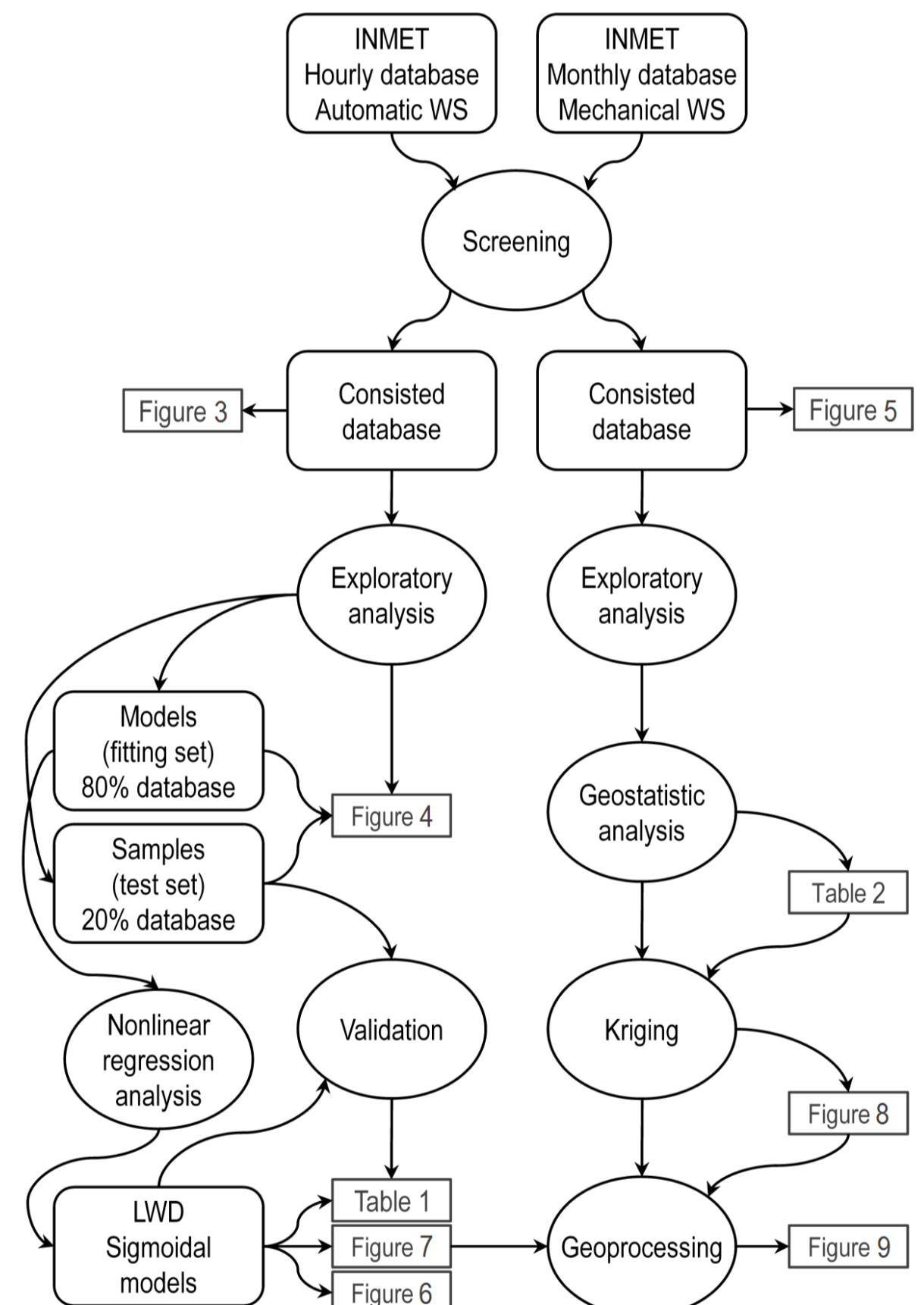


Figure 2. Flowchart of the procedures for leaf wetness duration (LWD) modeling.

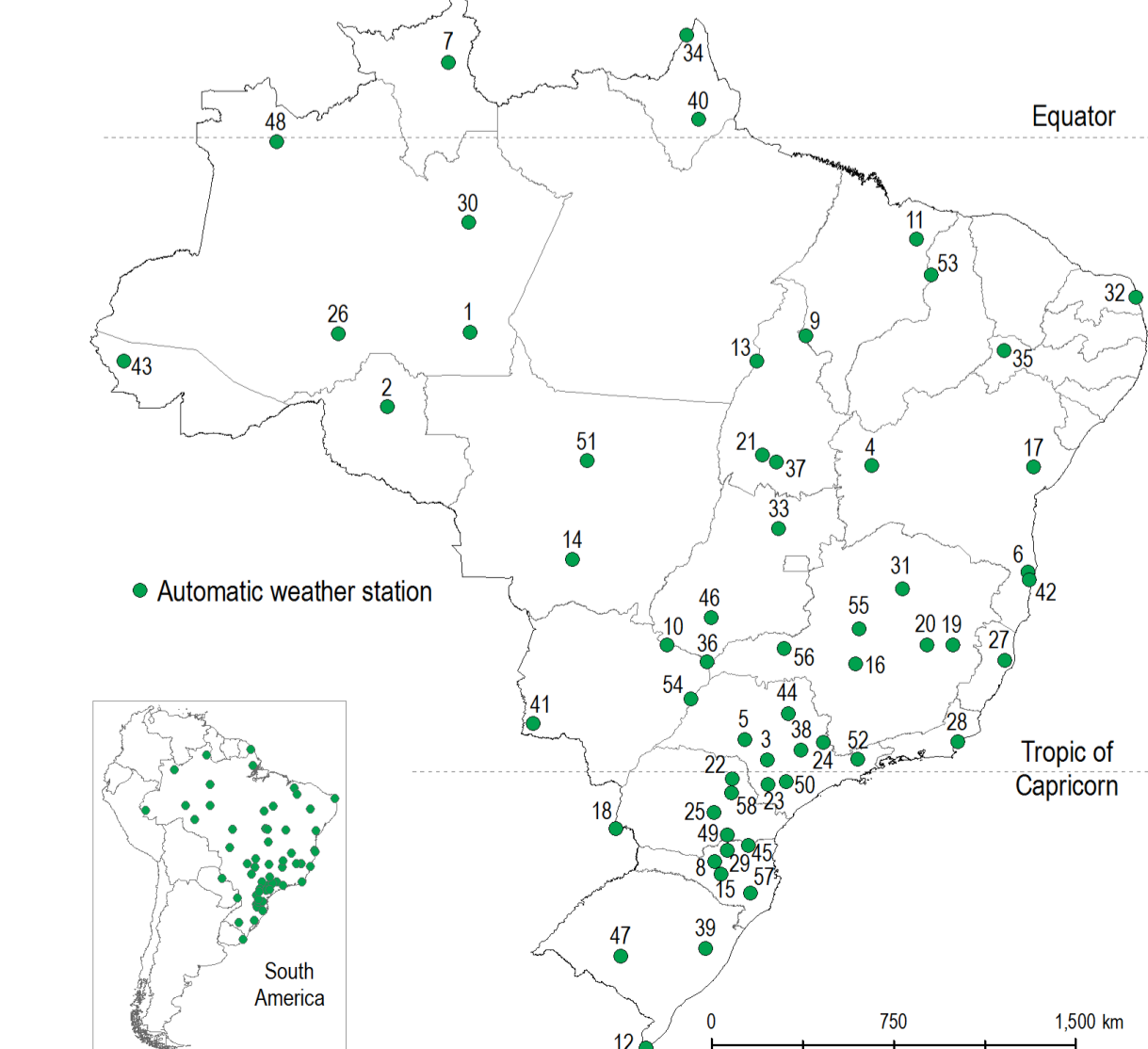


Figure 3. Location of the automatic weather stations used for LWD modeling with hourly RH data.

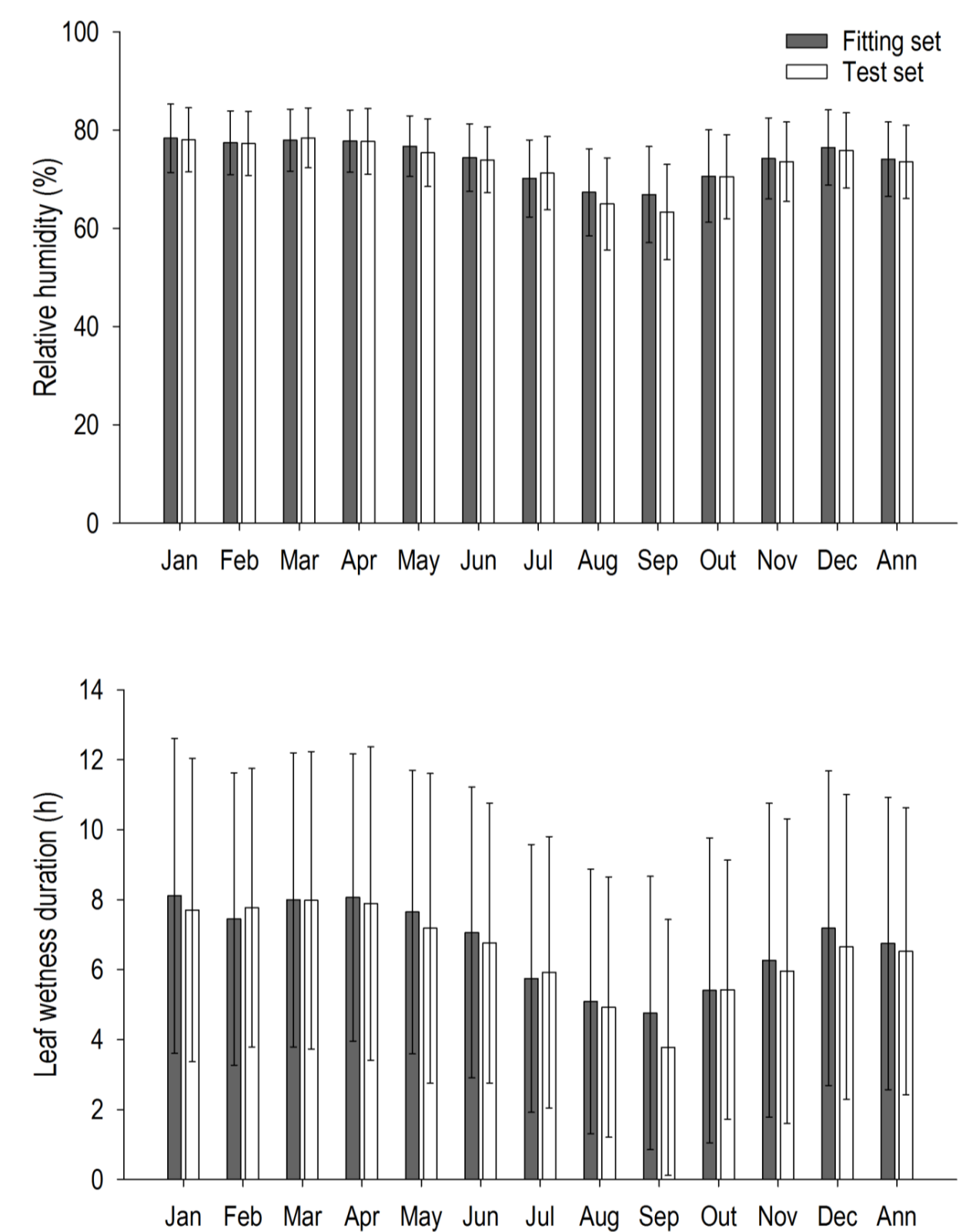


Figure 4. RH and LWD from 58 automatic weather stations in Brazil. Bars represent data variability (± SD) among the weather stations.

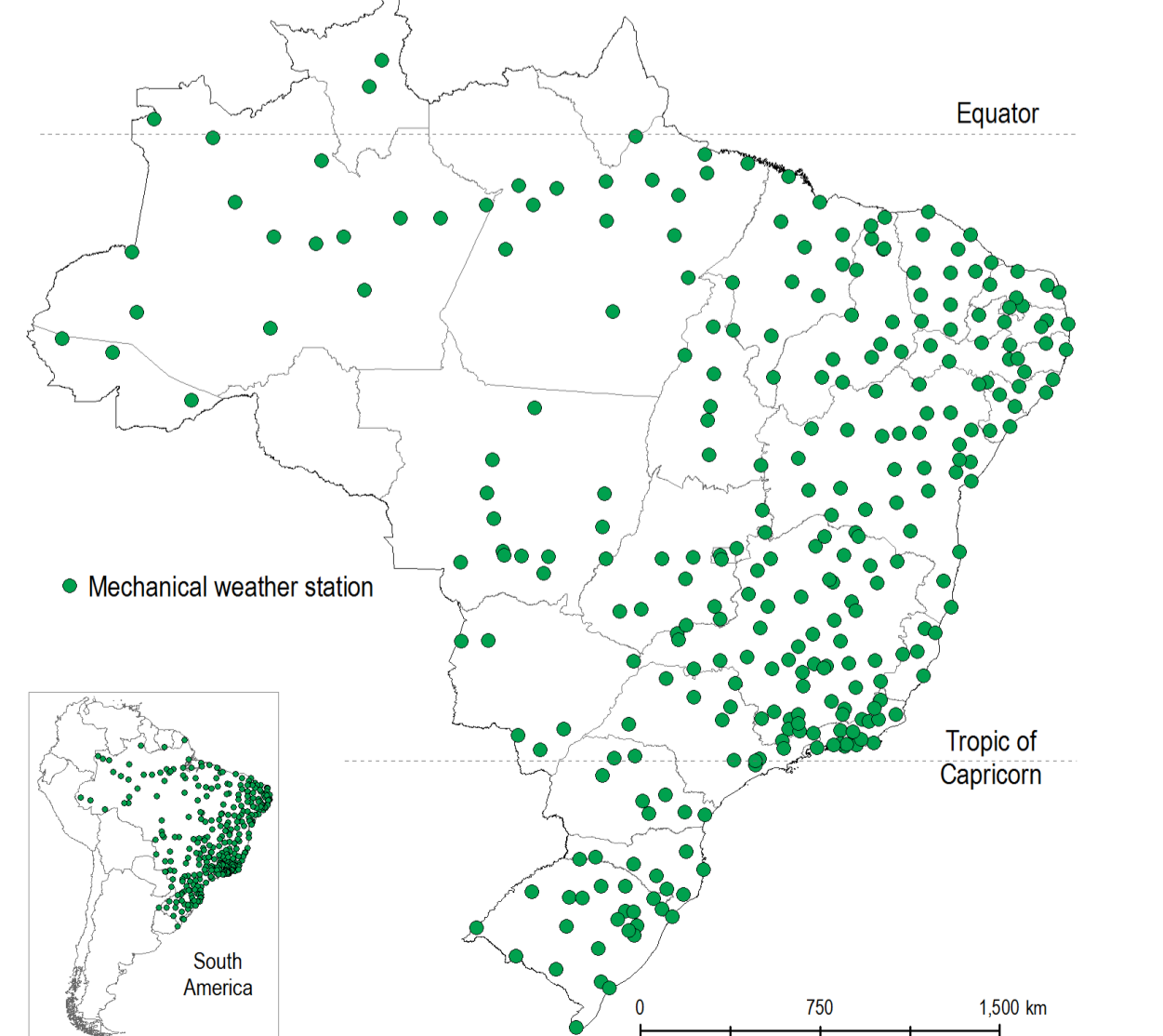


Figure 5. Location of the mechanical weather stations used for LWD modeling with monthly RH.

## Results



Figure 1. Leaf wetness in a corn leaf in the early morning

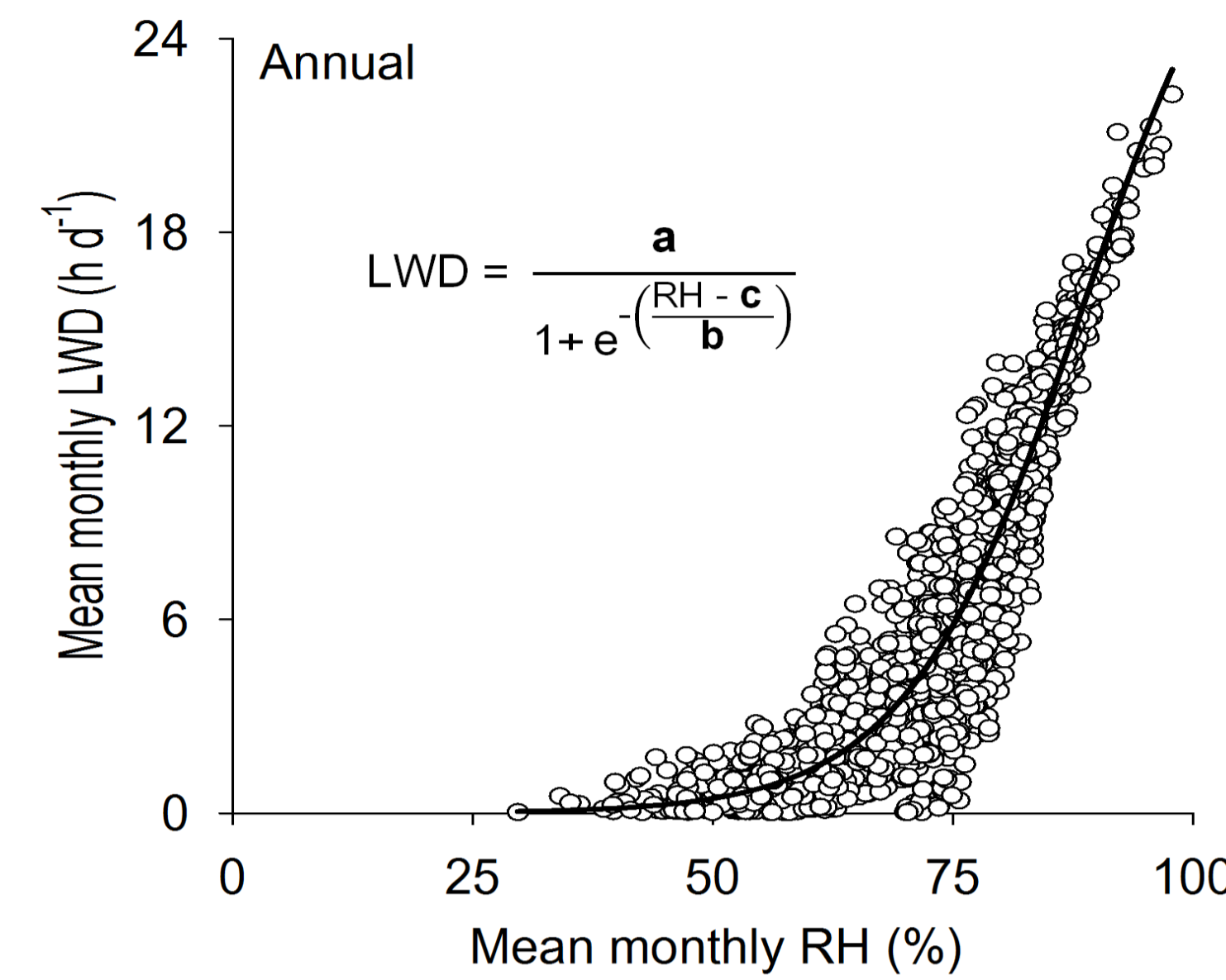


Figure 6. General model to estimate mean monthly LWD as a function of mean monthly RH.

Table 1 - Coefficients of the monthly LWD models.

| Month | Coefficients of sigmoidal model |                |                | Goodness-of-fit statistics                  |                        | Validation      |                 |                   |                     |                    |                  |
|-------|---------------------------------|----------------|----------------|---|------------------------|-----------------|-----------------|-------------------|---------------------|--------------------|------------------|
|       | a <sup>i</sup>                  | b <sup>i</sup> | c <sup>i</sup> | R <sup>2</sup> <sub>adj</sub> <sup>ii</sup> | p value <sup>iii</sup> | r <sup>iv</sup> | ME <sup>v</sup> | MAE <sup>vi</sup> | RMSE <sup>vii</sup> | dr <sup>viii</sup> | Pj <sup>ix</sup> |
| Jan   | 24.24                           | 7.39           | 84.30          | 0.91  | <0.0001                | 0.94            | -0.27           | 1.20              | 1.60                | 0.84               | 0.79             |
| Fev   | 26.47                           | 7.58           | 85.65          | 0.88  | <0.0001                | 0.96            | 0.29            | 1.00              | 1.20                | 0.86               | 0.83             |
| Mar   | 25.40                           | 7.74           | 84.89          | 0.88  | <0.0001                | 0.94            | -0.25           | 1.30              | 1.60                | 0.83               | 0.78             |
| Apr   | 27.06                           | 8.02           | 85.70          | 0.89  | <0.0001                | 0.92            | 0.03            | 1.10              | 1.50                | 0.84               | 0.78             |
| May   | 38.23                           | 9.50           | 91.66          | 0.90  | <0.0001                | 0.93            | 0.31            | 1.10              | 1.50                | 0.83               | 0.77             |
| Jun   | 38.73                           | 10.67          | 92.80          | 0.88  | <0.0001                | 0.93            | -0.03           | 1.20              | 1.70                | 0.84               | 0.78             |
| Jul   | 66.61 <sup>n.s.</sup>           | 11.81          | 102.03         | 0.87  | <0.0001                | 0.92            | 0.14            | 1.20              | 1.60                | 0.83               | 0.77             |
| Aug   | 43.78                           | 12.51          | 108.93         | 0.89  | <0.0001                | 0.96            | 0.34            | 1.00              | 1.30                | 0.87               | 0.84             |
| Sep   | 43.78                           | 10.30          | 93.56          | 0.84  | <0.0001                | 0.94            | -0.03           | 0.90              | 1.20                | 0.85               | 0.80             |
| Oct   | 31.35                           | 9.30           | 88.44          | 0.88  | <0.0001                | 0.94            | -0.10           | 1.10              | 1.50                | 0.85               | 0.80             |
| Nov   | 26.83                           | 8.32           | 85.72          | 0.89  | <0.0001                | 0.94            | 0.01            | 1.00              | 1.30                | 0.84               | 0.79             |
| Dec   | 24.57                           | 7.65           | 84.45          | 0.89  | <0.0001                | 0.95            | -0.17           | 1.00              | 1.20                | 0.86               | 0.81             |
| Ann   | 31.31                           | 9.13           | 88.47          | 0.87  | <0.0001                | 0.94            | 0.04            | 1.11              | 1.51                | 0.84               | 0.80             |

<sup>i</sup> = coefficients of the regression model; <sup>ii</sup> = adjusted coefficient of determination; <sup>iii</sup> = significance probability; <sup>iv</sup> = coefficient of correlation; <sup>v</sup> = mean error; <sup>vi</sup> = mean absolute error; <sup>vii</sup> = root-mean-square error; <sup>viii</sup> = refined agreement index; <sup>ix</sup> = performance index; <sup>n.s.</sup> not significant at the 0.05 level

Table 2 - Coefficients of the monthly leaf wetness duration (LWD) models.

| c   | Model             | <sup>2</sup> Co | <sup>3</sup> Co+C | <sup>4</sup> Ao | C/(Co+C) | <sup>5</sup> SDI | <sup>6</sup> R <sup>2</sup> | <sup>7</sup> RSS | <sup>8</sup> r |
|-----|-------------------|-----------------|-------------------|-----------------|----------|------------------|-----------------------------|------------------|----------------|
|     |                   | % <sup>2</sup>  | % <sup>2</sup>    | degree          | %        |                  |                             | % <sup>2</sup>   |                |
| Jan | <sup>1</sup> Sph. | 13.30           | 86.26             | 20.82           | 84.6     | strong           | 0.98                        | 122.0            | 0.76**         |
| Feb | Sph.              | 10.00           | 65.92             | 20.17           | 84.8     | strong           | 0.99                        | 35.90            | 0.79**         |
| Mar | Sph.              | 13.19           | 43.10             | 19.16           | 69.4     | moderate         | 0.96                        | 39.0             | 0.74**         |
| Apr | Sph.              | 13.10           | 44.06             | 11.07           | 70.3     | moderate         | 0.94                        | 47.5             | 0.67**         |
| May | Sph.              | 12.40           | 59.50             | 9.11            | 79.2     | strong           | 0.97                        | 52.0             | 0.71**         |
| Jun | Sph.              | 19.40           | 91.60             | 8.66            | 78.8     | strong           | 0.94                        | 228.0            | 0.72**         |
| Jul | Sph.              | 13.60           | 119.50            | 8.83            | 88.6     | strong           | 0.95                        | 378.0            | 0.77**         |
| Aug | Sph.              | 0.10            | 143.10            | 8.51            | 99.9     | strong           | 0.97                        | 461.0            | 0.81**         |
| Sep | Sph.              | 4.50            | 147.60            | 8.62            | 97.0     | strong           | 0.97                        | 371.0            | 0.82**         |
| Oct | Sph.              | 29.20           | 143.00            | 18.68           | 79.6     | strong           | 0.94                        | 836.0            | 0.82**         |
| Nov | Sph.              | 16.20           | 134.40            | 19.99           | 87.9     | strong           | 0.91                        | 139.0            | 0.82**         |
| Dec | Sph.              | 10.20           | 146.20            | 21.25           | 93.0     | strong           | 0.89                        | 2160.0           | 0.81**         |

<sup>1</sup>Sph = spherical; <sup>2</sup>Co = nugget; <sup>3</sup>Co+C = Sill (C = structural variance); <sup>4</sup>Ao = range (degrees); <sup>5</sup>SDI = spatial dependence index; <sup>6</sup>R<sup>2</sup> = model adjustment determination coefficient; <sup>7</sup>RSS = Residue Sum of Squares; <sup>8</sup>r = crossed validation correlation coefficient. \*\* significant at the 0.001 level.

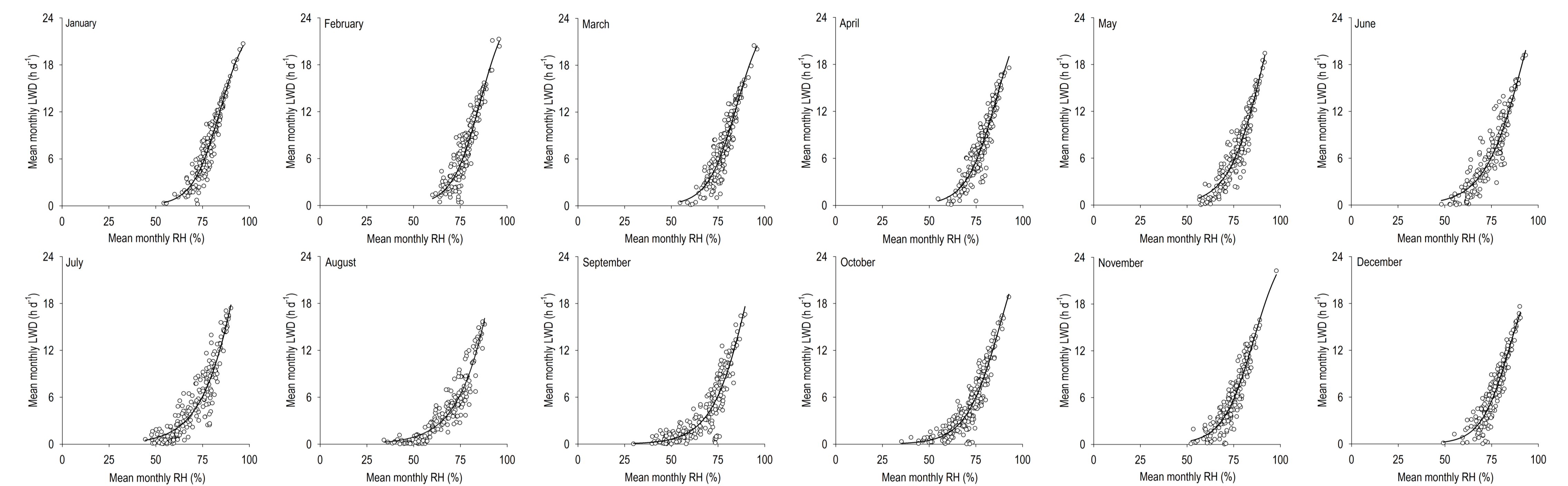


Figure 7. Models to estimate mean monthly LWD as a function of mean monthly RH.

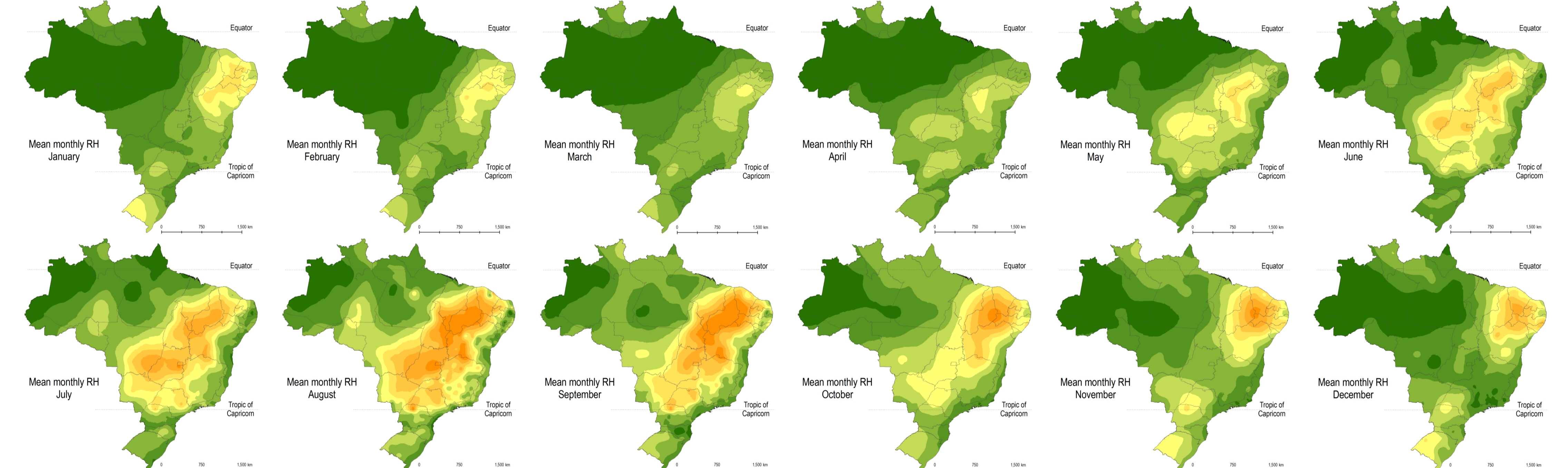


Figure 8. Spatial and temporal mean monthly RH variability in Brazil.

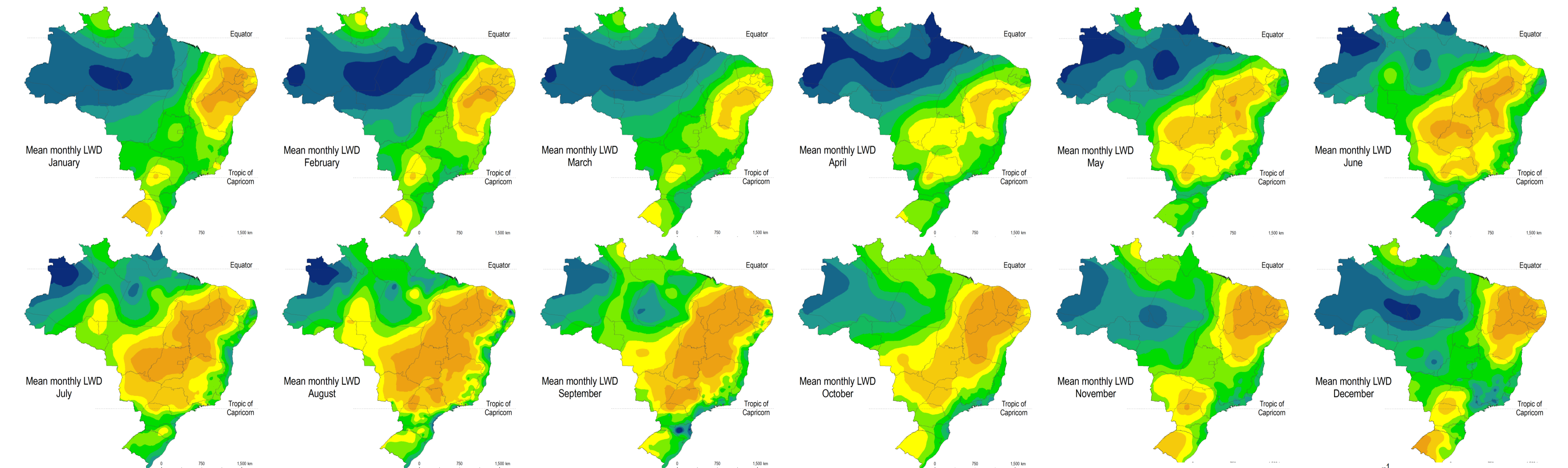


Figure 9. Spatial and temporal mean monthly LWD variability in Brazil.