

Predicted distribution and burden of podoconiosis in Cameroon.

Supplementary file

Text 1S. Formulation and validation of geostatistical model of podoconiosis prevalence

Let Y_i denote the number of positively tested podoconiosis cases at location x_i out of n_i sample individuals. We then assume that, conditionally on a zero-mean spatial Gaussian process $S(x)$, the Y_i are mutually independent Binomial variables with probability of testing positive $p(x_i)$ such that

$$\log \left\{ \frac{p(x_i)}{1 - p(x_i)} \right\} = \beta_0 + \beta_1 \text{Clay}(x_i) + \beta_2 \text{DSTL}(x_i) + \beta_3 \text{DSTW}(x_i) + \beta_4 E(x_i) + \beta_5 \text{Prec}(x_i) + \beta_6 \text{Silt}(x_i) + S(x_i)$$

where the explanatory in the above equation are, in order, fraction of clay, distance (in meters) to stable light (DSTL), distance to water bodies (DSTW), elevation (E), precipitation (Prec) (in mm) and fraction of silt at location x_i .

We model the Gaussian process $S(x)$ using an isotropic and stationary exponential covariance function given by

$$\text{Cov}\{S(x), S(x')\} = \sigma^2 \exp\{-||x - x'||/\phi\}$$

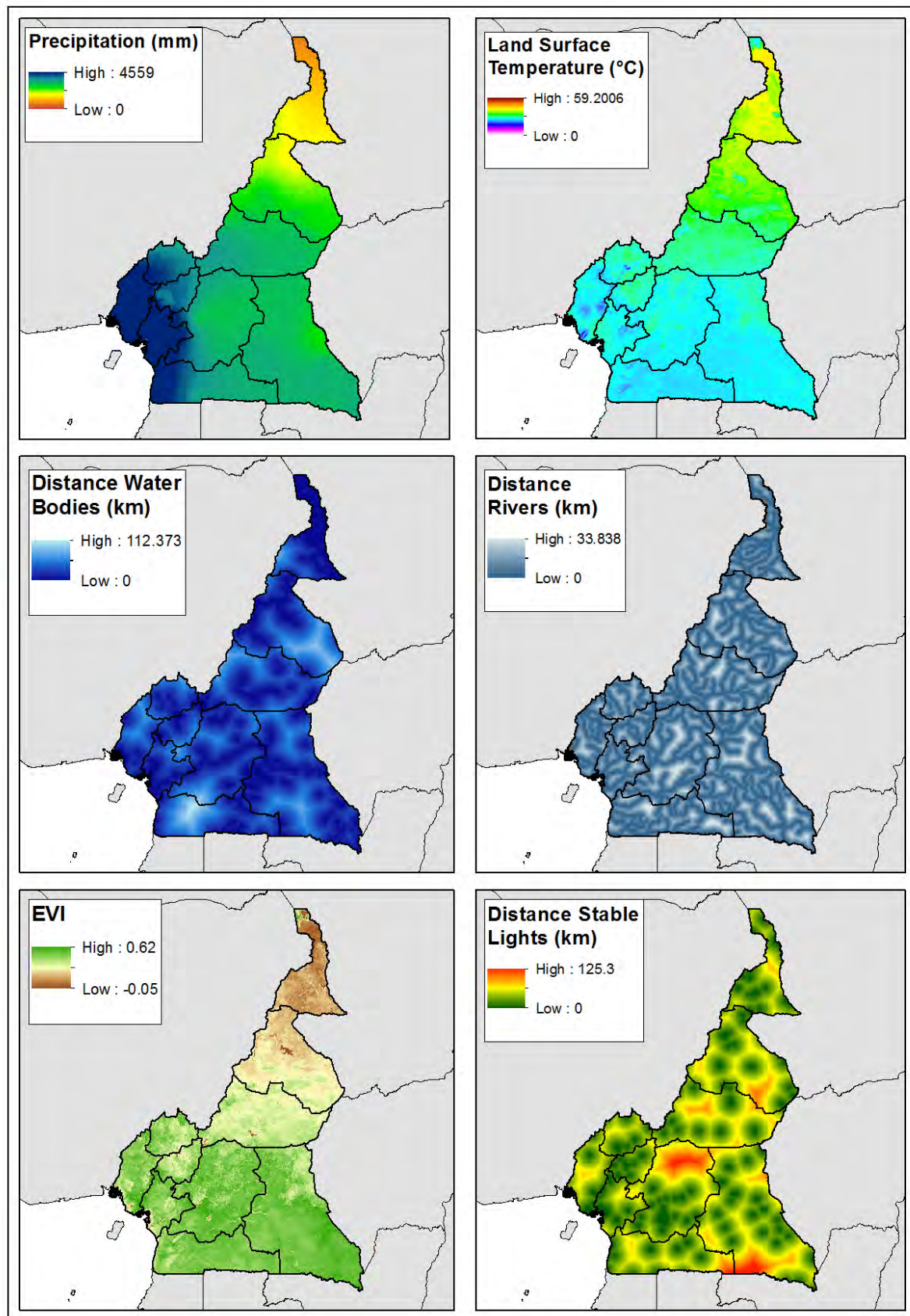
Where $||x - x'||$ is the Euclidean distance between x and x' , σ^2 is the variance of $S(x)$ and ϕ is a scale parameter that regulates how fast the spatial correlation decays to zero for increasing distance.

To check the validity of the adopted exponential correlation function for the spatial random effects $S(x)$, we carry out the following Monte Carlo algorithm.

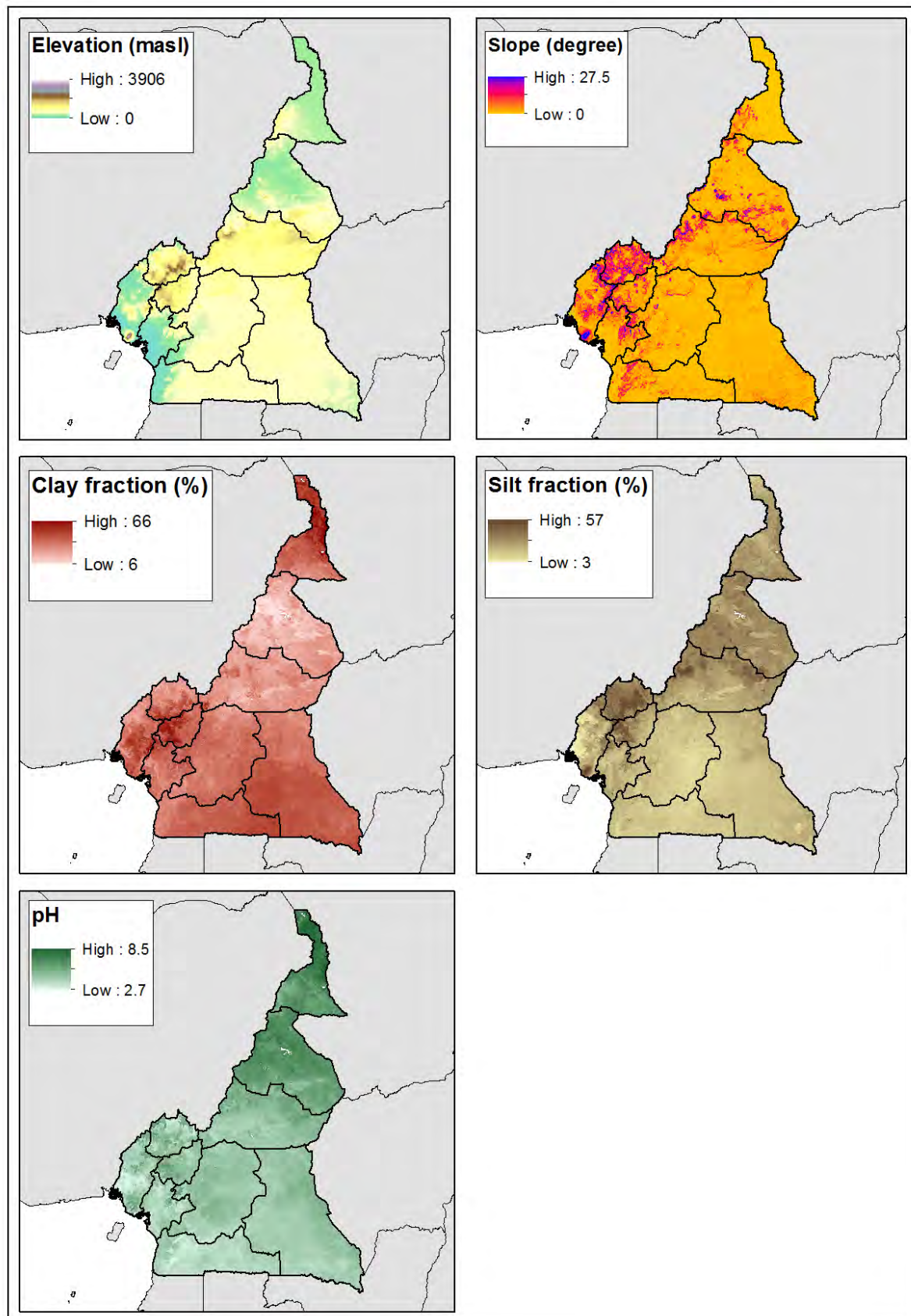
1. Simulate a binomial geostatistical data-set at observed locations x_i by plugging-in the maximum likelihood estimates from the fitted model.
2. Estimate the unstructured random effects Z_i from a non-spatial binomial mixed model obtained by setting $S(x) = 0$ for all locations x .
3. Use the estimates for Z_i from the previous step to compute the empirical variogram.
4. Repeat steps 1 to 3 for 10,000 times.
5. Use the resulting 1,000 variograms to compute the 95% tolerance bandwidth under the hypothesis that the analysed data were generated by the fitted model. If the empirical variogram from the original data, obtained as in step 2, lies within 95% bandwidth, we then conclude that we do not find evidence against the assumption of an exponential correlation function for $S(x)$.

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Figure 1S. Maps of covariates used to model environmental suitability and podoconiosis prevalence.

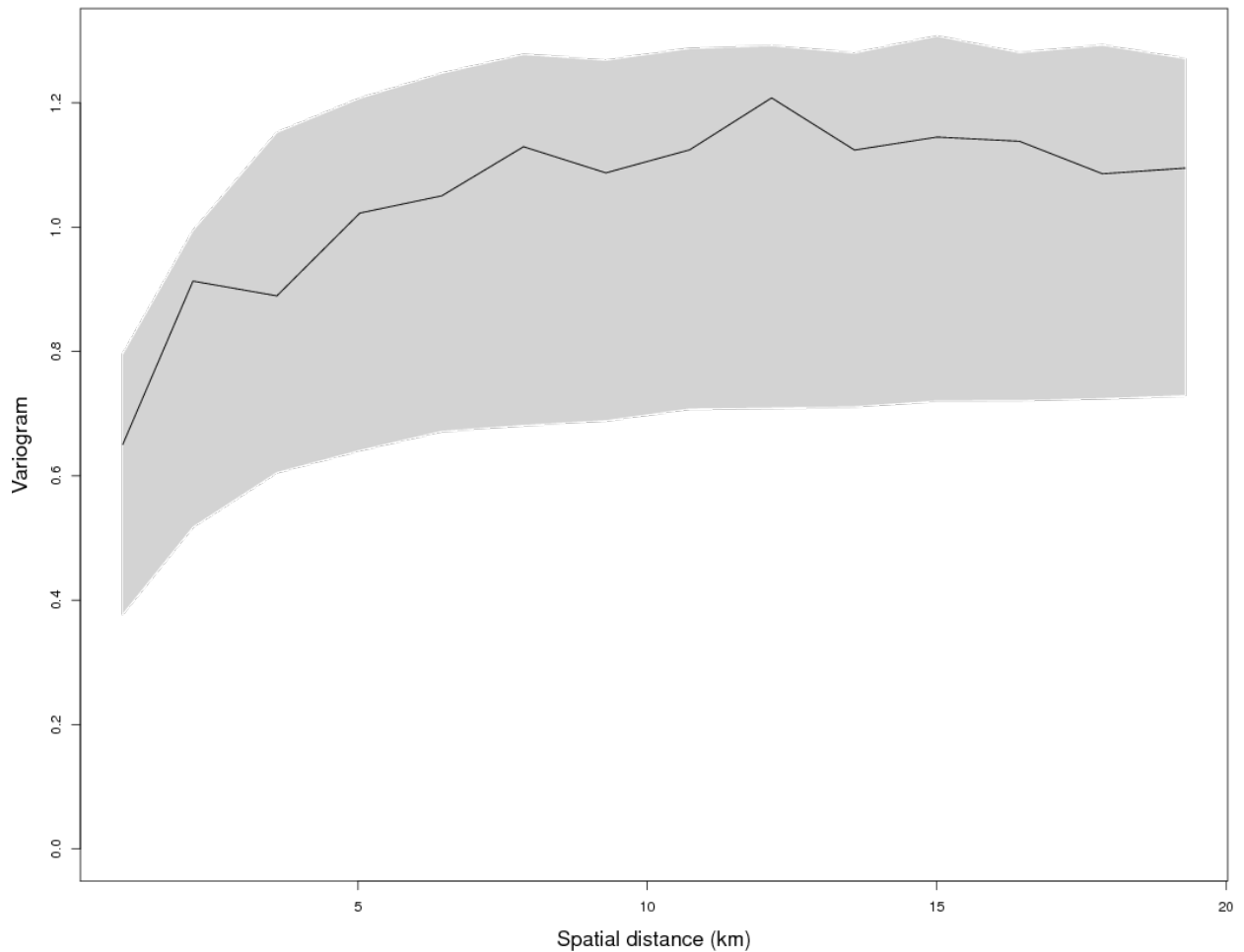


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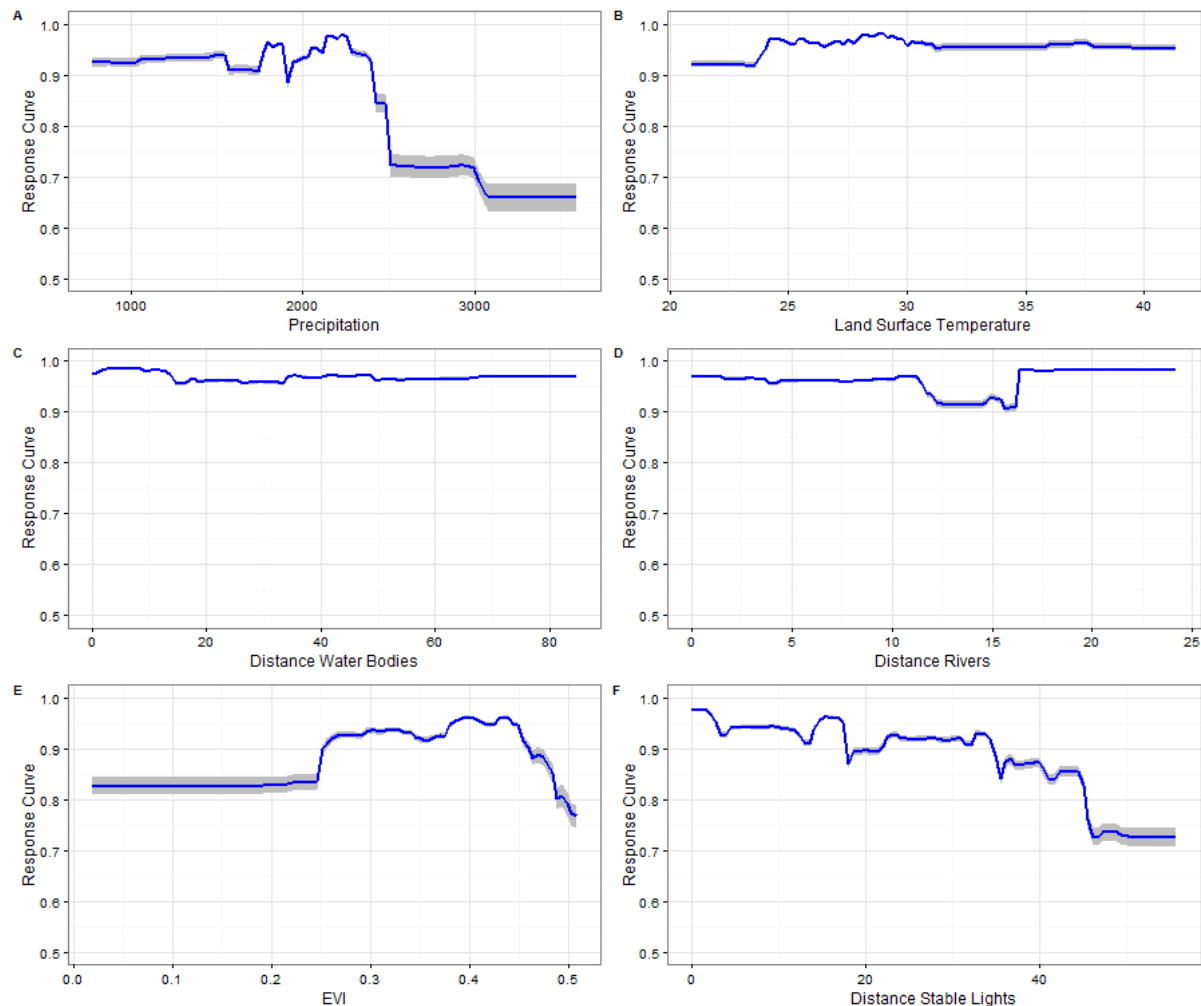
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Figure 2S. The results of the Monte Carlo validation procedure. The solid line is the observed variogram and the shaded area corresponds to the 95% bandwidth. The results lead us to conclude that the data are compatible with the assumption of an exponential spatial correlation function.



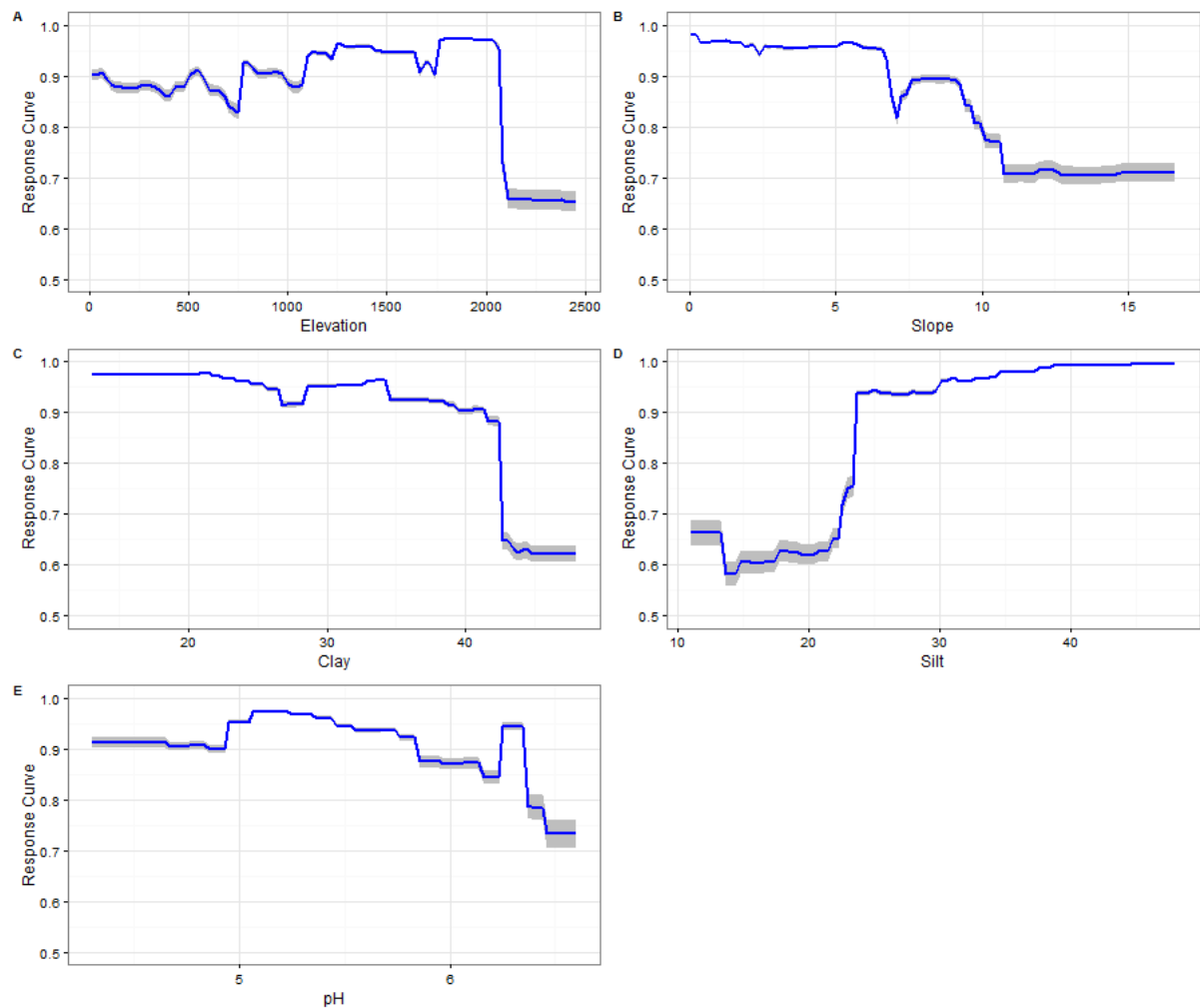
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Figure 3S Partial dependence plots of the relative contribution of climate, vegetation and water related covariates to the boosted regression tree (BRT) model for podoconiosis, averaged over 100 ensembles. Blue lines represent the mean partial dependence over all 100 BRT ensembles and grey envelopes the standard deviation from the mean. The y-axis is the transformed logit response and x-axis is the full range of covariates values.



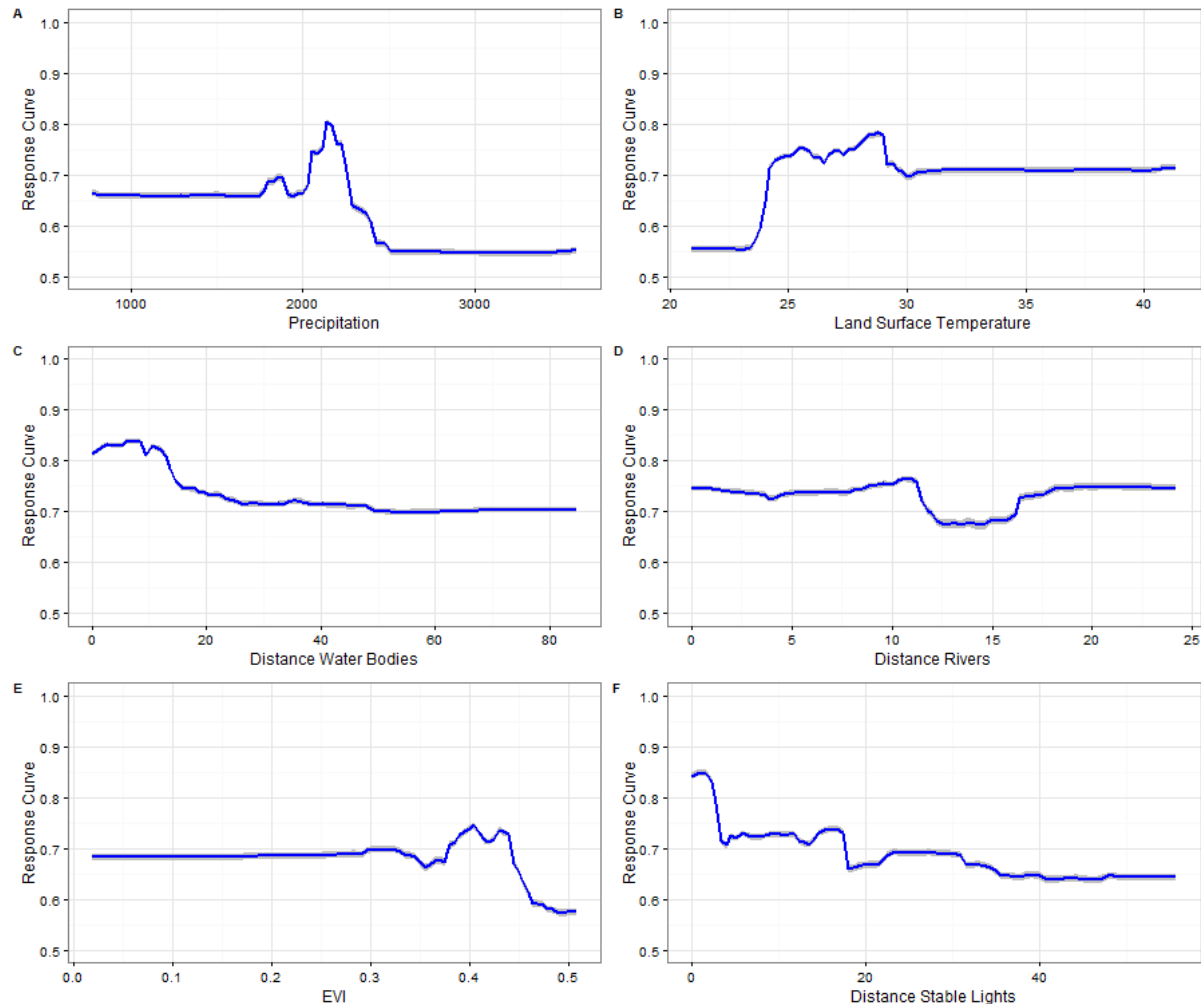
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Figure 4S Partial dependence plots of the relative contribution of topography and soil composition related covariates to the boosted regression tree (BRT) model for podoconiosis, averaged over 100 ensembles. Blue lines represent the mean partial dependence over all 100 BRT ensembles and grey envelopes the standard deviation from the mean. The y-axis is the transformed logit response and x-axis is the full range of covariates values.



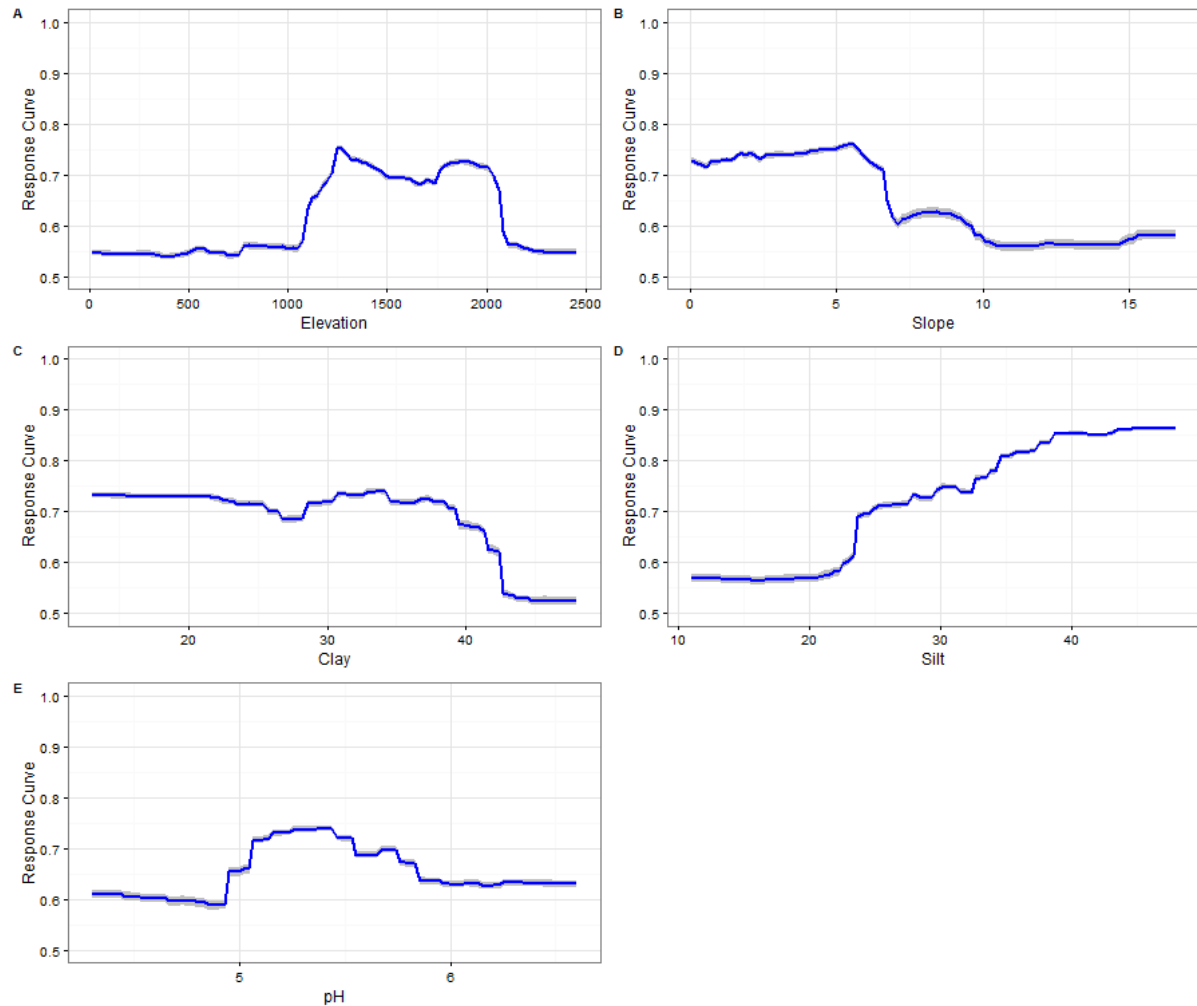
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Figure 5S Partial dependence plots of the relative contribution of climate, vegetation and water related covariates to the random forest (RF) model for podoconiosis, averaged over 100 ensembles. Blue lines represent the mean partial dependence over all 100 RF ensembles and grey envelopes the standard deviation from the mean. The y-axis is the transformed logit response and x-axis is the full range of covariates values.



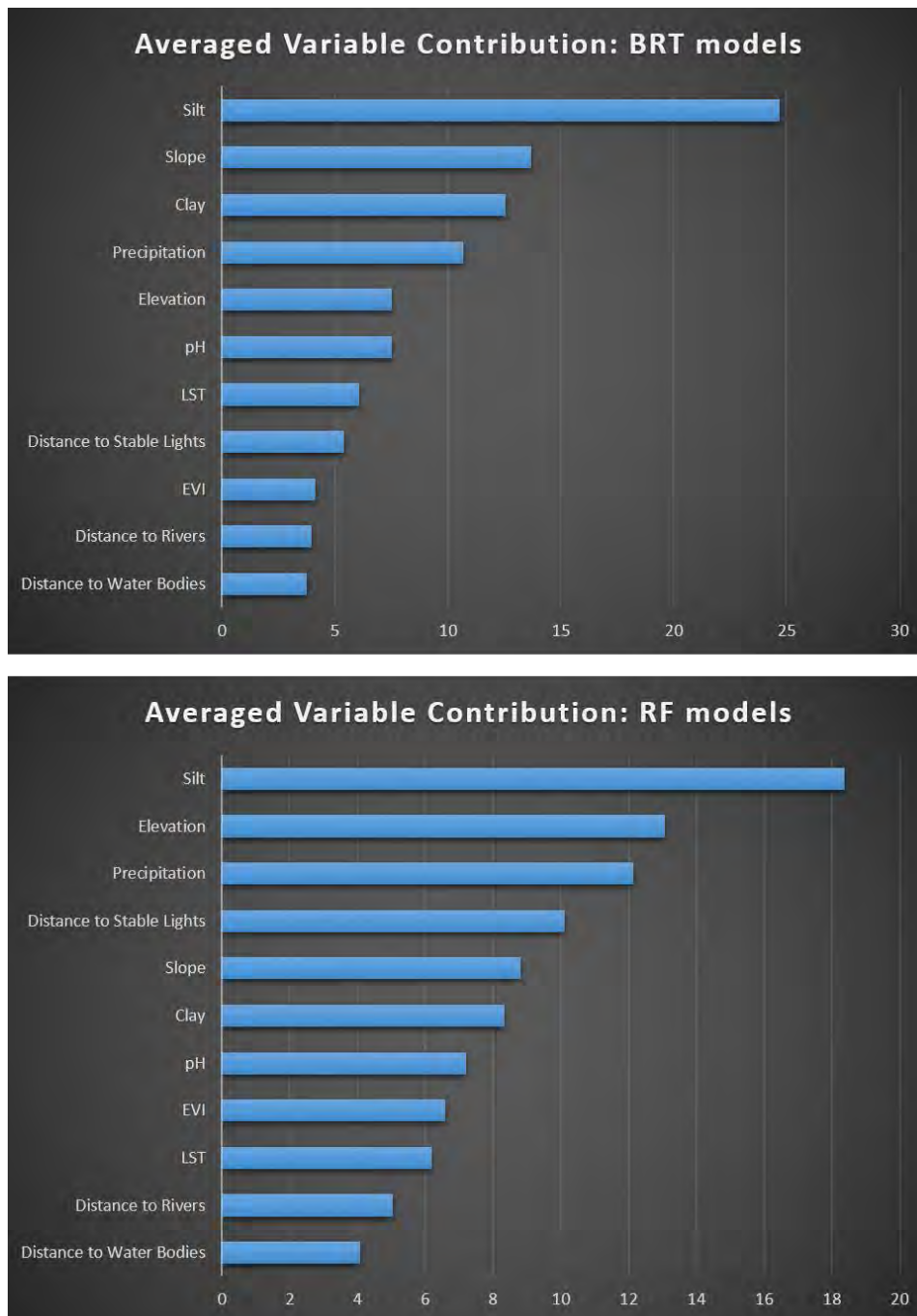
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Figure 6S Partial dependence plots of the relative contribution of topography and soil composition related covariates to the random forest (RF) model for podoconiosis, averaged over 100 ensembles. Blue lines represent the mean partial dependence over all 100 BRT ensembles and grey envelopes the standard deviation from the mean. The y-axis is the transformed logit response and x-axis is the full range of covariates values.



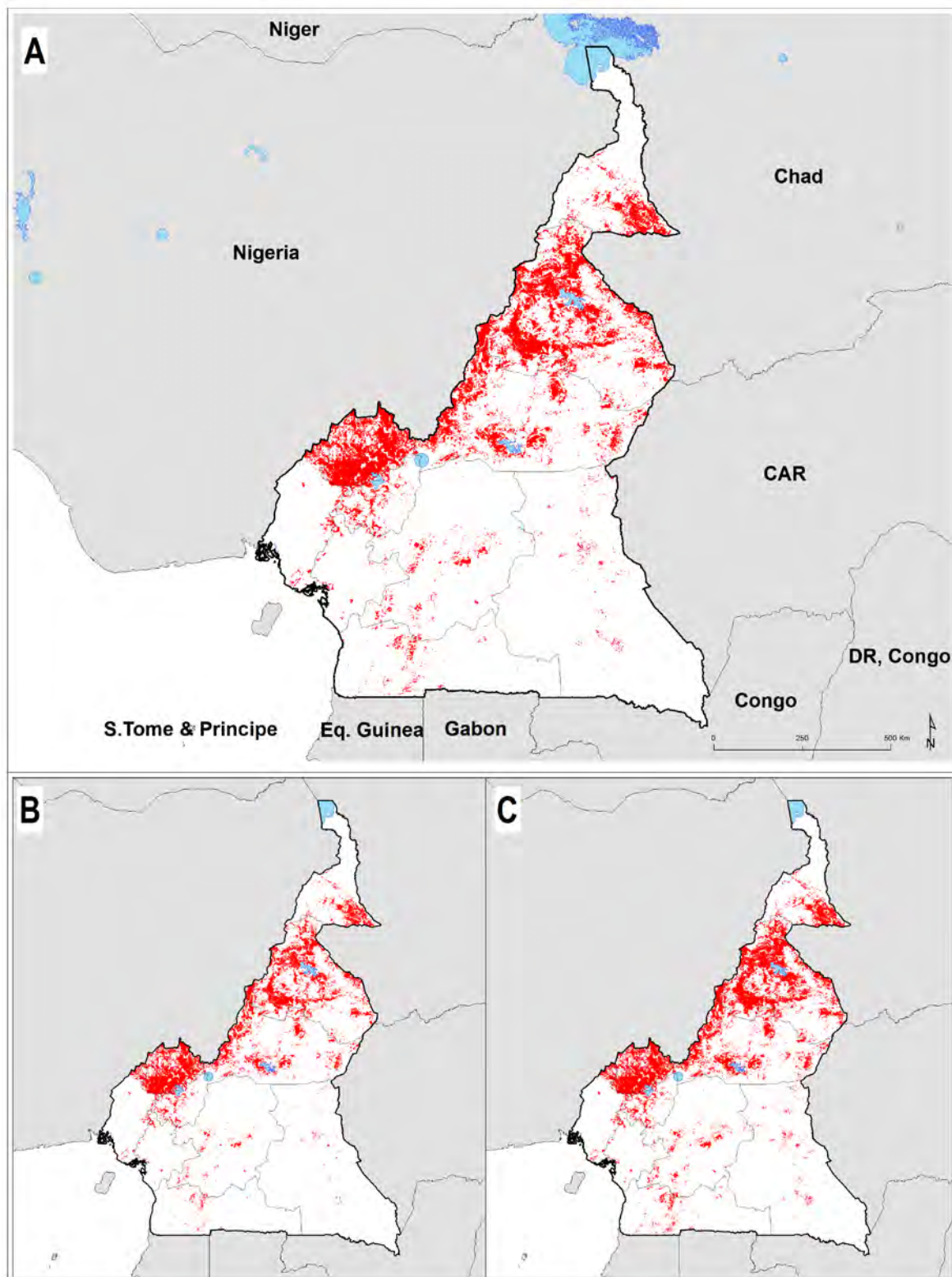
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Figure 7S. Variable contribution of final ensemble models based on *boosted regression trees* and *random forest*. Variable contribution is provided as percentage, and it shows the relative contribution of selected environmental predictors to the final ensemble model of predicted podoconiosis occurrence.



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Figure 8S Predicted occurrence of podoconiosis (A) and uncertainty range (B & C) across Cameroon. Optimal threshold was fitted to get better trade-off between sensitivity, specificity and proportion correctly classified (PCC).



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Table 1S. Estimation of podoconiosis cases by Health District in Cameroon

| SN | Country | Region | Health District | Podoconiosis Cases | Lower Bound | Upper Bound |
|----|----------|----------|-------------------|--------------------|-------------|-------------|
| 1 | Cameroon | Littoral | Ndom | 3 | 0 | 18 |
| 2 | Cameroon | Littoral | Ngambe | 10 | 0 | 63 |
| 3 | Cameroon | Littoral | Yabassi | 0 | 0 | 1 |
| 4 | Cameroon | Littoral | Nkongsamba | 0 | 0 | 0 |
| 5 | Cameroon | Littoral | Manjo | 776 | 37 | 4054 |
| 6 | Cameroon | Littoral | Melong | 15 | 0 | 91 |
| 7 | Cameroon | Littoral | Loum | 0 | 0 | 2 |
| 8 | Cameroon | Littoral | Abo | 44 | 1 | 266 |
| 9 | Cameroon | Littoral | Mbanga | 176 | 4 | 1055 |
| 10 | Cameroon | Littoral | Deido | 680 | 15 | 4050 |
| 11 | Cameroon | Littoral | Bonassama | 149 | 3 | 888 |
| 12 | Cameroon | Littoral | Mbangue | 1 | 0 | 6 |
| 13 | Cameroon | Littoral | Logbaba | 3304 | 154 | 17573 |
| 14 | Cameroon | Littoral | New Bell | 9 | 0 | 53 |
| 15 | Cameroon | Littoral | Nylon | 0 | 0 | 0 |
| 16 | Cameroon | Littoral | Pouma | 771 | 17 | 4671 |
| 17 | Cameroon | Littoral | Edea | 10 | 0 | 60 |
| 18 | Cameroon | Littoral | Nkondjock | 8 | 0 | 46 |
| 19 | Cameroon | Littoral | Manoka | 0 | 0 | 1 |
| 20 | Cameroon | Littoral | Boko | 0 | 0 | 0 |
| 21 | Cameroon | Littoral | Njombe Penja | 259 | 6 | 1524 |
| 22 | Cameroon | Littoral | Japoma | 4 | 0 | 22 |
| 23 | Cameroon | Littoral | Dibombari | 0 | 0 | 0 |
| 24 | Cameroon | Littoral | Cite Palmiers | 0 | 0 | 0 |
| 25 | Cameroon | Adamaoua | Tignere | 94 | 2 | 564 |
| 26 | Cameroon | Adamaoua | Ngoundal | 240 | 5 | 1440 |
| 27 | Cameroon | Adamaoua | Meiganga | 464 | 10 | 2770 |
| 28 | Cameroon | Adamaoua | Bankim | 104 | 2 | 621 |
| 29 | Cameroon | Adamaoua | Banyo | 215 | 5 | 1290 |
| 30 | Cameroon | Adamaoua | Djohong | 109 | 2 | 656 |
| 31 | Cameroon | Adamaoua | Tibati | 70 | 1 | 421 |
| 32 | Cameroon | Adamaoua | Ngaoundere Rural | 29 | 1 | 174 |
| 33 | Cameroon | Adamaoua | Ngaoundere Urbain | 956 | 20 | 5758 |
| 34 | Cameroon | Central | Djoungolo | 238 | 5 | 1447 |
| 35 | Cameroon | Central | Mbalmayo | 76 | 2 | 456 |
| 36 | Cameroon | Central | Yoko | 1 | 0 | 3 |
| 37 | Cameroon | Central | Efoulan | 730 | 17 | 4268 |
| 38 | Cameroon | Central | Mbankomo | 104 | 3 | 595 |
| 39 | Cameroon | Central | Evoudoula | 6 | 0 | 35 |
| 40 | Cameroon | Central | Mfou | 0 | 0 | 0 |

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| SN | Country | Region | Health District | Podoconiosis Cases | Lower Bound | Upper Bound |
|----|----------|---------------|-----------------|--------------------|-------------|-------------|
| 41 | Cameroon | Central | Obala | 15 | 0 | 89 |
| 42 | Cameroon | Central | Ebebda | 43 | 1 | 266 |
| 43 | Cameroon | Central | Bafia | 389 | 8 | 2344 |
| 44 | Cameroon | Central | Ntui | 17 | 0 | 101 |
| 45 | Cameroon | Central | Elig Mfomo | 19 | 0 | 115 |
| 46 | Cameroon | Central | Mbandjock | 224 | 5 | 1361 |
| 47 | Cameroon | Central | Nanga Eboko | 34 | 1 | 205 |
| 48 | Cameroon | Central | Akonolinga | 69 | 1 | 435 |
| 49 | Cameroon | Central | Ngog Mapubi | 80 | 2 | 483 |
| 50 | Cameroon | Central | Eseka | 142 | 3 | 847 |
| 51 | Cameroon | Central | Awae | 226 | 6 | 1265 |
| 52 | Cameroon | Central | Esse | 12 | 0 | 73 |
| 53 | Cameroon | Central | Soa | 73 | 2 | 452 |
| 54 | Cameroon | Central | Monatele | 7 | 0 | 41 |
| 55 | Cameroon | Central | Ngoumou | 153 | 3 | 902 |
| 56 | Cameroon | Central | Ayos | 0 | 0 | 1 |
| 57 | Cameroon | Central | Ndikinimeki | 56 | 1 | 331 |
| 58 | Cameroon | Central | Cite Verte | 4 | 0 | 24 |
| 59 | Cameroon | Central | Nkolbissong | 1 | 0 | 5 |
| 60 | Cameroon | Central | Biyem Assi | 598 | 14 | 3614 |
| 61 | Cameroon | Central | Saa | 19 | 0 | 116 |
| 62 | Cameroon | Central | Nkolndongo | 3936 | 99 | 23065 |
| 63 | Cameroon | Central | Okola | 0 | 0 | 0 |
| 64 | Cameroon | East | Abong Mbang | 16 | 0 | 94 |
| 65 | Cameroon | East | Messamena | 0 | 0 | 0 |
| 66 | Cameroon | East | Garoua Boulai | 13 | 0 | 78 |
| 67 | Cameroon | East | Lomie | 11 | 0 | 66 |
| 68 | Cameroon | East | Moloundou | 5 | 0 | 30 |
| 69 | Cameroon | East | Yokadouma | 42 | 1 | 254 |
| 70 | Cameroon | East | Ndelele | 29 | 1 | 177 |
| 71 | Cameroon | East | Mbang | 5 | 0 | 30 |
| 72 | Cameroon | East | Batouri | 193 | 6 | 1070 |
| 73 | Cameroon | East | Betare Oya | 6 | 0 | 36 |
| 74 | Cameroon | East | Kette | 18 | 0 | 106 |
| 75 | Cameroon | East | Nguelemendouka | 0 | 0 | 0 |
| 76 | Cameroon | East | Bertoua | 524 | 11 | 3135 |
| 77 | Cameroon | East | Doume | 54 | 1 | 318 |
| 78 | Cameroon | Extreme North | Kolofata | 143 | 3 | 870 |
| 79 | Cameroon | Extreme North | Meri | 31 | 1 | 186 |
| 80 | Cameroon | Extreme North | Bogo | 195 | 4 | 1173 |
| 81 | Cameroon | Extreme North | Maroua 2 | 286 | 6 | 1786 |
| 82 | Cameroon | Extreme North | Tokombere | 56 | 1 | 333 |

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|-----|----------|---------------|-----------------|--------------------|-------------|-------------|
| 83 | Cameroon | Extreme North | Gazawa | 29 | 1 | 179 |
| 84 | Cameroon | Extreme North | Kaele | 231 | 5 | 1392 |
| 85 | Cameroon | Extreme North | Guidiguis | 213 | 5 | 1254 |
| 86 | Cameroon | Extreme North | Guere | 244 | 5 | 1468 |
| 87 | Cameroon | Extreme North | Kar Hay | 419 | 9 | 2520 |
| 88 | Cameroon | Extreme North | Bourha | 70 | 2 | 418 |
| 89 | Cameroon | Extreme North | Moutourwa | 74 | 2 | 440 |
| 90 | Cameroon | Extreme North | Pette | 105 | 2 | 625 |
| 91 | Cameroon | Extreme North | Goulfey | 0 | 0 | 0 |
| 92 | Cameroon | Extreme North | Mogode | 35 | 1 | 212 |
| 93 | Cameroon | Extreme North | Hina | 280 | 6 | 1696 |
| 94 | Cameroon | Extreme North | Maroua 3 | 496 | 10 | 3014 |
| 95 | Cameroon | Extreme North | Koza | 24 | 1 | 142 |
| 96 | Cameroon | Extreme North | Mokolo | 14 | 0 | 85 |
| 97 | Cameroon | Extreme North | Kousseri | 28 | 1 | 173 |
| 98 | Cameroon | Extreme North | Maroua 1 | 35 | 1 | 212 |
| 99 | Cameroon | Extreme North | Makary | 0 | 0 | 0 |
| 100 | Cameroon | Extreme North | Mada | 6 | 0 | 35 |
| 101 | Cameroon | Extreme North | Roua | 184 | 4 | 1111 |
| 102 | Cameroon | Extreme North | Yagoua | 540 | 12 | 3212 |
| 103 | Cameroon | Extreme North | Vele | 424 | 9 | 2520 |
| 104 | Cameroon | Extreme North | Moulvoudaye | 239 | 5 | 1439 |
| 105 | Cameroon | Extreme North | Mindif | 179 | 4 | 1075 |
| 106 | Cameroon | Extreme North | Mora | 289 | 6 | 1738 |
| 107 | Cameroon | Extreme North | Maga | 315 | 7 | 1901 |
| 108 | Cameroon | North | Tchollire | 210 | 5 | 1260 |
| 109 | Cameroon | North | Poli | 353 | 8 | 2116 |
| 110 | Cameroon | North | Rey Bouba | 232 | 5 | 1387 |
| 111 | Cameroon | North | Pitoa | 219 | 5 | 1302 |
| 112 | Cameroon | North | Bibemi | 130 | 3 | 786 |
| 113 | Cameroon | North | Ngong | 72 | 2 | 434 |
| 114 | Cameroon | North | Garoua li | 2405 | 52 | 14612 |
| 115 | Cameroon | North | Lagdo | 44 | 1 | 268 |
| 116 | Cameroon | North | Garoua I | 203 | 4 | 1231 |
| 117 | Cameroon | North | Gaschiga | 135 | 3 | 795 |
| 118 | Cameroon | North | Figuil | 209 | 5 | 1249 |
| 119 | Cameroon | North | Touboro | 297 | 8 | 1749 |
| 120 | Cameroon | North | Golombe | 115 | 2 | 694 |
| 121 | Cameroon | North | Mayo Oulo | 255 | 5 | 1538 |
| 122 | Cameroon | North | Guider | 927 | 20 | 5526 |
| 123 | Cameroon | West | Batcham | 59 | 1 | 350 |
| 124 | Cameroon | West | Penka Michel | 142 | 3 | 856 |

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| SN | Country | Region | Health District | Podoconiosis Cases | Lower Bound | Upper Bound |
|-----|----------|------------|-----------------|--------------------|-------------|-------------|
| 125 | Cameroon | West | Bandjoun | 121 | 3 | 729 |
| 126 | Cameroon | West | Mbouda | 291 | 6 | 1732 |
| 127 | Cameroon | West | Dschang | 158 | 3 | 942 |
| 128 | Cameroon | West | Bangourain | 51 | 1 | 309 |
| 129 | Cameroon | West | Bangangte | 376 | 8 | 2241 |
| 130 | Cameroon | West | Bamendjou | 392 | 11 | 2205 |
| 131 | Cameroon | West | Baham | 117 | 3 | 701 |
| 132 | Cameroon | West | Bandja | 74 | 2 | 448 |
| 133 | Cameroon | West | Foumban | 124 | 3 | 753 |
| 134 | Cameroon | West | Malentouen | 50 | 1 | 296 |
| 135 | Cameroon | West | Foumbot | 127 | 3 | 768 |
| 136 | Cameroon | West | Santchou | 86 | 2 | 514 |
| 137 | Cameroon | West | Kekem | 181 | 4 | 1095 |
| 138 | Cameroon | West | Kouoptamo | 3 | 0 | 18 |
| 139 | Cameroon | West | Mifi | 1117 | 24 | 6749 |
| 140 | Cameroon | West | Massangam | 44 | 1 | 262 |
| 141 | Cameroon | West | Galim | 170 | 4 | 1028 |
| 142 | Cameroon | West | Bafang | 230 | 5 | 1370 |
| 143 | Cameroon | South | Ebolowa | 573 | 13 | 3419 |
| 144 | Cameroon | South | Meyomessala | 18 | 0 | 104 |
| 145 | Cameroon | South | Kribi | 196 | 4 | 1197 |
| 146 | Cameroon | South | Lolodorf | 14 | 0 | 84 |
| 147 | Cameroon | South | Ambam | 26 | 1 | 155 |
| 148 | Cameroon | South | Zoetele | 4 | 0 | 23 |
| 149 | Cameroon | South | Sangmelima | 7 | 0 | 42 |
| 150 | Cameroon | South | Olamze | 17 | 0 | 103 |
| 151 | Cameroon | South | Djoum | 2 | 0 | 15 |
| 152 | Cameroon | South | Mvangan | 18 | 0 | 110 |
| 153 | Cameroon | South West | Fontem | 601 | 13 | 3586 |
| 154 | Cameroon | South West | Kumba | 322 | 7 | 1842 |
| 155 | Cameroon | South West | Akwaya | 99 | 2 | 586 |
| 156 | Cameroon | South West | Ekondo Titi | 0 | 0 | 0 |
| 157 | Cameroon | South West | Buea | 89 | 3 | 506 |
| 158 | Cameroon | South West | Mbonge | 30 | 1 | 179 |
| 159 | Cameroon | South West | Bakassi | 1 | 0 | 9 |
| 160 | Cameroon | South West | Eyumodjock | 0 | 0 | 0 |
| 161 | Cameroon | South West | Wabane | 193 | 4 | 1166 |
| 162 | Cameroon | South West | Tiko | 87 | 3 | 485 |
| 163 | Cameroon | South West | Limbe | 1108 | 25 | 6594 |
| 164 | Cameroon | South West | Muyuka | 10 | 0 | 59 |
| 165 | Cameroon | South West | Konye | 0 | 0 | 0 |
| 166 | Cameroon | South West | Tombel | 18 | 0 | 111 |

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|-----------------------|----------|------------|-----------------|--------------------|--------------|----------------|
| 167 | Cameroon | South West | Nguti | 17 | 0 | 103 |
| 168 | Cameroon | South West | Mamfe | 189 | 5 | 1110 |
| 169 | Cameroon | South West | Bangem | 44 | 1 | 257 |
| 170 | Cameroon | South West | Mundemba | 0 | 0 | 1 |
| 171 | Cameroon | North West | Bafut | 541 | 23 | 2852 |
| 172 | Cameroon | North West | Fundong | 131 | 5 | 711 |
| 173 | Cameroon | North West | Nwa | 204 | 6 | 1157 |
| 174 | Cameroon | North West | Benakuma | 222 | 5 | 1310 |
| 175 | Cameroon | North West | Tubah | 251 | 12 | 1287 |
| 176 | Cameroon | North West | Ako | 142 | 4 | 826 |
| 177 | Cameroon | North West | Bamenda | 627 | 54 | 2707 |
| 178 | Cameroon | North West | Bali | 409 | 18 | 2112 |
| 179 | Cameroon | North West | Ndop | 304 | 19 | 1577 |
| 180 | Cameroon | North West | Wum | 140 | 3 | 827 |
| 181 | Cameroon | North West | Santa | 226 | 6 | 1281 |
| 182 | Cameroon | North West | Njikwa | 145 | 3 | 854 |
| 183 | Cameroon | North West | Mbengwi | 479 | 24 | 2396 |
| 184 | Cameroon | North West | Nkambe | 618 | 18 | 3512 |
| 185 | Cameroon | North West | Ndu | 225 | 8 | 1237 |
| 186 | Cameroon | North West | Oku | 127 | 5 | 690 |
| 187 | Cameroon | North West | Batibo | 888 | 40 | 4538 |
| 188 | Cameroon | North West | Kumbo East | 349 | 11 | 1971 |
| 189 | Cameroon | North West | Kumbo West | 251 | 11 | 1307 |
| National Total | | | | 41,556 | 1,170 | 240,992 |