## **Contents**

## Preface

1	Review of descriptive statistics	1
1.1	Mean and variance	1
1.2	Frequency distribution	2
1.2.1	Histograms	2
1.2.2	Fractile diagrams	2 2 3
1.3	Mode, median, skewness and kurtosis	5 7
1.4	Additional examples of histograms	7
1.4.1	Infiltration rate	7
1.4.2	Surface soil temperature	9
1.4.3	Mineral soil nitrogen	14
1.5	"Outliers"	14
1.6	Covariance	16
1.7	Linear regression	16
1.7.1	Examples of regression	17
1.7.1.1	Soil elevation and distance	17
1.7.1.2	Mineral soil nitrogen	17
1.7.2	Prudence regarding regression	17
1.7.2.1	Soil surface temperature and irrigation water salinity	19
1.7.2.2	Wheat yield and fine textural particles	20
1.7.2.3	Saturated hydraulic conductivity and porosity	22
1.8	References for the theory and calculations	24
1.9	Exercises and problems	25
2	Autocorrelation	31
2.1	Relevant questions	31
2.2	Framework for calculation	32
2.3	Results of the analysis for several data sets	35
2.4	Interpretation of the analysis	39
2.4.1	Observation length and correlation length	39
2.4.2	Frequency distribution and spatial or temporal relationships	42
2.5	Precautions and related topics	43
2.5.1	Selection of sampling interval	43
2.5.2	Stationarity and trends	44

2.5.2.1	Deterministic variations	46
2.5.3	Interpolation and contours	49
2.5.4	Minimum size of treated plots	49
2.5.5	Field-measured variables in deterministic equations	50
2.6	Potential research topics	51
2.6.1	Quantifiying taxonomic soil properties	51
2.6.2	Quantifying landscape soil properties	52
2.7	References for the theory and basis of the calculations	53
2.8	Exercises and problems	53
3	Cross correlation	63
3.1	Relevant questions	63
3.2	Framework for calculation	63
3.3	Example data sets	64
3.3.1	Soil water retention curve	64
3.3.1.1	Cross correlation results	68
3.3.1.2	Interpretation of the analysis of the soil water retention data	<i>7</i> 1
3.3.2	Wheat yield, soil water use and nitrogen use	74
3.3.3	Remotely sensed crop nitrogen status	<i>7</i> 5
3.3.4	Soil water pressure head	<i>7</i> 5
3.4	Other considerations	80
3.5	Precautions	82
3.5.1	Significance of cross correlation	82
3.6	Potential research topics	83
3.7	References for theory and basis of the calculation	84
3.8	Exercises and problems	85
4	Semivariograms	91
4.1	Relevant questions	91
4.2	Framework for calculation	91
4.2.1	Anisotropy	96
4.3	Examples of data sampled on a transect	97
4.3.1	Bounded or transitional semivariograms	97
4.3.2	Unbounded or nontransitional semivariograms	102
4.4	Examples of data sampled on a grid	104
4.5	Interpretation of the analysis	106
4.6	Precautions	109
4.7	Potential research topics	110
4.8	References for theory and basis of the calculations	111
4.9	Exercises and problems	112

## Contents

5	Kriging	119
5.1	Relevant questions	119
5.2	Framework for calculation	120
5.2.1	Illustrative example of the calculation	121
5.3	Examples of different kinds of kriging	124
5.3.1	Punctual kriging along a transect	124
5.3.2	Punctual kriging across a grid	126
5.3.3	Block kriging	129
5.3.3.1	Block kriging along a transect	130
5.3.3.2	Block kriging across an area	133
5.3.4	Indicator kriging	135
5.3.4.1	Indicator kriging of soil water content	136
5.3.4.2	Indicator kriging of dissolved organic carbon	140
5.3.5	Universal kriging	145
5.4	Interpretation of the analysis	149
5.4.1	Cross-validation or jack-knifing	149
5.5	Precautions	153
5.5.1	Concepts of stationarity	153
5.5.2	Semivariograms - always suspect	153
5.5.3	Kriging - a smoothing process	155
5.5.4	Impact of nugget on kriging	155
5.5.5	Meaning of the kriging variance	155
5.6	Potential research topics	156
5 <i>.7</i>	References for the theory and basis of the calculation	157
5.8	Exercises and problems	158
6	Crossvariograms and cokriging	168
6.1	Relevant questions	168
6.2	Framework for calculations	169
6.2.1	Crossvariogram	169
6.2.2	Cokriging	169
6.3	Example data sets of crossvariograms and cokriging	170
6.3.1	Almond yields	170
6.3.2	Spring barley grain yield and soil water content	173
6.4	Interpretation of the analysis	178
6.5	Precautions	181
6.5.1	Linear model of co-regionalization and the problem	181
(53	of positive definiteness	404
6.5.2	Other precautions	184
6.6	Potential research topics	185
6.7	References for theory and basis of the calculations	188
6.8	Exercises and problems	189

7	Spectral analysis	196
7.1	Relevant questions	196
7.2	Framework for calculations	196
7.3	Results of the analysis for several data sets	199
7.3.1	Boron concentration within a soil profile	199
7.3.2	Spatial intercropping patterns	199
7.3.3	Soil temperature	202
7.3.4	Wheat yield, soil water use and soil nitrogen use	203
7.3.5	Surface soil water content at different sampling dates	204
7.4	Potential research topics	205
7.5	Precautions	207
7.6	References for the theory and basis of the calculations	209
7.7	Exercises and problems	210
8	Cross spectral analysis and coherency	215
8.1	Relevant questions	215
8.2	Framework for calculation	216
8.3	Results of the analysis for several data sets	223
8.3.1	Soil temperature and irrigation water quality	22
8.3.2	Hourly microbial respiration, air temperature and soil temperature	223
8.3.3	Daily microbial respiration, soil temperature and rainfall	225
8.3.4	Temporal variation of water stored within soil profiles	229
8.3.5	Crop yield and soil nitrogen use	230
8.4	Potential research topics	232
8.5	Precautions	234
8.6	References for the theory and basis of the calculations	235
8.7	Exercises and problems	235
9	Autoregressive and moving average functions	240
9.1	Relevant questions	240
9.2	Framework for calculation	240
9.2.1	Random walk model	240
9.2.2	Autoregressive model $AR(p)$	241
9.2.3	Moving average model $MA(q)$	242
9.2.4	Autoregressive moving average model $ARMA(p, q)$	242
9.3	Example data sets	242
9.3.1	A random soil water content distribution	242
9.3.2	Linearly increasing elevation	24
9.3.3	Fluctuating boron concentration	24
9.3.4	A second order AR model	24
9.3.5	An ARMA model	248
9.4	Interpretation of the analysis	250

## Contents

9.5	Precautions	251
9.6	Potential research topics	251
9.6.1	Alternative description of landscape attributes	251
9.6.2	Alternative analysis of landscape attributes	252
9.6.2.1	Sorghum yield	253
9.6.2.2	Bromide distribution	255
9.7.	References for theory and basis of the calculations	257
9.8	Exercises and problems	258
10	Autoregressive state-space analysis	263
10.1	Relevant questions	265
10.2	Framework for calculation	265
10.2.1	State-space theory for autoregressive models	265
10.2.2	Kalman filtering and EM algorithm	267
10.2.3	Model identification and interpretation	269
10.2.4	First steps in the inspection of state-space analysis	271
10.2.5	Irregular observations	284
10.3	Example data set	287
10.3.1	Surface soil temperature and soil water content	287
10.3.2	Sorghum yield, soil salinity and soil water content	292
10.3.3	Soil salinity and inorganic solutes	294
10.3.4	Wheat grain yield and selected landscape observations	297
10.3.5	Nitrogen fixation	299
10.3.6	Hourly microbial respiration and air temperature	301
10.3.7	Daily microbial respiration, soil temperature and rainfall	302
10.4	Interpretation of the analysis	304
10.5	Precautions	306
10.6	Potential research topics	307
10.7	References for theory and basis of the calculations	308
10.8	Exercises and problems	310
11	Physical state-space models	316
11.1	Relevant questions	316
11.1.1	Relating the physical process to the relevant state-space model	316
11,1.2	Obtaining the necessary data to estimate the state-space model	317
11.1.3	Post-analysis questions	317
11.2	Framework for calculations	318
11.2.1	Brief review of physical equations in state-space models	318
11.2.2	State-space theory for physical equations	319
11.3	Applications of physical equations in state-space models	321
11.3.1	Time series of soil temperature	321
11.3.2	Time series of nitrogen mineralization	332

11.3.3	Carbon respiration and associated soil temperature	338
11.3.4	Soil hydraulic property determination and associated experimental	341
	uncertainty	
11.4	Precautions and suggestions	347
11.5	Potential research topics	349
11.5.1	Impact of measurement resolution	349
11.5.2	Underlying simplifying assumptions – a problem?	350
11.5.3	Applications for monitoring land surface processes	352
11.6	References for theory and basis of the calculations	355
12	Postscript	358
13	Appendices	367
14	Index	389