## **Contents**

| Contributors         |  | ix |  |
|----------------------|--|----|--|
| Foreword<br>M. Swift |  |    |  |
| _                    | acts of Trees on the Fertility of Agricultural Soils | •  |  |
| 1.1                  | Trees and the Development of Agriculture             | 1  |  |
| 1.2                  | Objectives and Structure of the Book                 | 9  |  |
| 2. Ecor              | nomic Aspects of Soil Fertility Management and       | 13 |  |
| Agro                 | oforestry Practices                                  |    |  |
| AM                   | I.N. Izac  |    |  |
| 2.1                  | Introduction   | 13 |  |
| 2.2                  | Factors Influencing Farmers' Decisions About Soil    | 14 |  |
|                      | Fertility Management Practices                       |    |  |
| 2.3                  | Hierarchy of Agricultural Systems as a Background to | 18 |  |
|                      | the Understanding of Farmers' Constraints            |    |  |
| 2.4                  | Anatomy of a Decision at the Farm Scale and Economic | 18 |  |
|                      | Methods for Understanding such Decisions             |    |  |
| 2.5                  | Landscape and Global Scales: Soil Fertility and      | 32 |  |
|                      | Agroforestry Trees as Part of Natural Capital        |    |  |
| 3. Desi              | gning Experiments and Analysing Data                 | 39 |  |
|                      | oe, B. Huwe and G. Schroth                           |    |  |
| 3.1                  | Synopsis   | 39 |  |

vi Contents

|    | 3.2    | Experimental Objectives, Treatments and Layout       | 40  |
|----|--------|--|-----|
|    | 3.3    | Fallow Experiments                                   | 48  |
|    | 3.4    | Measurements and Sampling Designs                    | 52  |
|    | 3.5    | Analysing the Data                                   | 61  |
|    | 3.6    | Spatial Structure and Its Analysis                   | 67  |
| 4. | Soil ( | Organic Matter                                       | 77  |
|    |        | hroth, B. Vanlauwe and J. Lehmann                    |     |
|    | 4.1    | Synopsis   | 77  |
|    | 4.2    | Methods for Total Soil Organic Carbon                | 86  |
|    | 4.3    | Physical Fractionation Methods                       | 86  |
|    | 4.4    | Chemical Methods                                     | 88  |
|    | 4.5    | Biological Methods                                   | 89  |
| 5. | Soil I | Nutrient Availability and Acidity                    | 93  |
|    |        | hroth, J. Lehmann and E. Barrios                     |     |
|    | 5.1    | Synopsis   | 93  |
|    | 5.2    | Methods for Soil Nitrogen                            | 104 |
|    | 5.3    | Methods for Soil Phosphorus                          | 112 |
|    | 5.4    | Methods for Soil Sulphur                             | 121 |
|    | 5.5    | Methods for Potassium, Calcium and Magnesium in Soil | 125 |
|    | 5.6    | Methods for Soil Acidity                             | 127 |
| 6. |        | mposition and Nutrient Supply from Biomass           | 131 |
|    | G. Sci |  |     |
|    | 6.1    | Synopsis   | 131 |
|    | 6.2    | Methods for Biomass and Nutrient Input with Litter   | 140 |
|    | 6.3    | Methods for Decomposition and Nutrient Release from  | 143 |
|    |        | Biomass  |     |
|    | 6.4    | Measures of Resource Quality                         | 148 |
| 7. | Nutri  | ent Leaching   | 151 |
|    | J. Leh | mann and G. Schroth                                  |     |
|    | 7.1    | Synopsis   | 151 |
|    | 7.2    | Methods for Soil Solution Composition                | 158 |
|    | 7.3    | Tracer Methods for Nutrient Leaching                 | 163 |
|    | 7.4    | Dyes as Tracers for Preferential Flow Paths          | 165 |
| 8. | Nutri  | ent Capture  | 167 |
|    |        | hroth and J. Lehmann                                 |     |
|    | 8.1    | Synopsis   | 167 |
|    | 8.2    | Tracer Methods for Nutrient Uptake                   | 174 |

Contents

| 9.  |                                | ent Exchange with the Atmosphere                                   | 181 |
|-----|--------------------------------|--|-----|
|     |                                | hroth and J. Burkhardt   |     |
|     | 9.1                            | Synopsis   | 181 |
|     | 9.2                            | Methods for Atmospheric Nutrient Inputs                            | 185 |
|     | 9.3                            | Methods for Nutrient Losses from Burning                           | 188 |
| 10. | Soil S                         | Structure  | 191 |
|     | M. G                           | rimaldi, G. Schroth, W.G. Teixeira and B. Huwe                     |     |
|     | 10.1                           | Synopsis   | 191 |
|     | 10.2                           | Methods for Soil Bulk Density                                      | 195 |
|     | 10.3                           | Methods for Aggregate Stability                                    | 196 |
|     | 10.4                           | Methods for Soil Porosity and Pore Size Distribution               | 198 |
|     | 10.5                           | Measuring the Role of Soil Organic Matter in Aggregate Stability   | 204 |
|     | 10.6                           | Soil Micromorphology and Image Analysis                            | 207 |
| 11. | Soil V                         |  | 209 |
|     | W.G.                           | Teixeira, F.L. Sinclair, B. Huwe and G. Schroth                    |     |
|     | 11.1                           | Synopsis   | 209 |
|     | 11.2                           | Methods for Soil Water Content                                     | 215 |
|     | 11.3                           | Methods for Soil Water Potential                                   | 221 |
|     | 11.4                           | Methods for Soil Hydraulic Properties                              | 225 |
|     | 11.5                           | Estimating Topsoil and Subsoil Water Use with Stable               | 232 |
|     |                                | Isotopes   |     |
| 12. | Root                           | Systems  | 235 |
|     | G. Sch                         | iroth  |     |
|     | 12.1                           | Synopsis   | 235 |
|     | 12.2                           | Methods for Studying Root Distribution                             | 240 |
|     | 12.3                           | Distinction of Roots of Different Species                          | 245 |
|     | 12.4                           | Methods for Root Dynamics, Production and Turnover                 | 246 |
| 13. | . Biological Nitrogen Fixation |  | 259 |
|     | K.E.                           | Giller   |     |
|     | 13.1                           | Synopsis   | 259 |
|     | 13.2                           | Microbiological Methods for Studying Rhizobia                      | 265 |
|     | 13.3                           | Simple Methods for Determining Whether a Legume is Fixing Nitrogen | 265 |
|     | 13.4                           | Isotope-based Methods for Measurement of Nitrogen Fixation         | 266 |
|     | 13.5                           | Estimating Nitrogen Fixation in Field Settings                     | 268 |
|     | 13.6                           | Methods Based on Nitrogen Fixation Transport Products              | 269 |
|     | 13.7                           | Estimating Total Amounts of Nitrogen Fixation                      | 270 |

viii Contents

| 14  | Myco                                     | arrhizas  | 271 |
|-----|--|---|-----|
|     | Mycorrhizas D.L. Godbold and R. Sharrock |   | 4,1 |
|     | 14.1                                     | Synopsis  | 271 |
|     | 14.2                                     | Inoculation Methods                                   | 280 |
|     |  | Sampling of Plant Roots for Mycorrhizal Studies       | 281 |
|     | 14.4                                     |   | 281 |
|     | 14.5                                     | Identification of Mycorrhizal Fungi                   | 283 |
|     | 14.6                                     | Estimation of Mineral Nutrient Uptake Through         | 286 |
|     |  | Mycorrhizas   |     |
| 15. | Rhizo                                    | osphere Processes                                     | 289 |
|     | D. Jon                                   | nes   |     |
|     | 15.1                                     | Synopsis  | 289 |
|     | 15.2                                     | Obtaining a Representative Sample of Rhizosphere Soil | 294 |
|     | 15.3                                     | Methods for Rhizosphere Soil Chemistry                | 297 |
|     | 15.4                                     | Methods for Rhizosphere Biological Activity           | 298 |
|     | 15.5                                     | Quantification of Root Carbon Loss into the           | 300 |
|     |  | Rhizosphere   |     |
|     | 15.6                                     | Rhizosphere Mathematical Modelling                    | 300 |
| 16. | Soil I                                   | Macrofauna  | 303 |
|     | P. Lar                                   | velle, B. Senapati and E. Barros                      |     |
|     | 16.1                                     | Synopsis  | 303 |
|     | 16.2                                     | Sampling of Macrofauna: the TSBF Methodology          | 318 |
|     | 16.3                                     | Other Sampling Methods                                | 320 |
|     | 16.4                                     | Manipulative Experiments                              | 322 |
| 17. | Soil I                                   | Erosion   | 325 |
|     | M.A.                                     | McDonald, A. Lawrence and P.K. Shrestha               |     |
|     | 17.1                                     | Synopsis  | 325 |
|     | 17.2                                     | Quantitative Methods                                  | 336 |
|     | 17.3                                     | Qualitative Methods                                   | 341 |
| Ref | ferenc                                   | es  | 345 |
| Ind | lev                                      |   | 493 |