Open Geospatial Data for Sustainability

Exploring and visualising with R

Richard T Cooper

Disclaimer: The author updated all information before publication, but online links may change and code may require adjustments as software and datasets evolve. While every effort has been made to ensure the accuracy of the book, occasional errors may remain due to its length and technical nature, and feedback is welcome to improve future editions.

First edition: December 2025

ISBN: 9798268144918

Publisher: Richard T Cooper

Websites:
https://sustainableos.international
https://www.linkedin.com/in/richardtcooper

Front cover image: Mekong delta, Vietnam (Sentinel-2 quarterly mosaics)
Back cover image: Tonle Sap, Cambodia (WorldCover annual cloudless mosaic)
Source: Images downloaded from https://dataspace.copernicus.eu/browser/

Contents

Abbreviations **xiii**

Preface **xv**

Introduction **1**

1 Coding in R with RStudio **5**
1.1 Introduction . . . 5
1.2 Installing RStudio Desktop . . . 5
1.2.1 Windows installation . . . 6
1.2.2 Linux installation . . . 6
1.3 Introduction to RStudio Desktop . . . 8
1.3.1 Running R code . . . 9
1.3.2 Installing R packages . . . 10
1.4 Getting started with coding in R . . . 11
1.4.1 Data types . . . 11
1.4.2 Data structures . . . 12
1.4.3 Geospatial R packages . . . 17
1.4.4 PS/EPS and PDF outputs . . . 17
1.4.5 Saving variables in RDS format . . . 18

2 Boundaries **21**
2.1 Introduction . . . 21
2.2 Prerequisite R setup . . . 21
2.3 Administrative boundaries . . . 23
2.3.1 geoBoundaries Global Administrative Database . . . 23
2.4 Shorelines . . . 32
2.4.1 OpenStreetMap . . . 32
2.4.2 GSHHG database . . . 36
2.4.3 Global Shoreline Vector (GSV) . . . 39
2.5 Maritime boundaries . . . 44
2.5.1 Marine Regions Databases . . . 44

3 Forests **55**
3.1 Introduction . . . 55
3.2 Prerequisite R setup . . . 55
3.3 Global Forest Change (2000–2023) . . . 57
3.3.1 Tree canopy cover in 2000 . . . 57

3.3.2 Tree cover loss (2001–2023) . . . 60
3.3.3 Tree cover gain (2000–2012) . . . 64
3.3.4 Tree cover loss in Cambodia . . . 67
3.4 Global Land Cover and Land Use Change (2000–2020) . . . 73
3.4.1 Retrieve and read in data . . . 74
3.4.2 Plot forest and LCLUC map . . . 75
3.5 Tropical Tree Cover (2020) . . . 79
3.5.1 Tropical Tree Cover in Siem Reap municipality (2020) . . . 80
3.5.2 Tropical Tree Cover in Nokor Thum commune (2020) . . . 83
3.6 Spatial Database of Planted Trees . . . 86
3.6.1 Retrieve the SDPT dataset . . . 86
3.6.2 Planted trees in Cambodia . . . 88
3.6.3 Planted trees in Ratanakiri province overlaid with forest loss by year since 2000 . . . 90
3.7 ESA WorldCover (2020, 2021) . . . 94
3.7.1 Plot land classes in Battambang municipality . . . 95

4 Rivers and Drainage Basins **101**
4.1 Introduction . . . 101
4.2 Key datasets . . . 101
4.2.1 GRDC Major River Basins of the World . . . 101
4.2.2 HydroBASINS (HydroSHEDS) . . . 102
4.2.3 Copernicus DEM . . . 103
4.2.4 OpenStreetMap . . . 103
4.3 Considerations for visualising 2D and 3D maps . . . 104
4.3.1 Addressing computer memory needs . . . 104
4.3.2 Prerequisite R setup . . . 106
4.4 Visualising the Chao Phraya River basin . . . 108
4.4.1 Create river basin boundary . . . 108
4.4.2 Create DEM of river basin . . . 110
4.4.3 2D and 3D mapping of the Chao Phraya River basin . . . 114
4.5 Visualising nested subbasins of the Chao Phraya River basin . . . 132
4.5.1 Create DEM of CPRB level-6 subbasin . . . 132
4.5.2 Retrieve OSM features . . . 137
4.5.3 3D rendering of Chiang Mai subbasin (level-6 HydroBASINS) . . . 139
4.5.4 3D rendering of Chiang Mai subbasin (level-7 HydroBASINS) . . . 151

5 Mangroves **161**
5.1 Introduction . . . 161
5.2 Key datasets . . . 161
5.2.1 Global Mangrove Watch . . . 161
5.2.2 Mangrove Frontal Genus Distribution . . . 162
5.3 Prerequisite R setup . . . 162
5.4 Mangrove mapping . . . 164
5.4.1 Retrieve boundaries of interest . . . 164
5.4.2 Retrieve Global Mangrove Watch data . . . 166
5.4.3 Retrieve OpenStreetMap map tiles . . . 167
5.4.4 Create raster of permanent mangrove extent (1996–2020) . . . 168

5.4.5 Create raster of mangrove loss and gain (1996–2020) . . . 169
5.4.6 Plot mangroves along the Samut Sakhon coastline . . . 170
5.4.7 Plot mangroves at the mouth of the Tha Chin River . . . 174
5.5 3D visualisation of coastline . . . 177
5.5.1 3D rendering with Copernicus DEM . . . 178
5.6 Frontal mangrove genera . . . 186
5.6.1 Frontal dominant genera by ecoregion . . . 187
5.6.2 Frontal dominant genera in Southeast Asia . . . 189

6 Biodiversity Conservation 197
6.1 Introduction . . . 197
6.2 Key datasets . . . 199
6.2.1 OpenStreetMap . . . 199
6.2.2 WDPA/WDOECM . . . 199
6.2.3 Ecoregions dataset . . . 199
6.3 Prerequisite R setup . . . 200
6.4 Protected areas and national parks . . . 202
6.4.1 Orthographic map projections . . . 202
6.4.2 Cambodia . . . 208
6.4.3 Indonesia . . . 225
6.5 Ecoregions . . . 242
6.5.1 Ecoregions of Cambodia . . . 242
6.5.2 Representativeness of ecoregions . . . 246

7 Infrastructure 253
7.1 Introduction . . . 253
7.2 Key datasets . . . 253
7.2.1 OpenStreetMap . . . 253
7.2.2 GRIP dataset . . . 254
7.2.3 Global Power Plant Database (GPPD) . . . 254
7.3 Prerequisite R setup . . . 255
7.4 Transportation . . . 256
7.4.1 Roads . . . 256
7.4.2 Railways . . . 268
7.5 Energy . . . 274
7.5.1 Power plants of the BMR (OSM) . . . 275
7.5.2 Power generators (OSM) . . . 280
7.5.3 Solar power plants (OSM and GPPD) . . . 284
7.6 Water . . . 288
7.6.1 Visualising the canal network of Cambodia . . . 288

8 Land Cover and Land Use 299
8.1 Introduction . . . 299
8.2 Key datasets . . . 299
8.2.1 Global 30-meter Land-Cover Dynamics Dataset (GLC_FCS30D) . . . 300
8.3 Prerequisite R setup . . . 301
8.4 Land cover change mapping . . . 302
8.4.1 Visualising relevant raster tiles . . . 303

8.4.2 Importing the GLC_FCS30D colour table . . . 309
8.4.3 Visualising land cover data for Chiang Mai . . . 310
8.4.4 Changes in land cover by watershed and province . . . 321
8.4.5 Changes in forest and impervious surface area by district . . . 333

9 Floods and Droughts 355
9.1 Introduction . . . 355
9.2 Key datasets . . . 356
9.2.1 GloFAS: Global river flood hazard return period maps . . . 356
9.2.2 Global high-resolution drought indices (SPEI-HR) . . . 356
9.3 Prerequisite R setup . . . 357
9.4 Flood mapping . . . 359
9.4.1 Flood hazard extent . . . 359
9.4.2 Flood hazard extent and depth . . . 365
9.4.3 Flood exposure of road infrastructure . . . 369
9.5 Drought mapping . . . 379
9.5.1 Global high-resolution drought indices . . . 379

10 Fires 399
10.1 Introduction . . . 399
10.2 Key datasets . . . 400
10.2.1 NASA FIRMS Fire data . . . 400
10.2.2 MODIS Burned Area Product . . . 400
10.3 Prerequisite R setup . . . 401
10.4 Mapping fires with NASA FIRMS . . . 402
10.4.1 Download FIRMS data . . . 402
10.4.2 Plotting FIRMS historical fire data . . . 404
10.5 Visualising MODIS Burned Area monthly data . . . 421
10.5.1 Download GeoTIFF version of MCD64A1 data . . . 421
10.5.2 Plot cumulative burned area . . . 421

Index 431