

The Urban Book Series

Uznir Ujang
Ram Narayan Yadava *Editors*

Innovations in Geospatial Technology for Sustainable Smart City Development

 Springer

The Urban Book Series

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Uznir Ujang • Ram Narayan Yadava
Editors

Innovations in Geospatial Technology for Sustainable Smart City Development

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About the Editors

Uznir Ujang is an Associate Professor at the Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia (UTM), where he also leads the 3D GIS Research Group. As a member of this esteemed faculty, ranked No. 1 in Malaysia and among the top 100 in the world for built environment by the QS World University Rankings 2025, he plays a key role in advancing research and innovation in the field of spatial science. UTM, a leading government-funded institution in Malaysia, attests to its excellence by securing the top spot in the country's engineering and technology rankings. Prof. Uznir's distinguished career is highlighted by his diverse affiliations and outstanding contributions. In addition to his academic role, he holds a prestigious position on the Malaysia Board of Technologists (MBOT), underlining his recognition as a technologist. Furthermore, he is a dedicated member of the Royal Institution of Surveyors Malaysia (RISM), showcasing his commitment to the geospatial profession. He is also a valued member of the Institute of Geospatial and Remote Sensing Malaysia (IGRSM) and contributes his expertise to the global geospatial community. His influence extends beyond Malaysia, as he actively engages with international organizations. His active participation extends to the International Society of Photogrammetry, Remote Sensing, and Spatial Science (ISPRS), where he collaborates with international peers and experts. Prof. Uznir's expertise spans a wide range of research domains in spatial applications. He has made significant strides in 3D city modeling, 3D geographic information systems (GIS), smart cities, building information modeling (BIM), topology, and spatial data structures. His work not only enriches academic knowledge but also finds practical applications in various industries. His innovative thinking and research have earned him significant recognition. He holds 12 intellectual properties (IP), including patents and copyrights, a testament to his ability to generate novel solutions that push the boundaries of spatial science. Beyond his academic and professional roles, Prof. Uznir is at the forefront of advanced research projects in 3D city modeling and applications, contributing to our understanding of urban environments and their practical implications. His substantial contributions to the academic community are evident in his authorship of over 100 scholarly articles, many of which have been published in highly regarded international journals and presented at prestigious

conferences. His work has garnered more than 1000 citations and an h-index of 18, underscoring his active and influential role in the scientific community. In summary, Prof. Uznir Ujang is a leading authority in the realm of spatial science, known for his dedication, expertise, and profound impact. His commitment to academic and professional excellence, coupled with innovative research, positions him as a prominent figure in the world of 3D GIS and related spatial applications.

Ram Narayan Yadava holds the position of Advisor (Research and International Affairs) at Mansarovar Global University, Madhya Pradesh, India. He has worked as an advisor of the AISECT Group of Universities and a founding Vice Chancellor of the AISECT University, Hazaribag (Jharkhand), India. Prof. Yadava is also a founding member of a premier scientific research organization named Advanced Materials and Processes Research Institute (AMPRI) under the umbrella of the Council of Scientific and Industrial Research (CSIR), India. His research interests include solid mechanics, environmental quality and water resources, hydrologic modeling, environmental modeling, and R&D planning and management. Dr. Yadava has executed a variety of research/consultancy projects in the areas of water resources planning and management, environment, remote sensing, mathematical modeling, and technology forecasting. He has adequate experience in establishing institutes/organizations. In addition, he has adequate experience in planning, formulating, executing, and managing R&D programs, including organizing seminars, symposia, conferences at national and international levels. He has guided a number of M. Tech. and Ph.D. students in the areas of mathematical sciences and Earth sciences. Dr. Yadava has visited and delivered invited lectures at different institutes/universities in India as well as abroad, including the USA, Canada, UK, France, Thailand, Germany, South Korea, Malaysia, Singapore, South Africa, Costa Rica, The Netherlands, France, China, Tunisia, and Australia. He is a recipient of Raman Research Fellowship and other awards. Dr. Yadava has been recognized for four decades of leadership in research and service to the hydrologic, environmental, and water resources profession. Dr. Yadava's contribution to the state of the art has been significant in many different specialty areas, including water resources management, environmental sciences, irrigation science, soil and water conservation engineering, and mathematical modeling. He has published more than 100 journal articles, 4 textbooks, and 16 edited reference books. He is a reviewer of scientific journals and a member of the scientific committee of international conferences. He also holds the position of President of the Intellectual's Association of Water, Environment, Energy, and Society (IAWEES).

Introduction

Contents

Introduction

Geospatial Technology in the Smart City Paradigm	3
Uznir Ujang and Ram Narayan Yadava	
1 Introduction to Smart Cities and Geospatial Technology	3
2 Understanding Smart Cities: Definitions, Components, and Global Perspectives	6
3 Geospatial Frontiers in Redefining Urban Environments	9
4 Objectives of the Book	11
5 Connecting Communities Across Disciplines	12
6 Mapping the Journey: Section Highlights and Themes	14
7 Interdisciplinary Lens in Smart Cities	15
8 Addressing the Complex Challenges of Modern Cities	18
9 Expert Insights on Geospatial Technologies and Smart City Development	22
10 Relevance and Impact of Geospatial Technology	24
11 Future Outlook	27
12 Summary	30
References	30

Smart Cities: A Paradigm Shift

Spatial Data Sharing in Smart Cities Implementation: A Systematic Literature Review	41
Zakri Tarmidi	
1 Introduction	41
2 Background of Study	42
2.1 Key Challenges in SDI Implementation in Smart City Initiatives	42
2.2 Studies on SDI Integration in Smart City Development	43
3 Methodology	44

4	Results.	46
4.1	General Characteristics of Selected Literature.	46
4.2	Findings From Selected Articles	47
5	Discussion.	53
6	Conclusion	55
7	Recommendation	55
	References.	56

Exploring the Use of Geospatial Technologies to Enhance Sustainable Bungalow Design for Smart Urban Development 59

Suzanah Abdullah, Ernieza Suhana Mokhtar, Izrahayu Che Hashim,
Haslina Hashim, Muhammad Aiman Khairil Nazri,
and Muhammad Aqmar Darwisy Muhammad Risham

1	Introduction.	59
2	Literature Review	60
2.1	Role of Geospatial Technology in Promoting Eco-Friendly Practices and Modern Construction Methods for Sustainable Bungalow Design in Smart Urban Development.	60
2.2	Geospatial Technology for Efficient and Sustainable Bungalow Design in Smart Urban Development	61
2.3	Using Geospatial Technology for Sustainable Bungalow Design with Green Infrastructure and Environmental Focus in Smart Urban Development.	62
3	Method and Materials	63
3.1	Elements of Modern Bungalow Design Concept.	63
3.2	Interior Elements	64
3.3	Exterior Elements.	66
4	Finding and Discussion.	68
5	Conclusion	68
	References.	69

Advancements in Geospatial Data Utilization: Driving Smart City Innovations and Sustainable Urban Management. 73

Bharath Haridas Aithal, Aniruddha Khatua, and Apratim Bhattacharya

1	Introduction.	73
2	Context	75
3	Image Classification Through Deep Learning	76
3.1	Object Detection.	77
3.2	Segmentation	79
4	Deep Learning in Extracting Vector Features from Remotely Sensed Images.	81
4.1	Georeferencing.	81
4.2	Image Digitization	83
4.3	Feature Extraction	84

5	Example Case Studies on Real-World Explanations	84
5.1	Case Study: YOLOV8 and SAM for Building Feature Extraction and Categorization	84
5.2	Case Study: Deep Learning-Based Automation for Rooftop Solar Potential Estimation Using High-Resolution UAV Data	89
6	Results and Discussion	91
7	Conclusion	93
	References	93
	Graph Database and GIS Integration for Infrastructure Asset Information Management in Smart Cities	97
	Muhammad Syafiq, Suhaibah Azri, and Uznir Ujang	
1	Introduction	97
2	Overview of Graph Databases for Smart Cities	98
3	Uses of Graph Database for Infrastructure Assets in Smart Cities	100
3.1	Indoor Navigation	100
3.2	Route Planning	104
3.3	Management of Building Information	105
4	Smart Cities Data Management Using Graph Database	108
5	Key Considerations in Graph Database Implementation for 3D City Models	109
6	Conclusion	112
	References	113
	Understanding the Key Features of Urban Mobility for Sustainable Smart Cities	117
	Zaharah Mohd Yusoff, Fazzami Othman, Nor Aizam Adnan, Uznir Ujang, and Adzlia N. Abd Rahman	
1	Introduction	117
2	Issues of Urban Mobility in Asian Cities	118
2.1	Scarcity of Urban Space	119
2.2	Traffic Congestions	120
2.3	Air Pollutions	121
3	The Features of Smart Urban Mobility	121
3.1	Mobility in Smart City Planning of Copenhagen, Denmark, and Portland, USA	122
4	Smart City Spatial Data Analysis	123
4.1	Spatial Network	124
4.2	Space Syntax and Its Roles in Urban Planning	125
5	Case Study	128
5.1	Case Study 1: Using Space Syntax for Revitalizing Historic Urban Areas—China	128
5.2	Case Study 2: Spatial Network Analysis for Urban Mobility—Medellín, Colombia	129
5.3	Case Study 3: Origin-Destination Analysis for TOD—Singapore. . .	130
6	Summary	131
	References	131

Enhancing Smart City Infrastructure with GNSS-Based Cadastral Reference Marks	135
N. G. K. Earn, A. H. M. Din, M. H. Hamden, and M. L. A. Affandi	
1 Introduction.	135
2 Data and Methods.	138
2.1 Principle and Concept of CRM Distribution	139
2.2 Field Equipment Setup.	139
2.3 Rapid Static GNSS Observation	139
2.4 Fieldwork for Ordinary Levelling and GNSS Heighting	140
2.5 Geoid Model Acquired from DSMM.	144
2.6 GNSS Data Processing.	145
2.7 Conventional Survey Data Processing	145
2.8 Formal Error: GNSS vs Conventional Survey	148
2.9 Theoretical Methodology vs Practicable Result	148
3 Result and Discussion.	149
3.1 Rapid Static Post-Processing	149
3.2 New Geographical and Cartesian Coordinates.	151
3.3 <i>Orthometric</i> Height using GNSS Levelling.	152
3.4 Formal Error: Conventional vs GNSS Observation.	154
3.5 Theoretical Methodology vs Practicable Result	156
4 Conclusion	158
References.	159

Geospatial Data Acquisition and Analysis

Coastal Erosion Assessment Using Three-Dimensional Octree-Duality Voxel Data Structure	165
Nurfairunnajiha Ridzuan and Uznir Ujang	
1 Introduction.	165
1.1 Overview of Coastal Erosion	165
1.2 Importance of Coastal Erosion Assessment	166
1.3 Role of GIS in Coastal Erosion Monitoring.	166
2 Geospatial Solutions for Smart Cities and Sustainable Development	168
2.1 Integrating Geospatial Solutions	168
2.2 Smart Cities and Sustainability	169
3 Coastal Erosion: Causes and Impacts	169
3.1 Natural Factors: Waves, Tides, Storm Surges, and Sea Levels	169
3.2 Climate Change Effects on Coastal Erosion	170
3.3 Socioeconomic and Environmental Impacts	170
4 Geographic Information System (GIS) in Coastal Monitoring.	170
4.1 GIS Capabilities for Spatial Data Handling.	171
4.2 Overview of GIS-Based Techniques	172
5 Three-Dimensional (3D) Octree-Duality Voxel Data Structure (ODVDS)	173
5.1 Introduction to 3D ODVDS	173
5.2 Octree and Duality Concept.	174
5.3 Voxel Concept for Volume Calculation	174

6 Data Acquisition and Processing 175

6.1 Obtaining Sentinel 2 Satellite Imagery 175

6.2 Data Processing Techniques..... 176

6.3 Conversion to 3D Perspective 176

7 Volume-Based Coastal Erosion Assessment..... 178

7.1 Creating and Computing the 3D Model of Coastal Areas Using
3D ODVDS 178

7.2 Comparison of Volumetric Models Over Time 178

8 Case Study: Volume-Based Assessment of Coastal Erosion
in Batu Ferringhi, Malaysia 179

8.1 Study Area Selection 180

8.2 Implementation of 3D ODVDS 180

8.3 Analysis of Results..... 181

9 Mitigation Strategies for Coastal Erosion..... 182

9.1 Selection of Appropriate Mitigation Strategies 182

9.2 Integration of GIS-Based Techniques 182

10 Conclusion 183

10.1 Summary of Findings..... 183

10.2 Future Directions in Coastal Erosion Mitigation..... 183

References..... 184

**Spatial Intelligence for Efficient High-Rise Building Maintenance
and Repair 189**

Usman Mehmood, Uznir Ujang, Suhaibah Azri, and Tan Liat Choon

1 Introduction to High-Rise Building Maintenance..... 189

1.1 Importance of Proactive Maintenance for High-Rise Buildings 190

1.2 Limitations of Traditional Reactive Maintenance Strategies..... 191

2 Understanding Spatial Data in Building Management 193

2.1 Types and Sources of Spatial Data..... 194

2.2 Role of GIS in the Maintenance of High-Rise Buildings 195

3 Evolution of Maintenance Strategies 196

4 Practical Applications and Case Studies..... 198

4.1 Real-World Examples of High-Rise Buildings Using Spatial
Data for Maintenance..... 200

4.2 Impact of Spatial Data-Driven Maintenance on Downtime
and Cost Reduction 202

5 Creating a Spatial Data-Driven Maintenance Plan..... 204

6 Emerging Technologies and Future Trends..... 206

6.1 Advancements in AI and Machine Learning for Predictive
Maintenance..... 208

6.2 Future Prospects of Spatial Data in High-Rise Building
Management..... 210

7 Discussion and Conclusion..... 212

References..... 214

Managing Spatiotemporal Evolution of Lifecycle Event in Graph Database for Asset Maintenance 219

Farah Ilyana Hairuddin, Suhaibah Azri, and Uznir Ujang

1 Introduction..... 219

2 Research Background 221

2.1 Spatiotemporal Evolution in Geographical Area 221

2.2 Storing the Evolution of Spatiotemporal Data in a Graph Databas..... 224

2.3 Integrating Blockchain with Graph Databasefor Asset Maintenance..... 226

3 Methodology 227

3.1 Defining Labelled Property Graph Data Structure for Asset Maintenance..... 229

3.2 Developing Asset Lifecycle Event Model in Graph Database..... 230

3.3 Conceptual Framework for Blockchain-Enhanced Asset Lifecycle Event Model..... 231

4 Results and Discussions 234

4.1 Retrieving Asset Lifecycle Event Path in Graph Database 235

4.2 Retrieving Asset Operational States and Maintenance Action Chronology in a Graph Database..... 236

4.3 Benefits and Implications of Blockchain Integration with Asset Lifecycle Event Graph Model 238

5 Future Direction: Leveraging Lifecycle Event of Urban Infrastructure ... 240

6 Conclusion 241

References..... 243

Urban Planning and Geospatial Integration

Living to the Dead Smart Urban Planning: Geospatial Approach for Sustainable Urban Cemeteries Management in Malaysia 249

Norzailawati Mohd Noor, Nurul Syahirah Khir Sabir, and Illyani Ibrahim

1 Introduction..... 249

2 Study Area..... 253

3 The Methodology 254

3.1 Data Collection..... 254

3.2 Pre-processing 255

3.3 Main Processing..... 257

3.4 Post-processing 257

4 Result and Findings..... 258

4.1 Main Processing..... 259

4.2 Discussion on Results 263

5 Conclusion 264

References..... 265

Harnessing Topology for Smart Urban Development: The Connectivity, Containment and Adjacency 269
Syahiirah Salleh, Uznir Ujang, and Suhaibah Azri

1 Introduction. 269

1.1 Overview of Urban Development Challenges 269

1.2 Importance of Sustainable Urban Growth 270

2 Understanding Topology. 271

2.1 Definition and Principles of Topology 271

3 Urban Spatial Interactions and Topology 276

3.1 Challenges in Urban Systems Spatial Interactions. 276

3.2 Role of Topology in Describing Urban Spatial Interactions 277

4 Vertical Growth and Connected Spaces 279

4.1 Addressing Vertical Growth Using Topology 280

4.2 Topological Insights for Connected Spaces 282

5 Topology-Driven Spatial Equity and Inclusivity in Urban Planning 282

5.1 Challenges in Achieving Spatial Equity and Inclusivity 282

5.2 Applying Topology for Spatial Equity and Inclusive Urban Development 283

6 Conclusion and Outlook 284

6.1 Utilising Topology for Sustainable Urban Planning and Design 285

6.2 Future Directions for Topological Urban Design and Planning. 286

References. 286

Enhancing Building Material Classification in Smart City Through Neural Network Technology. 289
Yang Jiao and Suhaibah Azri

1 Introduction. 289

2 AI Applications in Urban Planning and Development 291

2.1 Overview of AI in Urban Planning 291

2.2 Predictive Modeling and Scenario Analysis for Infrastructure Optimization. 292

2.3 Integration with Building Material Classification 293

3 Overview of AI-Based 3D Point Cloud Classification Method 294

3.1 Point Cloud and Challenges in Deep Learning Application 294

3.2 PointNet Architecture. 295

3.3 PointNet++ Architecture 296

4 Point Cloud Segmentation and Classification. 297

4.1 Data Preparation. 297

4.2 Set Up the Environment 298

4.3 Model Training. 299

4.4 Strategies to Improve Model Accuracy 300

5 Building Insulation Calculation 302

5.1 Segmentation of the Point Cloud Based on Color 302

5.2 U- and R-Value Calculation 302

6 Conclusion 305

7 Limitation & Recommendation 305

References. 306

Geospatial-Species: Amphibian Amidst Urban Expansion 309
Nurul Hazlina Acheh, Siti Nurbaidzuri Reli, Ramlah Zainudin,
Madinah Adrus, and Siti Nurlydia Sazali

1 Introduction 309

2 Methods 312

2.1 Data Collection and Analysis 312

3 Result and Discussion 312

3.1 Geospatial Species Mapping and Habitat Preference 313

4 Concluding Remarks 319

5 Recommendations 319

References 319

Sustainable Resource Management

Geospatial Approaches for Managing Water-Related Disasters 323
Aida Soraya Shamsuddin, Nurfashareena Muhamad,
Nur Maizatul Idayu Othman, Aziemah Zulkifli, Nuriah Abd Majid,
Lee Khai Ern, Goh Choo Ta, and Sharifah Norkhadijah Syed Ismail

1 Introduction 323

2 Geospatial Analysis Tools and Techniques 325

3 Understanding Water-Related Disasters in Urban Contexts
and Implications to Sustainable Development Goals (SDGs) 326

4 Applications of Geospatial Analysis in Smart City
Water Management 328

4.1 Risk Assessment and Resilience Planning 328

4.2 Urban Flood Management 329

4.3 Real-Time Monitoring and Early Warning Systems 329

4.4 Drought Management 330

4.5 Infrastructure Planning and Resource Allocation 331

4.6 Other Applications 331

5 Challenges and Opportunities 332

6 Future Directions and Recommendations 333

7 Conclusions 335

References 336

Geospatial Solutions for Public Service Planning in Smart Cities 339
Stephan Mäs and Falko Krügel

1 Introduction 339

2 Related Work 340

2.1 Access and Spatial Accessibility 340

2.2 Methodological Concepts for Measuring Accessibility 341

2.3 Central Places and Analytical Concepts for Urban Planning 343

3 User Groups 343

4	Relevant Data and Analysis Tools.	345
4.1	Service Infrastructure Data	345
4.2	Population Data	345
4.3	Routing and Accessibility	346
5	Examples of Planning Applications	347
5.1	Accessibility Analysis of Central Places	348
5.2	A Multi-Criteria Analysis Web Planning Tool for 15-Minute Cities.	350
5.3	Spatial Accessibility of Health Infrastructures.	353
6	Summary and Conclusion.	356
	References.	358

Environmental Conservation and Resilience

A Scoping Review: Integrating Big Data and GIS Applications in Environmental Science.

Izrahayu Che Hashim, Haslina Hashim, and Suzanah Abdulah

1	Introduction.	363
1.1	Methodology	365
2	Results.	366
2.1	Study Selection.	366
2.2	Included Studies.	367
3	Discussion.	373
3.1	Main Findings	373
3.2	Study Limitations.	376
4	Conclusion	376
	References.	377

The Accuracy Assessment of Mobile Geolocation Data for Urban Tree Inventory

Yi Peng Wang, Nurul Hawani Idris, Mohamad Jahidi Osman,
Nurain Othman, Ami Hassan Md Din, Zamri Ismail, Noor Izawati Alias,
and Mohamad Hafis Izran Ishak

1	Introduction.	381
1.1	The Smart Initiatives in Urban Tree Management.	381
1.2	Existing Methods for Urban Tree Inventory for Carbon Stock Quantification.	383
1.3	Performance of Consumer-Grade Smartphones.	383
2	Methodology.	384
2.1	Research Framework for Analyzing Mobile Geolocation Data Accuracy in Urban Tree Inventory.	384
2.2	Study Area and Sample Selection	386
2.3	Data Collection.	387
2.4	Accuracy Assessment.	389

3	Results and Discussion	393
3.1	Positional Accuracy of Smartphones and GNSS Devices (Comparison)	393
3.2	Correlation Analysis of Euclidean Distance, GNSS Signal Frequency, Time of Day, and Operating System	395
3.3	Evaluating Position Deviation and Outlier Robustness Using MM Estimation: Effects of GNSS Signal Frequency, Time of Day, and Operating System	396
4	Conclusion	398
	References.	399

Optimizing Urban Planning Through Geospatial Insights for Climate and Environmental Sustainability 403

Tehmina Bibi, Adnan Latif, Shehla Gul, Sobia Irum, Yasmeen Gul,
Kiran Hameed, Muhammad Ashfaq, and Fakhru Islam

1	Introduction.	403
2	Urban Dynamics	404
2.1	Urban Development and Climate Change	405
2.2	Urban Planning and Resilience	405
2.3	Urban Sensing	406
3	Geospatial Technologies for Urban Planning	406
3.1	Importance of Geospatial Technology for Urban Development	407
3.2	Impact of Geospatial Technology on Urban Development	407
3.3	Future of Geospatial Technologies in Urban Planning	408
4	Geospatial Technologies and Urban Resilience	408
4.1	Urban Water Resilience	408
4.2	Improved Public Transportation System	409
4.3	Identification of Underserved Areas.	409
4.4	Climate Resilient Structures.	410
4.5	Disaster Mitigation.	410
5	Geospatial Technology and IoT for Urban Planning	410
5.1	Role of Geospatial Technology and IoT in Urban Planning	411
5.2	Smart City Solutions	411
6	GeoAI for Urban Computing	412
6.1	How AI May Revolutionize Urban Planning.	412
6.2	Applications of GeoAI in Urban Computing.	413
6.3	Future of GeoAI in Urban Planning.	413
7	Smart Cities of the World	414
7.1	Components of Smart Cities	414
7.2	Renowned Smart Cities of the World.	414
7.3	Smart Cities in the Future	415
	References.	415

Case Studies: Real-world Applications

Urban Heat Islands' Dynamics and Vegetation Cover Changes' Implications for Urban Sustainability: A Case Study of Facativá Municipality, Colombia 421

Karel Aldrin Sánchez Hernández, Laura Catalina Castiblanco,
and Lady Johana Califa Montano

1	Introduction.	421
2	Case Study	423
3	Materials and Methodology	424
3.1	Estimation of Land Surface Temperature (LST)	425
3.2	Predictors and Downscaling Model	426
3.3	Spatiotemporal Land Use and Land Cover Dynamics Analysis	429
3.4	Urban Heat Island Analysis	430
4	Results.	431
4.1	Correlation and Spatiotemporal Predictors Analysis	431
4.2	Downscaling Model and LST Analysis	435
4.3	Land Use Dynamics Assessment	437
4.4	Urban Heat Island Analysis	441
5	Discussion.	443
6	Conclusions and Recommendations	444
	References.	444

Revolutionizing Infectious Disease Epidemiology in Smart Cities: Geo-AI Modeling for Outbreak Investigation, Prediction, and Control 451

Kurubaran Ganasegeran, Mohd Kamarulariffin Kamarudin, Jeff Blossom,
Nur'ain Mohd Ghazali, and Mohd Rizal Abdul Manaf

1	Introduction.	451
1.1	Innovations in Disease Surveillance.	453
1.2	A Transition from Conventional to Spatial Epidemiology.	453
2	Artificial Intelligence in Infectious Disease Epidemiology	453
3	Geo-Artificial Intelligence Within Smart Cities for Infectious Disease Epidemiology	454
3.1	Surveillance Systems: The Purpose Enhanced.	455
4	Historic Transitions of Human Civilizations and Habitats Alongside Outbreak Emergence	458
4.1	Outbreak Investigations	459
4.2	Case Detection	460
5	Geo-AI Applications and Computational Approaches in Outbreak Investigations	461
5.1	Wastewater-Based Epidemiology in Smart Cities	461
5.2	Case Study 1: Innovative Use of Wastewater Surveillance with GIS at the University of North Carolina	464
5.3	Foodborne Outbreak Investigations Using Spatial-Epidemiological Technologies	467

6	Geo-AI Applications and Computational Approaches in Outbreak Predictions.	468
6.1	Case Study 2: SEIR Applications to COVID-19 in Italy - An Epidemiological Case Analysis	469
6.2	Case Study 3: Geo-Epidemiological Assessment of COVID-19 Spread Using the SEIR Model.	471
6.3	Case Study 4: Geo-Epidemiological Study of COVID-19 Vaccination Rates in Malaysia	474
6.4	Setting the Scene: Geo-Epidemiological Study of Dengue Prediction - The Concepts	475
6.5	Case Study 5: Dengue Outbreak Prediction for Malaysia	478
7	Strengths and Limitations	488
8	Conclusion	490
	References.	491

Integrating Geospatial Solutions for Smart Cities: A Case Study of Landslide Susceptibility Analysis in Penang Island for Sustainable Development 497

Tharshini Murthy, Izham Mohamad Yusoff, Ismail Ahmad Abir, and Chan Huah Yong

1	Introduction.	497
2	Materials and Method	499
2.1	Study Area	499
2.2	Data Acquisition.	500
2.3	Average Nearest Neighbor (ANN).	501
2.4	Landslide Conditioning Factors	502
2.5	Flow Chart	503
3	Results and Discussion	504
4	Conclusion	510
5	Recommendations.	510
	References.	511

The Impact of MRT Development on Land Use Patterns in Cheras, Kuala Lumpur (2010–2020): A Study in Spatial Synergy and Sustainable Urban Development 515

Nuriah Abd Majid, Ruslan Rainis, and Nurzahidah Mohd Zaki

1	Introduction.	515
2	Background.	516
3	Methodology	517
3.1	Classification of Land Use	518
3.2	Case Study: Cheras, Kuala Lumpur.	519
4	Findings and Discussion	523
4.1	Impact of MRT Development	523
4.2	Sustainable Development and Spatial Synergy	527
5	Conclusion	528
	References.	530

Harnessing Geospatial Technologies for Enhancing Urban Mobility and Accessibility: The Case of Autonomous Vehicles. 531

Khaula Alkaabi

1	Overview of Autonomous Vehicles (AVs)	531
1.1	Definition and Evolution of AVs	531
1.2	Timeline of AV Development.	532
1.3	The Impact of AVs on Urban Mobility.	534
2	Geospatial Technologies in Urban Planning.	535
2.1	Geographic Information Systems (GIS).	535
2.2	Remote Sensing	536
2.3	Advancement in Geospatial Technologies.	536
3	Global Advances in Autonomous Vehicles: USA, China, and UAE Initiatives.	539
3.1	Current Landscape of Automated Vehicles in the USA.	539
3.2	China's Advances in Connected and Autonomous Vehicles	540
3.3	The TXAI Ride-Sharing Initiative in Abu Dhabi, UAE.	542
4	Interdisciplinary Collaboration.	543
5	Incorporating Autonomous Vehicles (AVs) into Smart City Framework	544
5.1	Defining Smart City Framework	544
5.2	Role of AVs in Smart Cities	545
5.3	Creating Inclusive and Resilient Urban Landscapes	546
6	Future Directions	547
6.1	Policy and Regulation Consideration.	547
6.2	Long-Term Impact on Urban Mobility	547
7	Conclusion	548
	References.	549

Update, Conclusion and Recommendation

A Vision for Tomorrow's Smart Cities 557

Uznir Ujang and Ram Narayan Yadava

1	Introduction.	557
2	Smart Cities and Global Perspectives.	559
2.1	How Smart Cities Differ from Traditional Cities?.	559
2.2	Key Components of Smart Cities.	559
2.3	The Current Global Status of Smart Cities	560
3	Emerging Trends in Smart Cities	561
3.1	Integration of AI and Machine Learning in Urban Planning.	561
3.2	IoT and Real-Time Data Monitoring	562
3.3	Digital Twins and 3D Urban Simulations	563
3.4	Sustainable Urban Mobility and Smart Transportation	564
3.5	Blockchain for Urban Governance and Land Management.	565

4	Potential Future Scenarios	565
4.1	Scenario 1: Fully Automated Smart Cities.....	566
4.2	Scenario 2: Hyperconnected Citizen-Centric Cities	566
4.3	Scenario 3: Resilient and Climate-Neutral Cities	567
5	Interdisciplinary Collaboration and Policy Frameworks	568
5.1	Aligning Smart Cities with SDG 11: Building Sustainable and Inclusive Urban Futures	568
5.2	Developing Ethical AI Frameworks for Smart City Applications.....	570
5.3	Ensuring Equitable Access to Digital Infrastructure and Geospatial Data	570
5.4	Implementing Strong Cybersecurity Measures to Protect Urban Geospatial Data	571
5.5	Creating Flexible Regulatory Frameworks to Support Emerging Smart City Technologies	571
6	Strategic Recommendations	572
6.1	Enhance Data Integration and Standardization	572
6.2	Invest in Capacity Building and Education	573
6.3	Strengthen Public-Private Partnerships (PPPs)	573
6.4	Emphasize Sustainability and Inclusivity	574
7	Conclusion	575
	References.....	576
	Index.....	581

Smart Cities: A Paradigm Shift

Geospatial-Species: Amphibian Amidst Urban Expansion



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1 Introduction

The order *Anura* encompasses amphibians commonly known as frogs and toads. It is characterised by tailless adults, long hind limbs adapted for jumping, and permeable skin for respiration. *Anura* is one of the most diverse vertebrate groups, with thousands of species distributed globally, except in polar regions and extremely dry deserts (Glime & Boelema, 2017). Amphibians are useful bioindicators of environmental stress, the state of an ecosystem, and alterations within it (Zaghloul et al., 2020). According to Hamer and McDonnell (2008), urbanisation reduces the species richness and abundance of individual amphibian species, which results in habitat loss and an increase in mortality (Smallbone et al., 2011). The causes of the worldwide decreases in amphibians have been a source of intense concern; while many of the theories are controversial, at least some of them can be correlated to illness and susceptibility to altered spectra of solar radiation (Lewis, 2006). Therefore, multiple factors across different spatial scales, from specific breeding sites to entire landscapes, can influence the survival of *anuran* populations within urban environments (Miller, 2008). Several processes that take place in urban and suburban settings, such as habitat loss, fragmentation and isolation, and creation and restoration, have an impact on the quantity and kind of amphibian habitat that is accessible in a landscape. Although higher abundance was sometimes observed in smaller, highly disturbed fragments with low species richness, there was a clear positive relationship between fragment size and *anuran* species abundance. Similarly, studies on fragmentation involving small animals, birds, and

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309

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invertebrates have also shown increased abundance in certain disturbed fragments (Debinski & Holt, 2000).

It has made far-reaching changes in the way researchers and conservationists study on the species distributions. According to Malczewski (2004), the use of GIS evolved when planning viewpoints alterations from scientific to political, process-oriented, and communication-focused to collective-design assessments. Predictive models illustrate habitat distribution and evaluate their suitability and potential for supporting species. It is a robust tool for utilising spatial data, allowing analysis and visualisation of patterns and relationships as well as data management (Rivieccio et al., 2003; Gibson et al., 2004; Johnson & Gillingham, 2005; Ahmad & Pandey, 2018). It is an integrative system that integrates concepts from various fields, such as agriculture, botany, computer science, economics, mathematics, photogrammetry, surveying, zoology, and geography. The two main focuses of most definitions are technology or problem-solving and the traditional understanding of GIS is that it is a collection of tools for handling, manipulating, analysing, and producing spatial data (Malczewski, 2004). According to Danks and Klein (2002), it offers data on animal habitat, habitat assessment, and habitat forecast, all of which are helpful when introducing new species to a given area. The application of this technology eases the analysis and mapping of animal distribution, migration, and habitat patterns, hence offering valuable insights into wildlife management tactics (Gibson et al., 2004). A potent tool for carrying out conservation goals is the species distribution model (Carroll et al., 2001; Raxworthy et al., 2003; Johnson et al., 2004; Johnson & Gillingham 2005). Considering this, the technological viewpoint on GIS highlights four system components: data input, management and storage, data modification and analysis, and data output (Malczewski, 2004). Data input is the collection and conversion of data into a format suitable that includes collecting, reformatting, georeferencing, compiling, and recording data. These systems support a variety of data input methods, including keyboard entry, manual locating devices, automated devices, and data file importing. Furthermore, the establishment of open-access databases and uniform standards for gathering and disseminating data will enhance cooperation between institutions and scholars. Addressing the issues pertaining to global biodiversity and creating large-scale, successful conservation plans require a coordinated approach (Suzzi & Devarajan, 2023). It is thought to be a useful tool for modelling the distributions of a variety of species and charting the patterns of environmental fluctuations by using maps of vegetation types and data of species distribution (Ahmad & Pandey, 2018). Maps of habitats are a useful tool for communications because they show where conservationists should concentrate their efforts to reduce disturbance and human development, or they can be used to help with reserve placement, habitat restoration, and species reintroduction (Johnson & Gillingham, 2005). As an illustration, data on abundance, density, or the presence—absence gathered during surveys for the target species is commonly used to develop habitat appropriateness models (Guisan & Zimmermann, 2000). Advancements in large-scale geographical data, along with the accessibility of GIS, statistical tools,

and enhanced computational power, have significantly enhanced the capacity to model and map important relationships between species and their environments (Rushton 2003). GIS modelling and spatial analysis help us understand the distribution and ecology of *anurans*. Future developments in interdisciplinary collaboration, community engagement, and technology advancements believe that GIS will continue to be an essential part of amphibian biodiversity preservation, which will help to preserve these essential elements of global ecosystems (Newman et al., 2010).

This research study delves into the intricate relationship between urbanisation, tourism development, and the distribution of *anuran* species within a designated tourism zone. As global urbanisation continues to accelerate, particularly in areas designated for tourism, there arises a pressing need to comprehend the ecological consequences of this rapid urban expansion. Amphibians, especially *anurans*, play a crucial role in assessing environmental health, as their heightened sensitivity to habitat alterations and pollution makes them key indicators of ecosystem changes. However, the impact of urbanisation on their populations within tourism zones is notably under-explored. The overarching problem lies in the potential threats posed to *anuran* biodiversity by urban development, including habitat loss, fragmentation, altered microclimates, and exposure to pollutants. The study seeks to address this knowledge gap by investigating the specific ramifications of urbanisation on *anuran* distribution patterns within a tourism area, aiming to provide significant contributions to urban ecology and amphibian conservation. Its findings are intended to support sustainable development initiatives and promote efforts to preserve biodiversity in these vital ecosystems.

These tools help to understand amphibian distribution patterns, preferred habitats, and conservation tactics. This comprehensive examination will touch on habitat modelling, spatial analysis, monitoring, conservation planning, and the difficulties associated with using GIS for species mapping. Geospatial species mapping, using advanced GIS technologies, visualises and analyses spatial relationships between *anuran* populations and their environment. It uses data from data of species sighting during field surveys, remote sensing, and satellite imagery to create detailed maps that reveal the patterns on the habitats in response to urban development. The study aims to determine if specific habitats are compromised or if adaptive mechanisms are in play.

Geospatial species mapping also serves as a foundation for predictive modelling, identifying conservation priorities and informing sustainable urban planning practices. This research enhances our understanding by utilising GIS mapping techniques to create distribution maps and the density of *anuran* species with the delicate interplay between urbanisation and amphibian ecology, promoting insights for preserving biodiversity in urban landscapes. The primary objective is to understand how urban landscape features influence the species distribution and movement. This study focuses on specific urban areas and *anuran* species, aiming to identify critical habitats and corridors that support *anuran* populations.

2 Methods

During the night excursion between 7.00 p.m. and 11.00 p.m., field surveys are conducted to gather data on *anuran* population surveys in the study area, recording species sightings and their corresponding locations using GPS device along selected area at Kuching Waterfront, Sarawak.

2.1 Data Collection and Analysis

The collected data are integrated into ArcGIS software by creating spatial data layers. These layers include points representing *anurans*' locations, polygons showing different habitat types. Geospatial mapping is applied to create spatial representations of each species distribution and their correlation with environmental factors. To visualise geographical correlations, point layers for *anuran* occurrences are created and overlaid them with environmental layers; these layers include points representing locations and polygons showing different habitat types of preference for each species. Maps and visuals were created to represent the *anuran* distribution and kernel density. The procedures were carried out in accordance with the flow chart presented in Fig. 1.

3 Result and Discussion

Anuran sampling activity was conducted during nighttime excursions along the Kuching Waterfront, spanning from 7.00 p.m. to 11.00 p.m. A comprehensive sampling effort revealed a total of 97 individual of *anurans* across four species. The most prevalent species encountered was the Asian Common Toad (*Duttaphrynus*

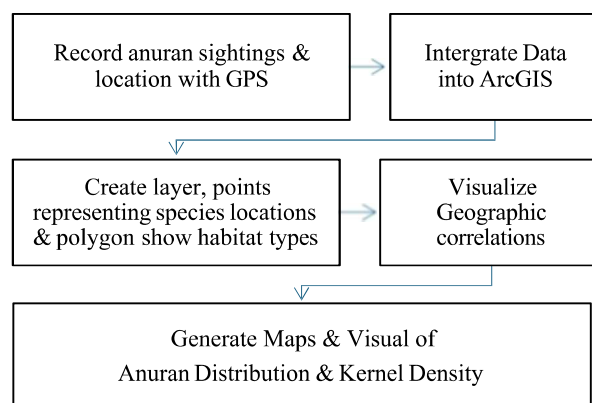


Fig. 1 Flow chart of methodologies for this study

melanostictus), constituting 75 individuals predominantly under resting conditions. In contrast, the Banded Bullfrog (*Kaloula pulchra*) species, comprising 10 individuals, exhibited a preference for polluted areas, often scavenging rubbish and inhabiting humid environments in small groups. Additionally, 11 individuals of the Asian Grass Frog (*Fejervarya limnocharis*) species were documented in muddy fields and a Four-lined Tree Frog (*Polypedates leucomystax*) sighted. Table 1 details the *anurans* discovered at the study sites, while their distribution percentages are illustrated in a pie chart (Fig. 2).

Based on Inger et al. (2017), *D. melanostictus* is a stout species with warty skin, commonly found in disturbed lowland areas such as urban and agricultural zones. *K. pulchra* features a stocky body with dark brown backs and copper-brown stripes, thriving in urban and rural environments and burrowing underground during dry periods. *F. limnocharis* is a small, adaptable frog with a pointed snout, frequently seen in rice paddies, gardens, and forest clearings. *P. leucomystax* is an arboreal species with variable coloration, inhabiting forest edges, wetlands, and semi-urban areas, where it breeds in shallow pools with foam nests. These species exhibit notable adaptability to diverse habitats.

3.1 Geospatial Species Mapping and Habitat Preference

Sampling at nighttime is particularly effective for amphibians, as many species are nocturnal and more active during these hours. This method ensures a higher likelihood of encountering various species and observing their natural behaviours. The

Table 1 Number of *anurans* sighted

Common names	Scientific names	Total individuals
Asian Common Toad	<i>Duttaphrynus melanostictus</i>	75
Banded Bullfrog	<i>Kaloula pulchra</i>	10
Asian Grass Frog	<i>Fejervarya limnocharis</i>	11
Four-Lined Tree Frog	<i>Polypedates leucomystax</i>	1

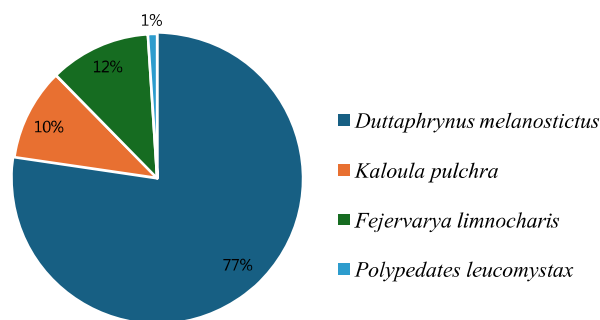


Fig. 2 Distribution percentages of *anurans* recorded along the study area

comprehensive sampling effort revealed a total of 97 individual of *anurans* across various species, providing a robust dataset for analysis. The most prevalent species encountered was *D. melanostictus*, with 75 individuals predominantly found under resting conditions. This high prevalence suggests that the Kuching Waterfront provides suitable resting habitats for this species, likely due to the availability of shelter and food resources. The dominance of this species indicates its adaptability to urban environments. Its presence under resting conditions suggests that it utilises the waterfront's sheltered areas for refuge. *K. pulchra* comprising 10 individuals, exhibited a preference for polluted areas, often scavenging rubbish and inhabiting humid environments in small groups. This behaviour indicates a tolerance for disturbed habitats and a potential role in urban waste management by scavenging. *F. limnocharis* mostly documented in muddy fields, this species' preference for such environments highlights its need for moist, muddy habitats that are essential for its breeding and feeding activities. The sighting of *P. leucomystax* shows that this species can be found in disturbed habitats, which are closely associated with human settlement. Figures 3 and 4 display the composition of specific zones within the study area, offering a visual representation for each zone. The collected data are then generated into distribution and kernel density maps by using ArcMap.



Fig. 3 Selected zones for study area along the Kuching Waterfront, Sarawak

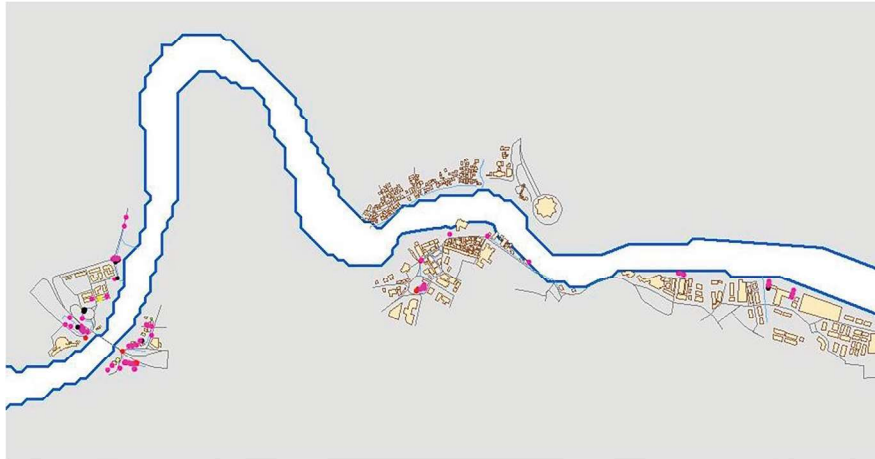


Fig. 4 Visualisation of the selected zones for study area along Kuching Waterfront, Sarawak

Based on the visual representation provided by the distribution map (Fig. 5), the locations of various *anuran* species are plotted. The presence of each of the different species highlights their respective ranges and habitat preferences. The results indicate that most *anuran* species are concentrated around water bodies, underscoring their reliance on these habitats. This concentration also suggests a high adaptability to varying degrees of habitat fragmentation and connectivity. The observed distribution patterns imply that disturbances, such as anthropogenic activities, can have both positive and negative impacts on species populations (Rubenina et al., 2021). Positive effects may include the creation of new habitats or resources, while negative effects could involve habitat destruction and increased pollution. These findings emphasise the need for careful management of urban environments to support amphibian biodiversity.

According to the kernel density map of *anuran* distribution (Fig. 6), Zone A (Fig. 3) recorded approximately 288 tourists and showed the highest *anuran* densities, represented by the darkest red areas on the map. Zone B (Fig. 3), with 301 tourists recorded, also exhibited considerable *anuran* densities, although slightly lower than those in Zone A. Zone C (Fig. 3), where 666 tourists were recorded, displayed the lowest *anuran* densities. The reduced number of *anuran* observations in Zone C could be linked to factors associated with increased tourist activity in the area. According to Morrison et al. (2012), the combination of habitat disturbance, pollution, noise, light pollution, and increased predation likely contributes to the low *anuran* density in areas with high tourist activity. These factors create an environment that is less conducive to anurans survival and reproduction, leading to reduced sightings in such areas. This map helps to visualise the relationship between *anuran* density and tourist activity, highlighting areas where frog and toad populations are thriving despite the moderate tourist presence and

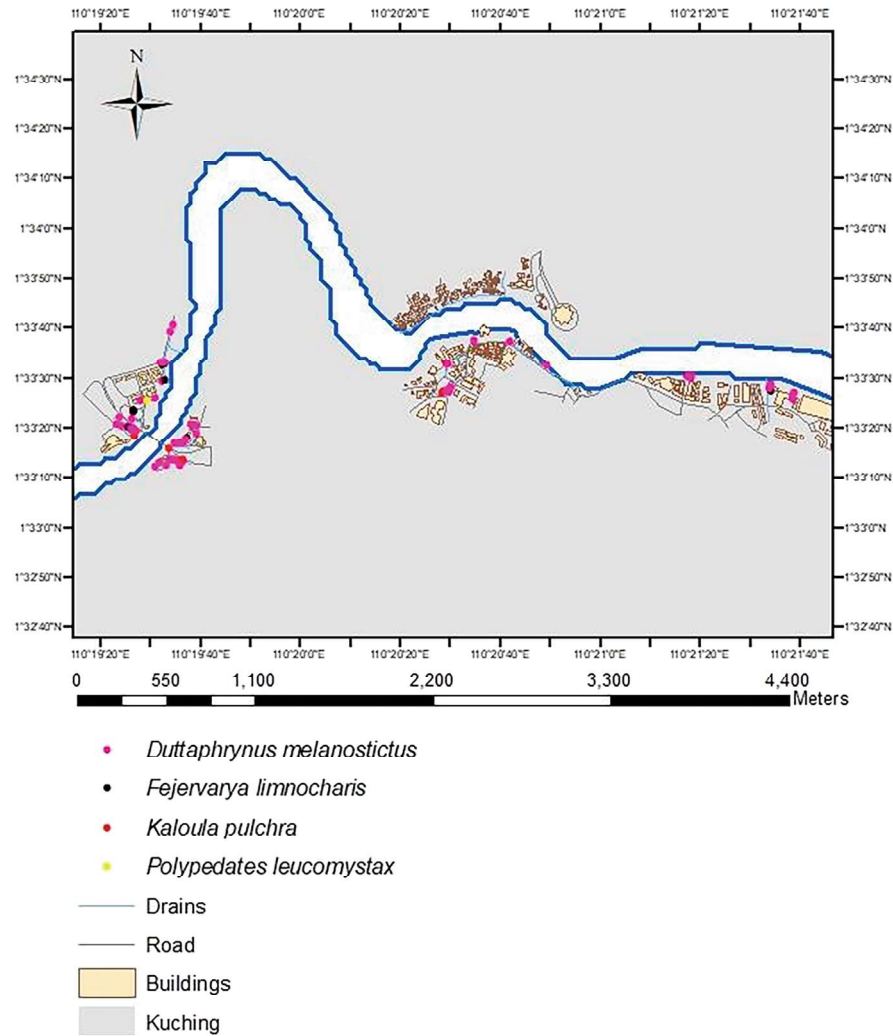


Fig. 5 Geographical positions of *anuran* species along Kuching Waterfront, Sarawak

areas where high tourist activity may be negatively impacting their populations (Gillespie et al., 2020).

Based on Fig. 7, species distribution can be related to the 3D mapping of buildings which come up with the understanding on how the physical structure of urban environments influences the presence and behaviour of different species. These can be visualised by using ArcScene to generate the 3D maps that can identify ecological corridors and barriers, revealing how species move and interact within the city. Additionally, buildings can create microclimates that affect temperature, humidity,

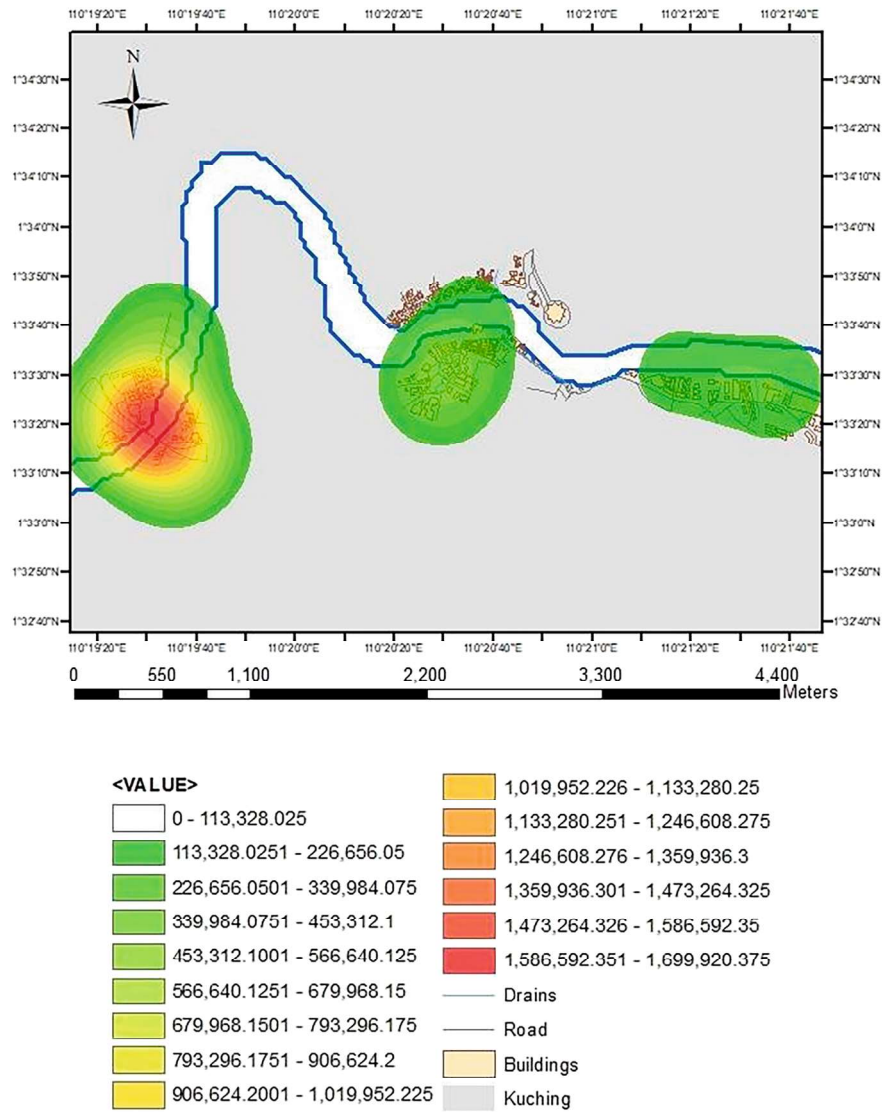


Fig. 6 Kernel density map of *anuran* distribution in Kuching Waterfront, Sarawak

and wind patterns, influencing species distribution by providing favourable conditions for certain species. The presence of buildings also impacts resource availability, such as food and water, which can be predicted using 3D mapping models. Furthermore, human activity levels around buildings can deter or attract certain species, highlighting the importance of considering urban structures in biodiversity conservation (Choi et al., 2021).

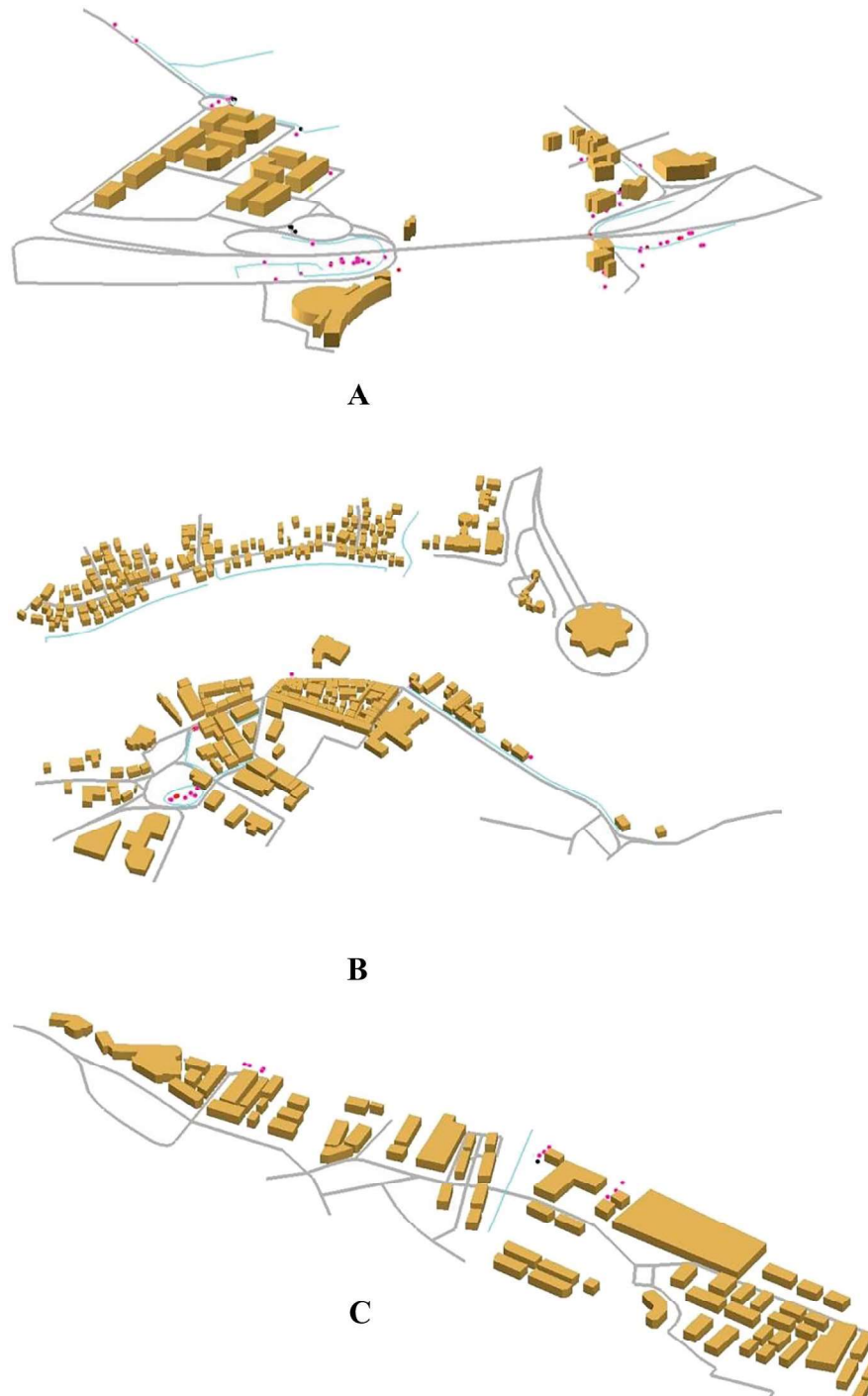


Fig. 7 3D map of *anurans*' distribution along Kuching Waterfront, Sarawak

4 Concluding Remarks

This research study findings provide valuable insights into the ecological roles of these *anuran* species within the urban landscape of Kuching Waterfront. Each species shows unique habitat preference and behaviour, contributing to the overall biodiversity and ecological balance of the area. The research project on geospatial mapping of *anuran* distribution in urban areas using ArcGIS has offered significant insights into the complex interplay between urbanisation and wildlife habitats. This study underscores the importance of understanding and maintaining urban landscape connectivity to support biodiversity, particularly for sensitive species like *anurans*. These insights are crucial for urban conservation planning. Understanding the habitat preferences and behaviours of *anuran* species can inform the design of urban green spaces, ensuring they provide suitable habitats for diverse wildlife. Conservation efforts should focus on preserving and enhancing these habitats, mitigating pollution, and creating corridors that facilitate the movement of *anuran* populations across the urban landscape.

5 Recommendations

Future studies could expand the scope to include other species and explore the long-term impacts of urbanisation on biodiversity. Additionally, advancements in GIS technology and data collection methods, such as remote sensing and citizen science, can enhance the accuracy and scope of future research.

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