EARTH OBSERVATION FOR SUSTAINABLE CITIES AND COMMUNITIES

JOINT VIRTUAL WORKSHOP
MARCH 30 - APRIL 1 2021

EARSeL Remote Sensing For UN Sustainable Development Goals
Joint EARSeL LULC & NASA LCLUC Workshop
EARSeL Joint Workshop Urban Remote Sensing

liege2021.earsel.org

Co-organised by

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ORGANISING COMMITTEE

EARSeL stands for European Association of Remote Sensing Laboratories. It is a scientific network of European remote sensing institutes, coming from both academia and the commercial/industrial sector.

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Sebastian Van Der Linden	Univ Greifswald	GER

PLENARY SESSIONS

1. URBAN CLIMATE & URBAN GREEN

Chairman: Ioannis MANAKOS (The Centre for Research and Technology, Greece)

Keynote speaker: Benjamin BECHTEL (University of Bochum, Germany)

2. USE OF HYPERSPECTRAL & COMMERCIAL DATA IN URBAN CONTEXT

Chairman: Garik GUTMAN (NASA, USA)

Keynote speaker: Son VAN NGHIEM (NASA Jet Propulsion Laboratory, USA)

3. URBAN SOCIAL SCIENCES & POLICIES

Chairman: Carsten JURGENS (Ruhr-Universität Bochum, Germany)

Keynote speakers: Catherine LINARD (University of Namur, Belgium) & Monika KUFFER (University of Twente, The Netherlands)

4. URBAN GROWTH & SETTLEMENT

Chairman: Chris JUSTICE (University of Maryland, USA)

Keynote speaker: Peilei FAN (Michigan State University, USA)

5. LAND USE & LAND COVER

Chairman: Mattia CRESPI (Sapienza University of Rome, Italy)

Keynote speakers: Devis TUIA (EPFL ENAC, Environmental Computational Science and Earth Observation Laboratory, Switzerland) & Pierre-Philippe MATHIEU (Head of the ESA Φ-lab Explore Office, Italy)

6. SUSTAINABLE DEVELOPMENT GOALS

Chairman: Lena HALOUNOVA (Czech Technical University in Prague, Czech Republic)

Keynote speaker: Karen SETO (Yale University, USA)

LIST OF PRESENTATIONS

Tuesday, March 30, 2021

1:00pm - 1:15pm CET

Opening Ceremony

PLENARY 1: Urban climate & Urban green
Chairman: Ioannis Manakos, The Centre for Research and Technology, GRE

Keynote Speech - Urban environmental change from space

Benjamin Bechtel
Ruhr-University Bochum, Germany

1:15pm - 3:30pm CET

Mapping Functional Urban Green Types With The Combined Use Of Hyperspectral, Multispectral And LiDAR Data

Jeroen Degerickx[1,2], Martin Hermy[2], Ben Somers[2]
[1]VITO, Belgium; [2]Division of Forest, Nature and Landscape, KULeuven, Belgium

Green Growth? On The Relation Between Population Density, Land Use And Vegetation Cover Fractions In A City Using A 30-Years Landsat Time Series.

Thilo Wellmann[1,2], Franz Schug[1], Dagmar Haase[1,2], Dirk Pflugmacher[1], Sebastian van der Linden[1,3]
[1]Humboldt-Universität zu Berlin, Germany; [2]UFZ Leipzig, Germany; [3]University of Greifswald, Germany

Evaluating Built-up Indices for DisTrad Thermal Sharpening over the Arid and Semi-Arid Regions; Case Study: Gaza Strip

Wiesam A. Essa[1,2], Jonathan Huck[2], Rachid Lhissou[3]
[1]Department of Geography, University of Mancheter, United Kingdom; [2]Department of Geography, Al-Aqsa Univeristy. Palestine; [3]Centre Eau Terre Environnement (ÉTÉ-INRS), Universitie du Quebec, Canada

Mapping Of Urban Land Surface Temperatures By The Future THRISHNA Mission : Focus On Inversion And Sharpening Methods

Aurélie Michel, Carlos Granero-Belinchon, Xavier Briottet
ONERA-DOTA, France

Monitoring Water Vapour Distribution Over Cities Using Galileo Signals From Connected Vehicles: A Feasibility Study

Steffen Schön[1], Lucy Icking[1], Gael Kermarrec[2]
[1]Institut für Erdmessung, Leibniz Universität Hannover, Germany; [2]Geodetic Institute, Leibniz Universität Hannover, Germany

Early Detection Of Heracleum mantegazzianum (Giant Hogweed) From UAV Images Using SVM And OBIA

Sheeba Lawrence[1], Wietske Bijker[2], Valentyn Tolpekin[3]
[1]eLEAF B.V., the Netherlands; [2]University of Twente, Faculty ITC, the Netherlands; [3]ICEYE, Finland

Mapping Of Tree Species In The City: Challenges Of The Application Project

Dominik Kopeć[1,2], Jan Niedzielko[1], Adam Kania[3], Justyna Wylazłowska[1], Anna Halladin-Dąbrowska[1], Jakub Charyton[1], Łukasz Sławik[1,4]
[1]MGGP Aero Sp. z o.o.; [2]University of Lodz; [3]Definity Sp. z o.o.; [4]University of Warsaw

Copernicus Land Monitoring Service new High Resolution Layer 2015: the Small Woody Features – research, development and production story

Antoine Masse, Loic Faucqueur, Nathalie Morin, Pierre-Yves Rémy, Justine Hugé, Fabrice Dazin, Carlos De Wasseige, Christophe Sannier
CLS Lille, 61rue de la Cimaise, Villeneuve d'Ascq, France

Rapid Country-Scale Inundation Mapping For Urban Planning In Bangladesh Using Copernicus Sentinel-1 Data And Google Earth Engine

Lukas Wimmer, Nicolas Jakob Wagener
Federal Institute for Geosciences and Natural Resources (BGR), Germany

Evaluation Of Green Infrastructure Development With High Spatial Resolution Worldview-2 Images In The Baoshan District, Shanghai, China

Lars Gruenhagen[1], Malte Bührs[1], Matthias Falke[1], Luis Inostroza[1], Harald Zepp[1], Carsten Jürgens[1], Thomas Schmitt[1], Nannan Dong[2]
[1]Ruhr-University Bochum, Geography Department, Germany; [2]Tongji-University, College of Architecture and Urban Planning, China

3:30pm - 4:00pm CET

Coffee break & Poster Session

PLENARY 2: Use of Hyperspectral & Commercial data in Urban context
Chairman: Garik Gutman, NASA, USA

4:00pm - 6:00pm CET

Keynote Speech – Four-Dimensional Observations of Urban Changes and Environmental Impact Assessments

Son Van Nghiem
Jet Propulsion Laboratory, California Institute of Technology, United States of America

Household Wealth in HD: Mapping the Demographic and Health Surveys Wealth Index in Sub-Saharan African Cities with Very-High-Resolution Satellite Data

Stefanos Georganos[1], Assane Niang Gadiaga[2], Catherine Linard[2], Tais Grippa[1], Sabine Vanhuysse[1], Nicholus Mboga[1], Eléonore Wolff[1], Sébastien Dujardin[2], Moritz Lennert[1]
[1]Université libre de Bruxelles, Belgium; [2]University of Namur, Belgium

Analysing the Robustness of Sampling in Gradient Analysis of Urban Material Mixtures

Chaonan Ji[1,2], Marianne Jilge[1], Uta Heiden[1], Marion Stellmes[3], Hannes Feilhauer[3,4]
[1]German Aerospace Center, Germany; [2]Humboldt-Universität zu Berlin, Germany; [3]Freie Universität Berlin, Germany; [4]FAU Erlangen-Nürnberg, Germany

Towards a Generic Spectral Library for Urban Mapping Applications

Frederik Priem[1], Marianne Jilge[2], Uta Heiden[2], Ben Somers[3], Frank Canters[1]
[1]Vrije Universiteit Brussel, Cartography and GIS Research Group, Belgium; [2]Deutsches Zentrum für Luft- und Raumfahrt, Earth Observation Center, Germany; [3]KU Leuven, Division of Forest, Nature and Landscape, Belgium

Settlement Monitoring For Renewable Energy Provision In Indigenous Communities Of The Ecuadorian Amazon

Valerie Graw[1], Javier Muro[2], José Jara[3,4], Leo Zurita[5], Andreas Rienow[1], Esteban Calderón[4], Richard Resl[5]

[1]Ruhr-University Bochum, Department of Geography, Germany; [2]University of Bonn, Center for Remote Sensing of Land Surfaces (ZFL), Germany; [3]Tratural, energía removable, Cuenca, Ecuador; [4]Universidad del Azuay (UDA), Ecuador; [5]Universidad San Francisco de Quito (USFQ), Ecuador

Regression-based Unmixing Of Urban Land Cover Across Multiple Cities – Evaluating Multi-site Libraries And Gaussian Process Uncertainties For Model Generalization

Akpona Okujeni[1], Sam Cooper[1], Patrick Hostert[1,2], Sebastian van der Linden[3]

[1]Earth Observation Lab, Humboldt-Universität zu Berlin; [2]Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys), Humboldt-Universitat zu Berlin; [3]Institute of Geography and Geology, Universität Greifswald

Roof Material Mapping: Application Over Liège Using Open-Source Object-Based Supervised Classification Algorithms

Coraline Wyard[1], Benjamin Beaumont[1], Rodolphe Marion[2], Laure Roupioz[3], Eric Hallot[1]

[1]ISSeP, Belgium; [2]CEA, France; [3]ONERA, France

The Garden Monitor (Garmon) : What is a garden ? Technically...

Jo Van Valckenborgh, Stijn Van der Linden, Ben Somers, Jingli Yan, Veerle Strosse

Informatie Vlaanderen, Belgium

Blue-green Microstructures - Detection Of Geometrical And Permeability Features Of Microstructures

Agnieszka Kinga Kuras[1], Øivind Due Trier[2], Thomas Thiis[1], Vetle Odin Jonassen[3], Niki Gaitani[4], Christian Rogass[5], Ingunn Burud[1]

[1]Norwegian University of Life Sciences, Faculty of Science and Technology, PB 5003, 1430 Aas, Norway; [2]Norwegian Computing Center, Section for Earth Observation, Oslo, Norway; [3]Terratec AS, Vækerøveien 3, 0281 Oslo, Norway; [4]Norwegian University of Science and Technology, Department of Architecture and Technology, Høgskoleringen 1, 7491 Trondheim, Norway; [5]Helmholtz Centre for Environmental Research, UFZ, Permoserstraße 15, 04318 Leipzig, Germany

Potential of Green Roofs in the East bank of Liege, Belgium

Mitali Yeshwant Joshi[1], Simon Rohon[1], Gilles-Antoine Nys[2], Jacques Teller[1]

[1]University of Liege, LEMA, Department of Urban and Environmental Engineering, Belgium; [2]University of Liege, Geomatics unit, SPHERES, Department of Geography, Belgium

Continental-scale Mapping and Analysis of 3D Building Structure

Mengmeng Li[1], Elco Koks[1], Hannes Taubenböck[2,3], Jasper van Vliet[1]

[1]VU University Amsterdam, Institute for Environmental Studies, the Netherlands; [2]German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Germany; [3]Julius-Maximilians-Universität Würzburg, Institute for Geography and Geology, Germany

Using Multiple Molor Spaces of Orthophotos and Computer Vision Method for Building Segmentation and Change Recognition

Lingli Zhu , Heli Laaksonen, Jani Kylmäaho, Juha Vilhomaa, Juha Hyyppä, Mikko Sippo

National land survey of Finland, Finland

3D Data On Regional Scale: What Are The Main Mapping Products And Associated Users?

Yohann François[1], Nathalie Stephenne[2], Philippe Lejeune[1], Adrien Michez[1]

[1]University of Liège / Gembloux Agro-Bio Tech, Belgium; [2]Service Public de Wallonie (SPW), Geomatic Department, Belgium

Wednesday, March 31, 2021

1:00pm - 3:30pm CET

PLENARY 3: Urban social Sciences & Policies
Chairman: Carsten Jürgens, Ruhr-Universität Bochum, GER

Keynote Speech - Mapping Urban Population Distribution In Data-Scarce Countries

Catherine Linard
Université de Namur, Belgium

Keynote speech - The complexity of cities in the Global South from Space

Monika Kuffer
University of Twente, The Netherlands

The Potential of SAR and OPTICAL Sentinel Images for the Automatic Monitoring of Redevelopment Sites

Sophie Petit[1], Mattia Stasolla[2], Wyard Coraline[1], Gerard Swinnen[1], Odile Close[1], Benjamin Beaumont[1], Christophe Rasumny[3], Xavier Neyt[2], Eric Hallot[1]
[1]Remote Sensing and Geodata Unit, Institut Scientifique de Service Public, Belgium; [2]Royal Military Academy, Belgium; [3]Land Planning, Housing, Heritage and Energy, Service Public de Wallonie, Belgium

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Assessing the Capabilities of Sentinel-1 and 2 for Citywide Slum Mapping with Machine Learning

Sabine Vanhuysse[1], Taïs Grippa[1], Monika Kuffer[2], Stefanos Georganos[1], Nicholus Mboga[1], Eléonore Wolff[1], Moritz Lennert[1]
[1]Université libre de Bruxelles (ULB), Department of Geosciences, Environment and Society, Belgium; [2]University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), The Netherlands

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Citizens and Satellites – Multisource Monitoring of Urban Sprawl in Context of Climate Change Adaptation based on Remotely Sensed Time Series and Crowdmapping in German Metropolitan Regions

Gohar Ghazaryan[1], Francis Hugenroth[2], Carsten Jürgens[3], Sarah Sticksel[3], Birte Trampnau[3], Anke Valentin[2], Andreas Rienow[3]
[1]University of Bonn, Germany; [2]Science Shop Bonn, Germany; [3]Ruhr-University Bochum, Germany

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Copernicus for Urban Resilience in Europe: The CURE Project Idea

Nektarios Chrysoulakis[1], Zina Mitraka[1], Mattia Marconcini[2], David Ludlow[3], Zaheer Khan[3], Brigitte Holt Andersen[4], Tomas Soukup[5], Andreas Walli[6], Alessandra Gandini[7], Jürgen Kropp[8], Dirk Lauwaet[9], Christian Feigenwinter[10]
[1]FORTH, Institute of Applied and Computational Mathematics, Remote Sensing Lab, Greece; [2]DLR, Deutsches Zentrum für Luft- und Raumfahrt, Germany; [3]University of the West of England, Bristol, United Kingdom; [4]Institute of Applied Economics Aps, Denmark; [5]Gisat S.R.O., Czech Republic; [6]GeoVille Informationssysteme und Datenverarbeitung GMBH, Austria; [7]TECNALIA, Fundacion Tecnalia Research & Innovation, Spain; [8]PIK, otsdam Institut fuer Klimafolgenforschung, Germany; [9]VITO, laamse Instelling voor Technologisch Onderzoek N.V., Belgium; [10]Universitaet Basel, Switzerland

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Multinomial Logistic Regression And Cellular Automata For Modelling Of Urban Sprinkling

Lucia Saganeiti[1], Ahmed Mustafa[2], Beniamino Murgante[1], Jacques Teller[3]
[1]School of Engineering, University of Basilicata, Potenza, Italy; [2]Urban systems lab, the new school, New York, USA; [3]LEMA, Urban and Environmental Engineering Department, Liège University, Belgium

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Leveraging IDP Sites as Pseudo-administrative Boundaries for Improved Gridded Population Mapping

Hannah Rosenblum, John T. Fitzwater, Derek Azar, Joshua Comenetz, Arthur Desch, Nicholas John
U.S. Census Bureau

The Utility of Gridded Mapping Systems to Capture Deprived Urban Areas in Low-income Country Cities

Michael Malkin[1,2], Monika Kuffer[2], Jon Wang[2]
[1]Karlsruhe Institute of Technology, Germany; [2]University of Twente, ITC, The Netherlands

A Spatial Assessment of Low-Income Housing Estate Programs In The Periphery Of Mexico City Using Remote Sensing And Census Data

Stéphane Couturier[1,2], Adrian Flores[3], Roberto Huerta Luna[1], Richard Sliuzas[2], Monika Kuffer[2], Javier Osorno Covarrubias[1]
[1]UNAM, Mexico; [2]University of Twente, Netherlands; [3]University of Anáhuac, Mexico

3:30pm - 4:00pm CET

Coffee break & Poster Session

PLENARY 4: Urban growth & Settlement
Chairman: Chris Justice, University of Maryland, USA

4:00pm - 6:00pm CET

Keynote Speech - Urbanization and sustainability under global change and transitional economies: Synthesis from Southeast, East, and North Asia (SENA)

Peilei Fan
Michigan State University, Center for Global Change and Earth Observations (CGCEO), United States of America

Knowledge Gaps In Earth Observation-based Mapping Of Human Settlements: From An Ontological Perspective.

Jiong Wang[1], Monika Kuffer[2]
[1]Utrecht University, Netherlands, The; [2]University of Twente, Netherlands, The

Identifying Human Settlement Growth Types Using Symbolic Machine Learning and Geographic Information Systems: Assiut Governorate as a Case Study

Mahmood Abdelkader[1,2], Luc Boorboem[1], Richard Sliuzas[1], Jaap Zevenbergen[1]
[1]ITC, Twente University, Netherlands, The; [2]Faculty of Engineering, Assiut University, Egypt

Global Building Map from Sentinel-1 satellite mission

Marco Chini[1], Ramona Pelich[1], Renaud Hostache[1], Patrick Matgen[1], Carlos López-Martínez[2]
[1]Luxembourg Institute of Science and Technology, Luxembourg; [2]Univeristat Politecnica de Catalunya

Automated Urban Footprint Mapping Over Large Areas: a Method Implemented for Massive Streams of Sentinel-2 Data

Romain Wenger[1], David Michéa[2], Anne Puissant[1]
[1]LIVE CNRS UMR 7362, University of Strasbourg, France; [2]ICUBE CNRS UMR 7357, University of Strasbourg, France

Beyond Built-up Land: Towards A More Nuanced Analysis Of Settlement System Changes

Jasper van Vliet[1], Mengmeng Li[1], Yuan Wang[1], Peter Verburg[1,2]
[1]VU University Amsterdam, Netherlands, The; [2]Swiss Federal Research Institute WSL, Switzerland

Spatial analysis of Slum Characteristics based on the Generic Slum Ontology – Case of two Brazilian cities

Divyani Kohli, Monika Kuffer
ITC, University of Twente, Netherlands

The Morphology Of The Arrival City

Hannes Taubenboeck[1], Michael Wurm[2], Nicolas Kraff[2], Maria Hochleitner[3]
[1]German Aerospace Center (DLR),; [2]German Remote Sensing Data Center (DFD); [3]European Space Imaging, Germany

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Urban Growth Analysis Using Satellite Data and Socioeconomic Variables in Uyo (Nigeria)

Etido Essien, Cyrus Samimi
University of Bayreuth, Germany

A Random Forest Dasymetric Approach For Mapping The Population Distribution At High Spatial Resolution

Eric Hallot[1], Armand Okende[1,2], Tais Grippa[2], Benjamin Beaumont[1]
[1]Remote Sensing and Geodata Unit, Institut Scientifique de Service Public, Belgium; [2]ANAGEO-DGES, Université Libre de Bruxelles, Belgium

Thursday, April 1, 2021

PLENARY 5: Land Use & Land Cover
Chairman: Mattia Crespi, Sapienza University of Rome, IT

1:00pm - 3:30pm CET

Keynote speech - Artificial Intelligence Helps Monitoring Urban Functions

Devis Tuia
EPFL ENAC, Environmental Computational Science and Earth Observation Laboratory (ECEO), Switzerland

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Keynote Speech - The Rise of Artificial Intelligence for Earth Observation (AI4EO)

Pierre-Philippe Mathieu
European Space Agency (ESA), Italy

An Open Source Mapping Scheme For Developing Wallonia's INSPIRE Compliant Land Cover And Land Use Datasets.

Benjamin Beaumont[1], Tais Grippa[2], Moritz Lennert[2], Julien Radoux[3], Céline Bassine[3], Pierre Defourny[3], Eleonore Wolff[2]
[1]Remote Sensing and Geodata Unit, Institut Scientifique de Service Public, Belgium; [2]ANAGEO-DGES, Université Libre de Bruxelles, Belgium; [3]Earth and Life Institute, Université catholique de Louvain, Belgium

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Towards Automated Urban Map Revision Using Deep Neural Networks on Airborne Lidar and Hyperspectral Data

Øivind Due Trier
Norwegian Computing Center, Norway

Fully Convolutional Networks For Landcover Classification From Historical Black And White Aerial Photographs Of Central Africa

Nicholus Mboga[1], Tais Grippa[1], Stefanos Georganos[1], Sabine Vanhuysse[1], Benoit Smets[2,3], Olivier Dewitte[2], Eléonore Wolff[1], Moritz Lennert[1]
[1]Université libre de Bruxelles, Department of Geosciences, Environment & Society, Av Franklin Roosevelt 50-1050 , Brussels, Belgium; [2]Department of Earth Sciences, royal Museum for Central Africa, Leuvensesteenweg 13, 3080 Tervuren, Belgium; [3]Cartography and GIS Research Group, department of Geography, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium

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Assessment of Texture Features' Contribution in Discriminating Natural Bare Areas vs. Artificially Covered Ones: Chania Case Study

Ioannis Manakos[1], Adel Ledawi[2], Argyrios Stergioudis[1], Chariton Kalaitzidis[2]
[1]Centre for Research and Technology Hellas, Greece; [2]International Centre for Advanced Mediterranean Agronomic Studies, Mediterranean Agronomic Institute of Chania, Greece

Mapping Settlement And Vegetation Continuous Fields At National Scale In A Temperate Environment Using Sentinel-2

Franz Schug[1], David Frantz[1], Akpona Okujeni[1], Sebastian van der Linden[1,2], Patrick Hostert[1,3]
[1]Earth Observation Lab, Humboldt-Universität zu Berlin, Germany; [2]Institute of Geography and Geology, Universität Greifswald, Germany; [3]Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys), Humboldt-Universitat zu Berlin, Germany

Land Cover Semantic Segmentation Of SPOT-6/7 And Sentinel-2 Data Using CNN

Arnaud Le Bris, Olivier Stocker
Univ. Gustave Eiffel, IGN-ENSG, LaSTIG, France

Using Sentinel-1/2 Data to Detect New Urban Elements in Agricultural Parcels

Alban Jago, Emilie Bériaux, Cozmin Lucau-Danila, Viviane Planchon
Walloon Agricultural Research Centre - CRA-W, Belgium

Regional Environment Monitoring Using Copernicus Sentinel-1 SAR Images: Interferometric SAR Coherence as an Indicator of Dynamic Land Cover Changes

Dominique Derauw[1], Ludivine Libert[1,2], Anne Orban[1], Christian Barbier[1]
[1]Centre Spatial de Liège, University of Liège, Belgium; [2]Enveo, Austria

3:30pm - 4:00pm CET

Coffee break & Poster Session

PLENARY 6: Sustainable Development Goals
Chairman: Lena Halounova, Czech Technical University in Prague, CZ

4:00pm - 6:00pm CET

Keynote speech - Climate Change Mitigation and Adaptation: Strategic Directions for Urban Remote Sensing

Karen Seto
Yale University, School of the Environment, United States of America

UrbanTEP – EO Data Processing, Integrative Data Analysis and Monitoring for SDG Reporting

Felix Bachofer[1], Thomas Esch[1], Jakub Balhar[2], Martin Boettcher[3], Enguerran Boissier[4], Mattia Marconcini[1], Annekatrin Metz-Marconcini[1], Michal Opletal[2], Fabrizio Pacini[4], Tomas Soukup[2], Vaclav Svaton[5], Julian Zeidler[1]
[1]German Aerospace Center (DLR), Germany; [2]GISAT s.r.o., Czech Republic; [3]Brockmann Consult GmbH, Germany; [4]Terradue Srl., Italy; [5]IT4Innovations, VSB-Technical University of Ostrava, Czech Republic

COPERNICUS Global Land Products and Services and the Sustainable Development Goals

Pietro Ceccato[1], Michael Cherlet[2], Marie Lang[3]
[1]SPACEBEL, Belgium; [2]EC Joint Research Center, Italy; [3]Université de Liège, Belgium

Automatic Detection Of Urban Vacant Land: An Open-Source Approach For Sustainable Cities

Shaojuan Xu[1,2], Manfred Ehlers[2]
[1]Research Institute for Regional and Urban Development, Germany; [2]Osnabrück University, Germany

Earth Observation for Sustainable Development in Urban Areas: Results and Achievements from ESA's EO4SD-Urban project

Manuela Hirschmugl[1,4], Jan Kolomaznik[2], Tomas Soukup[2], Amelie Broszeit[3], Carina Sobe[1], Herwig Proske[1]
[1]Joanneum Research, Austria; [2]GISAT; [3]GAF AG; [4]University of Graz, Institute of Geography and Regional Science

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An Integrated Deprived Area Mapping "System"

Monika Kuffer[1], Dana Thomson[2], Gianluca Boo[2], Ron Mahabir[3], Tais Grippa[4], Sabine Vanhuysse[4], Joao Porto de Albuquerque[5], Ryan Engstrom[6], Robert Ndugwa[7], Jack Makau[8], Caroline Kabaria[9]
[1]University of Twente, ITC, The Netherlands; [2]University of Southampton, Geography and Environmental Science UK; [3]George Mason University, Department of Computational and Data Sciences, USA; [4]Université Libre de Bruxelles, IGEAT, Belgium; [5]Warwick University, Institute for Global Sustainable Development, UK; [6]George Washington University, Department of Geography, USA; [7]UN-Habitat, GUO, Kenya; [8]Slum Dwellers International, Kenya; [9]African Population and Health Research Center, Kenya

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Urbanisation and Ground Deformation Patterns in Khulna, Bangladesh in the Context of a Climate Change Adapted Urban Planning

Nicolas Jakob Wagener, Lukas Wimmer, Andre Cahyadi Kalia
Federal Institute for Geosciences and Natural Resources (BGR), Germany

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Supporting Urban Sanitation Management Through The Integration Of EO-based Indicators

Barbara Riedler[1], Johannes Nödel[1], Rosi Siber[2], Nienke Andriessen[2], Linda Strande[2], Stefan Lang[1]
[1]University of Salzburg, Austria; [2]Eawag, Switzerland

E-shape: Fostering And bridging The European Earth Observation Ecosystem

Francesca Piatto
EARSC, Belgium

Remote Sensing As Support To Cartography Of The Quality Of Water At The Prefecture Of Mohammedia (Marroco)

Rachida El Morabet[1], Larbi Bahrazi[2], Soufiane Bouhafa[3]
[1]faculté des lettre et des sciences humaines Mohammedia Maroc; [2]faculté des lettre et des sciences humaines Mohammedia Maroc; [3]faculté des lettre et des sciences humaines Mohammedia Maroc

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Vegetation Dynamics in African Drylands: A Remote Sensing Based Assessment Using the Vegetation Degradation Index in an Agro-Pastoral Region of Botswana

Felicia Olufunmilayo Akinyemi[1], Margaret O. Kgomo[2]
[1]Universität Bern, Bern, Switzerland; [2]Department of Wildlife and National Parks, Serowe, Botswana

6:00pm - 6:15pm CET

Closing ceremony

ABSTRACTS

Urban environmental change from space

Corresponding Author:
benjamin.bechtel@rub.de

Benjamin Bechtel[1]

[1] Ruhr-University Bochum, Germany

Yet remote sensing is potentially useful to observe a much larger range of urban environmental impacts. In their classical review, Grimm et al. (2008) identified five types of urban ecosystems changes with global environmental impact, namely land use and land cover, biogeochemical cycles, climate, hydrosystems, and biodiversity. More recently, Zhu et al. (2019) used the same categories to review a large body of urban remote sensing literature with respect to their contributions of identification and understanding key urban processes. This presentation summarizes the state reached in these different categories and highlights interesting examples of recent studies giving particular emphasis on the role of scale.

This presentation summarizes the state reached in the five types of urban ecosystems changes with global environmental impact, namely land use and land cover, biogeochemical cycles, climate, hydrosystems, and biodiversity; and highlights interesting examples of recent studies giving particular emphasis on the role of scale

Mapping functional urban green types with the combined use of hyperspectral, multispectral and LiDAR data

EARSeL Liege 2021
Abstract
Corresponding Author:
jeroen.degerickx@vito.be

Jeroen Degerickx[1], Martin Hermy[2], Ben Somers[2]

[1] Vlaams Instituut voor Technologisch Onderzoek (VITO), Belgium
[2] KULeuven, Division of Forest Nature and Landscape, Belgium

Keywords: ecosystem services, urban green typology, OBIA, Random Forest, rule-based classification

The challenge

Urban green is known to provide ample benefits to human society and, as such, is expected to play a major role in safeguarding the quality of life in our future cities. In order to optimize the design and management of green spaces with regard to the provisioning of these ecosystem services, there is a clear need for uniform and spatially explicit datasets on the existing urban green infrastructure within and across cities. Current mapping approaches however largely focus on large land use units (e.g. park, garden), or broad land cover classes (e.g. tree, grass), not providing sufficient thematic detail to adequately model urban ecosystem service supply. We therefore proposed a functional urban green typology and explored the potential of both passive (2 m hyperspectral and 0.5 m multispectral optical imagery) and active (airborne LiDAR) remote sensing technology for mapping the proposed types using object-based image analysis and machine learning.

Methodology

Based on a literature review, a functional urban green typology consisting of 23 types was established, in which urban green types were defined mainly in function of plant type (e.g. deciduous tree versus tall herbaceous vegetation) and spatial configuration (e.g. tree row versus solitary tree). We adopted a two-stage classification approach, targeting each of these two aspects separately. The first part consisted of an object-based, hierarchical random forest classification in which different combinations of input features derived from hyperspectral, multispectral and lidar data were tested to reveal their relevance for urban green mapping. Image segmentation was fully based on height and intensity features from LiDAR data. Additional post-classification rules were designed to tackle errors typically occurring due to shadow and adjacency effects. Final classification results were then used as building blocks in a second, rule-based classification approach to make a distinction between patches, rows and individual trees and shrubs. This latter approach entailed merging of adjacent trees and shrubs, followed by a classification based on size, shape and distance to other trees/shrubs. The proposed methodology was tested on the city of Brussels, Belgium.

Results

When targeting basic urban green classes (tree, shrub, herbaceous, lawn, agriculture and green roofs), high classification accuracies (> 0.8) were attained, irrespective of the image datasets being used. Most of the classes could be mapped with adequate accuracy using just LiDAR data. Only when more detailed classes are of interest (e.g. deciduous and evergreen trees), the higher added value of hyperspectral data compared to multispectral data became clear. Adopting a hierarchical classification approach and applying dimensionality reduction to the hyperspectral data (Minimum Noise Fraction) significantly boosted accuracies. However, high spectral similarities, along with adjacency and shadow effects still caused severe confusion, resulting in accuracies < 0.5 for some detailed functional types. Our post-classification procedure was visibly able to increase the spatial coherence of the classification and notably improved identification of building edges and pavement shadowed by trees (see Figure 1). Our relatively simple classification procedure designed for tackling spatial configuration worked well for the distinction between narrow hedges and larger groups and patches of shrubs. Detection of tree rows on the other hand was not always successful, particularly in case the tree row directly interacted with a neighbouring tree patch or when the crowns of individual trees within the row were not overlapping.

Outlook for the future

Within this study we only focused on remote sensing imagery acquired on one particular moment in time (Summer 2015) and were confronted with high spectral similarities between different urban green types. A logical next step is to include multitemporal imagery (e.g. from Sentinel-2 or Planet SkySat) in our classification workflow, as phenological information is expected to significantly increase separability between the different urban green classes. In addition, we aim to combine our highly detailed functional green maps with existing knowledge on ecosystem service provisioning, as such generating spatially-explicit information on the distribution of ecosystem services throughout the city. This in turn will allow the identification of priority zones where urban green should be further developed.

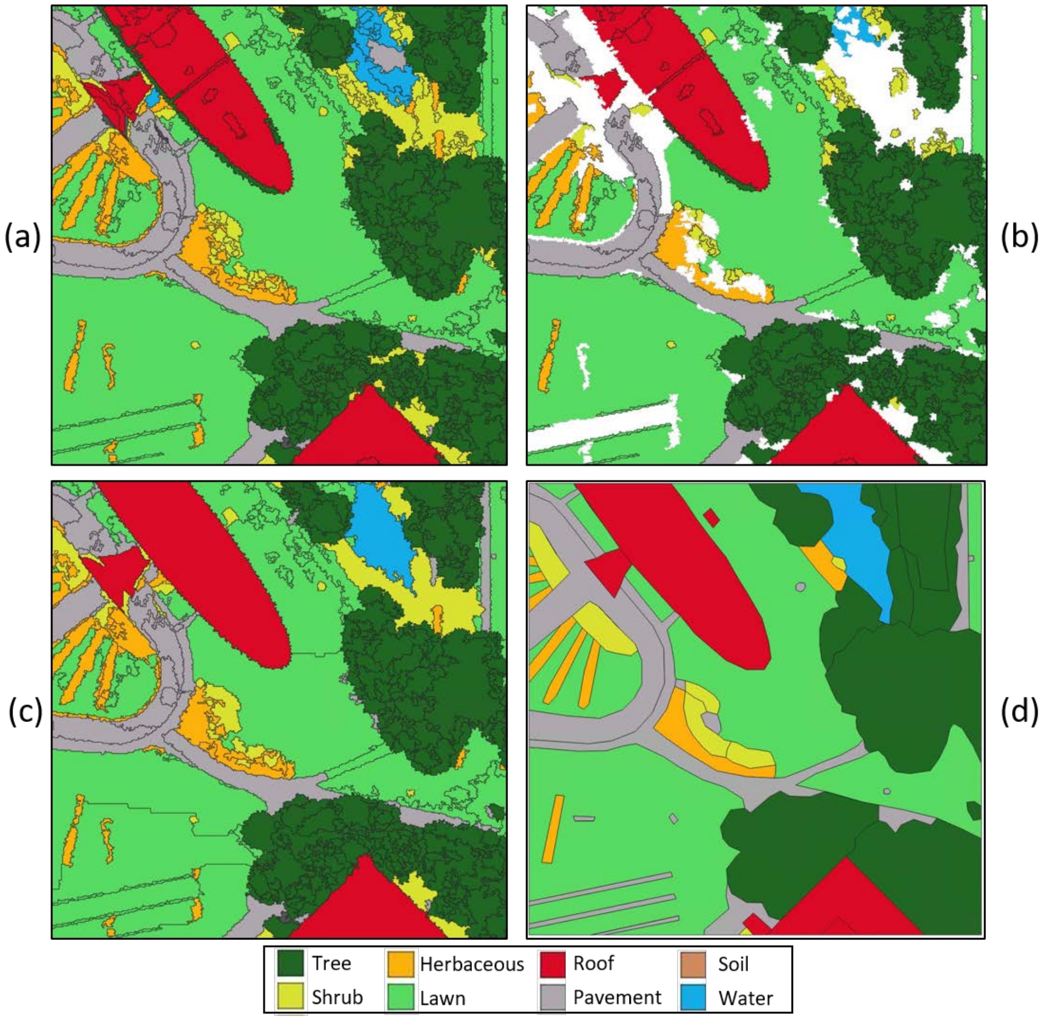

Figure 1 Example of classification results obtained for basic classes and for one out of twenty validation blocks (100 × 100 m), including (a) first classification result, (b) first classification result where areas featuring high classification uncertainty (class membership probability < 0.7) are masked out (white), (c) result after post-classification correction and (d) manually digitized reference data.

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Abstract
Corresponding Author:
thilo.wellmann@hu-berlin.de

Green growth? On the relation between population density, land use and vegetation cover fractions in a city using a 30-years Landsat time series.

Thilo Wellmann[1, 2], Franz Schug[1], Dagmar Haase[1, 2], Dirk Pflugmacher[1] ,Sebastian van der Linden[1, 3]

[1] Department of Geography, Humboldt-Universität zu Berlin, Rudower Chaussee 16, D-12489 Berlin
[2] Department of Computational Landscape Ecology, Helmholtz Centre for Environmental Research—UFZ, Permoserstr. 15, D-04318 Leipzig
[3] Institute of Geography and Geology, University of Greifswald, Friedrich-Ludwig-Jahn-Str. 16, D-17487 Greifswald

Keywords: COMPACT CITY; DISPERSED GREEN CITY; SPECTRAL UNMIXING; LANDSAT; BERLIN

The challenge

Both compact and dispersed green cities are considered sustainable urban forms, yet some developments accompanied with these planning paradigms seem problematic in times of urban growth. A compact city might lose urban green spaces due to infill and a dispersed-green city might lose green in its outskirts through suburbanisation. To study these storylines, we introduce an operationalised concept of contrasting changes in population density (shrinkage or growth) with vegetation density (sealing or greening) over time. These trends are ascribed to different land use classes and single urban development projects, to quantify threads and pathways for urban green in a densifying city.

Methodology

We acquired Landsat satellite imagery for seven years between 1988 and 2018. Imagery was pre-processed and a regression-based unmixing approach was performed in order to generate fraction maps of vegetated and non-vegetated surfaces. Results were validated for the year 2015. Two indicators were derived from the resulting historic and recent fraction maps: Firstly, population vs vegetation pathways portraying the development of both entities in an integrated way and secondly, a spatio-temporal evaluation of the urban vegetation cover per land use class. Based on this pathways and threads are drawn for different urban developments and density types.

Results

We mapped the development in vegetation density over 30 years as subpixel fractions based on a Landsat time series with an accuracy of an MAE 0.12 (for 2015). From this product we derive further indicators, finding that the case study city Berlin, Germany, developed into a city that is both gaining in vegetation—greening—and population—growing—in recent years but featured highly diverse trends for both compact and green city districts before that. Pathways to achieve a greening-growing scenario in a compact city include green roofs, brownfield and industrial revitalisation, and bioswales in predominantly green city districts. A threat for compact cities poses infill developments without greening measures. A threat for dispersed-green cities is microsealing in private residential gardens—gravel gardens—or car parking infrastructure.

Outlook for the future

We conclude that neither a compact nor a dispersed-green city form concept logically leads to a development towards more environmental quality—here vegetation density—in times of densification but rather context specific urban planning. Therefore, quantifications of such different spatial (de)densifying processes—here we measure the evolvement of vegetation density—is key in disentangling urban developments to produce future sustainable urban form(s). Thus, the question to ask is not: Is the city compact or spread, but rather is it compact and spread in 'the right place' and 'at the right time' and, most importantly, are the processes leading to a degree of compactness or dispersion appropriate for the given urban form and for the number of inhabitants.

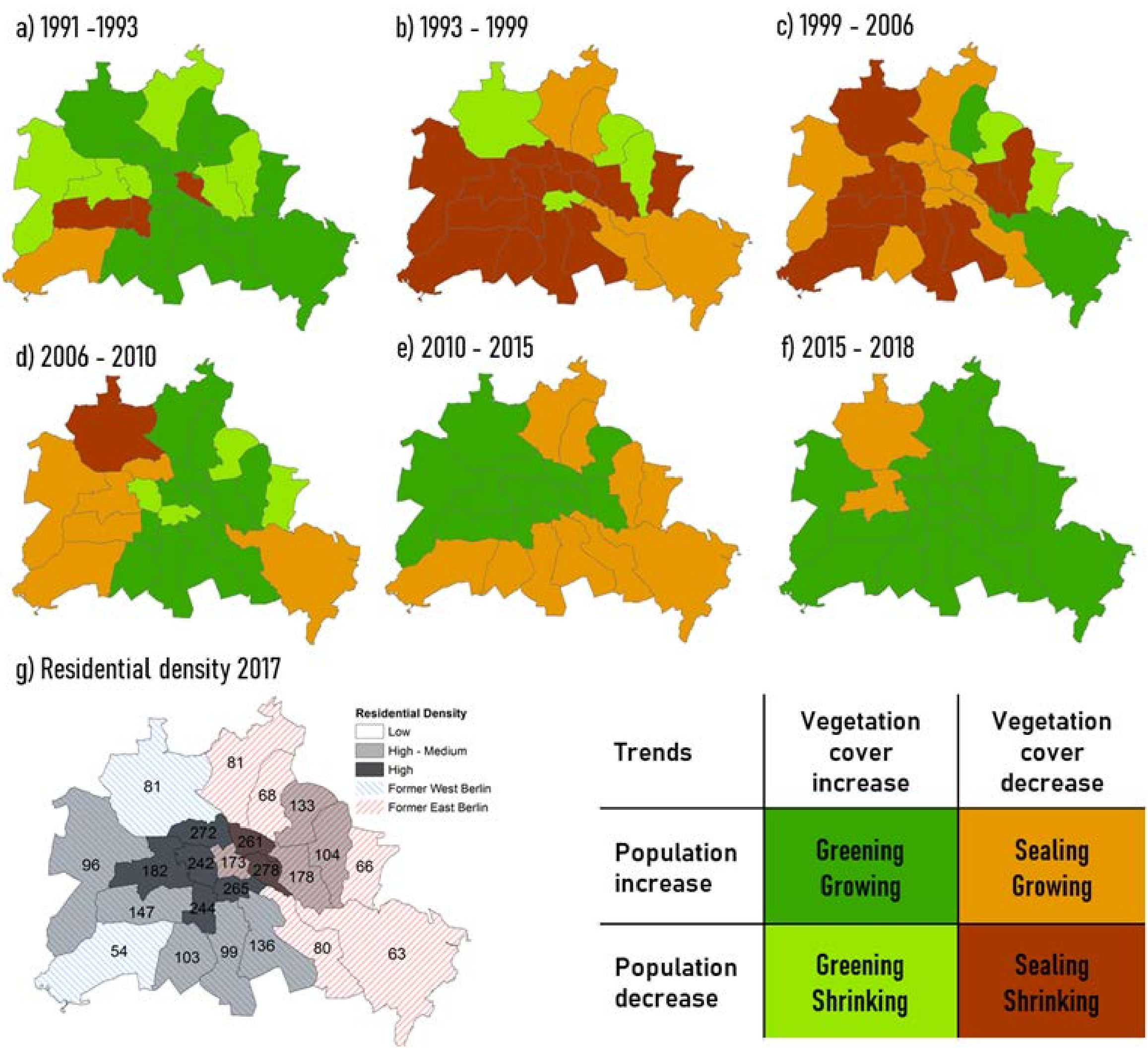

Figure Annual change in vegetation cover in regard to population density between 1991 and 2018 (a – f) and the residential density in the year 2017 discriminating dense and dispersed areas of Berlin.

Literature

Wellmann, T., Schug, F., Haase, D., Pflugmacher, D., & van der Linden, S. (2020). Green growth? On the relation between population density, land use and vegetation cover fractions in a city using a 30-years Landsat time series. *Landscape and Urban Planning*, *202*(October), 103857. https://doi.org/10.1016/j.landurbplan.2020.103857

Evaluating Built-up Indices for DisTrad Thermal Sharpening over the Arid and Semi-Arid Regions; Case Study: Gaza Strip

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Abstract
Wiesam Essa : Wiesam.essa@manchester.ac.uk

Wiesam Essa[1+2], Jonathan Hucks[1], Rachid LHISSOU[3]

[1] UNIVERSITY OF MANCHESTER, DEPARTMENT OF GEOGRAPHY, UK
[2]AL-AQSA UNIVERSIT, PALESTINE
[3]UNIVERSITIE DU QUEBEC, CANADA

KEYWORDS: LAND SURFACE TEMPERATURE, THERMAL SHARPENING, BUILT-UP INDICES, DISTRAD, LANDSAT 8

The Challenge

DisTrad technique is successfully adapted to downscale land surface temperature (LST) over urban areas with a humid climate using built-up spectral indices. However, other climate urban areas such as arid and semi-arid climate type show different spectral characteristics due to differences in land use/land cover properties and climate. This paper compares 21 SIs including built-up and other land cover indices for characterizing LST spatial pattern over arid and semi-arid areas of the Gaza Strip. A second-order polynomial regression fit is found between SIs and LST in two land cover scenarios: " All classes" and "urban class", later regression models used for downscaling simulated MODIS LST image (1000 m) to 100 m. SIs (30 m) and LST image (100 m) is derived from Landsat 8 image of summer 2017. SIs with highest correlation (R2) at 1000 m scale in "All" class are; DBSI (0.66) and ABEI (0.59), and in the "urban" class are; DBSI (0.64) and BAEI (0.57). Moreover, downscaling was validated using visual and statistical analysis with the observed LST reveals best R2 results when using ABEI (0.77) and DBSI (0.73) in "All" class, and DBSI (0.59) and BAEI (0.58) in the "urban" class.

Methodology

Many remote sensing spectral indices (SIs) have become readily available and considered promising for characterizing land surface temperatures (LST), especially for urban land covers areas. In this study, a set of 21 SIs including built-up and other land cover SIs have been investigated such as; ABEI, BAEI, BI, BRBA, BSI, BUI, DBSI, ENBI, IBI, I_imp, MSAVI2, NBI, NBUI, NDBI, NDSI, NDVI, SAVI, UI, VgNIR-BI, VrNIR-BI, and VIBI, the full description of these SIs are in table 1, the SIs are evaluated for characterizing LST in the Gaza Strip. The performance of the SIs are tested as inputs in DisTrad framework over two land covers scenarios; "all" classes (including urban, sand, vegetation, and bare soil), and in "urban" class. Support vector machine (SVM) method was used for land cover classification. The LST and SIs are derived from a Landsat 8 image of 2017 in summer-time season. LSTs retrieved using the Semi-Automatic Classification Plugin (SCP) [47], the free-open-source software QGIS retrieve LST using the metadata and the emissivity (e) values of various land cover types based on Mallick et al. [48] method. SIs - LST regression analysis are evaluated in two scales (100 m and 1000 m). DisTrad method applied to downscale simulated MODIS thermal image (the observed Landsat TIR image averaged to 1000 m) to 100 m resolution. Spatial regression analysis (R2 and RMSE error) and visual interpretation between the observed and sharpened LST products are used to evaluate the sharpening at 100 m resolution. The downscaled and observed images were compared (Fig. 1).

Table 1. 21 remote sensing spectral indices (SIs) used for statistical correlation with the Landsat 8\land surface temperature (LST) including symbol, name, description, and reference.

Index ID	Index Name	Description
ABEI	Automated Built-Up Extraction Index	$0.312\ \rho Costal + 0.513\ \rho Blue - 0.086\ \rho Green - 0.441\ \rho Red + 0.052\ \rho NIR - 0.198\ \rho SWIR1 + 0.278\ \rho SWIR$
BAEI	Built-up Area Extraction Index	$\frac{\rho RED + 0.3}{\rho Green + \rho SWIR1}$
BI	Bare Soil Index	$BI = \rho RED + \rho SWIR1 - \rho NIR$
BRBA	Band Ratio for Built-Up Area	$\frac{\rho RED}{\rho SWIR1}$
BSI	Bare Soil Index	$\frac{(\rho SWIR1 + \rho RED) - (\rho NIR + \rho BLUE)}{(\rho SWIR1 + \rho RED) + (\rho NIR + \rho BLUE)}$
BUI	Built-Up Index	$NDBI - NDVI$
DBSI	Dry Bare-Soil Index	$\frac{\rho SWIR1 - \rho Green}{\rho SWIR1 + \rho Green}$ – NDVI
ENBI	Enhancement Built-Up Index	$NDWI - FVC$
IBI	Index-Based Built-Up Index	$\frac{(NDBI - (SAVI + MNDWI))/2}{(NDBI + (SAVI + MNDWI))/2}$
P_Imp	Impervious Fraction	$P\_imp = 1 - P_v$ $P_v = \frac{(NDVI) - (NDVI)_o}{(NDVI)_s + (NDVI)_o}$
MSAVI2	Modified Soil-Adjusted Vegetation Index	$\frac{2 \times \rho NIR + 1 - \sqrt{(2 \times \rho NIR + 1)^2 - 8(\rho NIR - \rho RED)}}{2}$
NBI	New Built-Up Index	$\frac{\rho RED\ x\ \rho SWIR1}{\rho NIR}$
NBUI	New Built-Up Index	$EBBI - SAVI - MNDWI$
NDBI	Normalized Difference Built-Up Index	$\frac{\rho SWIR - \rho NIR}{\rho SWIR + \rho NIR}$
NDSI	Normalized Difference Soil Index	$\frac{\rho NIR - \rho RED}{\rho NIR + \rho RED}$
NDVI	Normalized Difference Vegetation Index	$\frac{\rho NIR - \rho RED}{\rho NIR + \rho RED}$
SAVI	Soil Adjusted VI	$\frac{(\rho NIR - \rho RED)}{(\rho NIR + \rho RED + 1)} \times 1$
UI	Urban Index	$\frac{[\rho SWIR2 - \rho NIR]}{[\rho SWIR2 - \rho NIR]}$
VgNIR-BI	Visible Based Indices	$\frac{\rho Green - \rho NIR}{\rho Green + \rho NIR}$
VIBI	Vegetation Index Built-Up Index	$\frac{\left(\frac{\rho NIR - \rho RED}{\rho NIR + \rho RED}\right)}{\left(\frac{\rho NIR - \rho RED}{\rho NIR + \rho RED}\right) + \left(\frac{\rho SWIR1 - \rho NIR}{\rho SWIR1 + \rho NIR}\right)}$
VrNIR-BI	Visible Based Indices	$\frac{\rho RED - \rho NIR}{\rho RED + \rho NIR}$

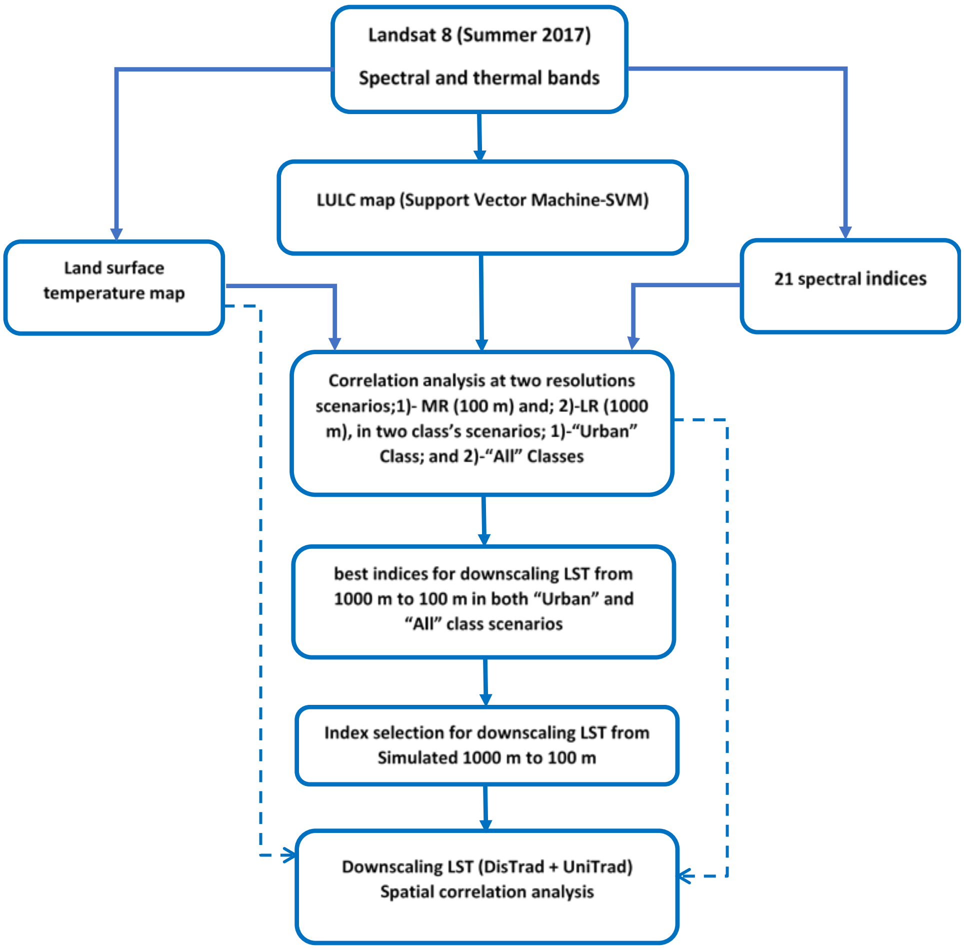


Figure. 1 Flowchart showing the procedure and the methodology for evaluating 21 spectral indices for downscaling land surface temperature. The flowchart includes the procedure of regression analysis and the spatial correlation.

Results

Figure. 2 shows the land cover classification map including the eight classes; built-up, sand, bare soil, crops, trees, shrubs, greenhouses, and wastewater using the SVM method.

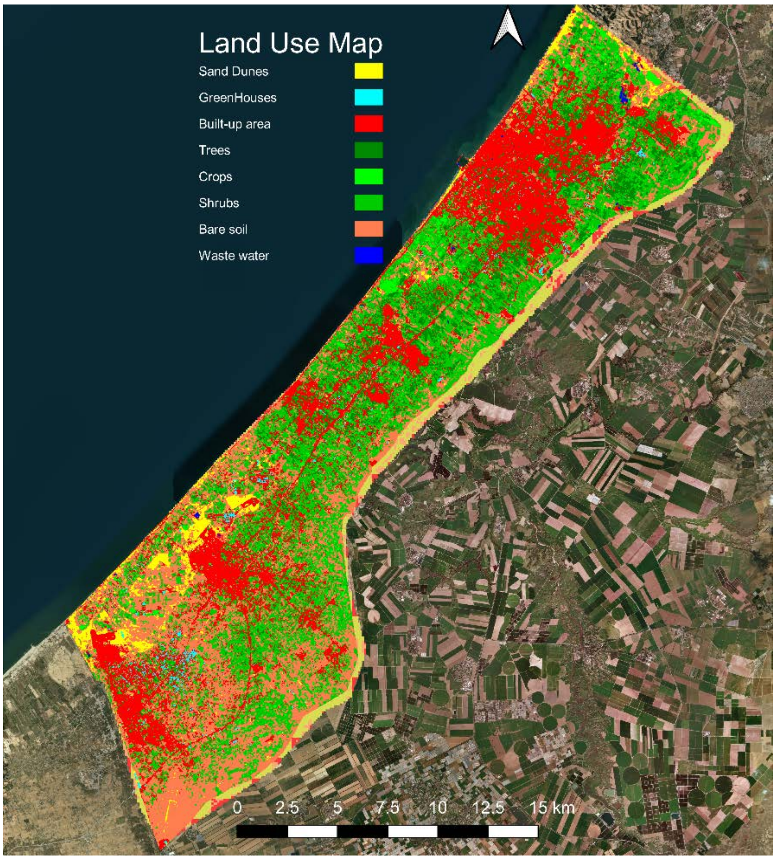


Figure 2. Land-use/Land-cover classification map of the Gaza Strip (June 2017) indicating eight land covers, using the support vector machine (SVM) method).

The statistical relationships between LSTs and SIs investigated at two class-based scenarios includes "ALL" class (figure 3), and 2) "Urban" classes (figure 4). The scale dependency also analysed at two scales; 1) 100 m, and 2) 1000 m.

Figure 3 shows the SIs robustness for estimating LSTs in "Urban" class based on the higher correlation (R2) at 1000 m resolution to follow the order; DBSI (0.64; 1.18), BAEI (0.57; 1.28), BSI (0.56; 1.30), NDBI (0.46; 1.43) etc. However, at 100 m resolution to follow the order; MSAVI2 (0.50; 1.68), P_imp (0.42; 1.81), BAEI (0.33; 1.65), NBI (0.33; 1.95) etc., respectively.

For the "All" class at 1000 m resolution (Figure 4) to follow the order; DBSI (0.66; 1.22), ABEI 0.59; 1.35), BSI (0.56; 1.40), BAEI (0.47; 1.54), NDBI (0.43; 1.59) etc., respectively. While, at 100 m resolution to follow the order; DBSI (0.58; 1.57), ABEI (0.52; 1.69), BSI (0.49; 1.73), BAEI (0.44; 1.83), NDBI (0.40; 1.89) etc., respectively.

In the "urban" class, MSAVI2 and P_imp have the highest correlation at 100 m resolution, however, a lower correlation (R2 =0.20) at 1000 m resolution, which reveals they are a scale dependent. In the "All" class, DBSI, ABEI, BSI, BAEI, and NDBI show to maintain the highest correlation among other indices at the two analysed resolution (100 m and 1000 m), which mean that those indices are scale independent and perform well in downscaling LST applications.

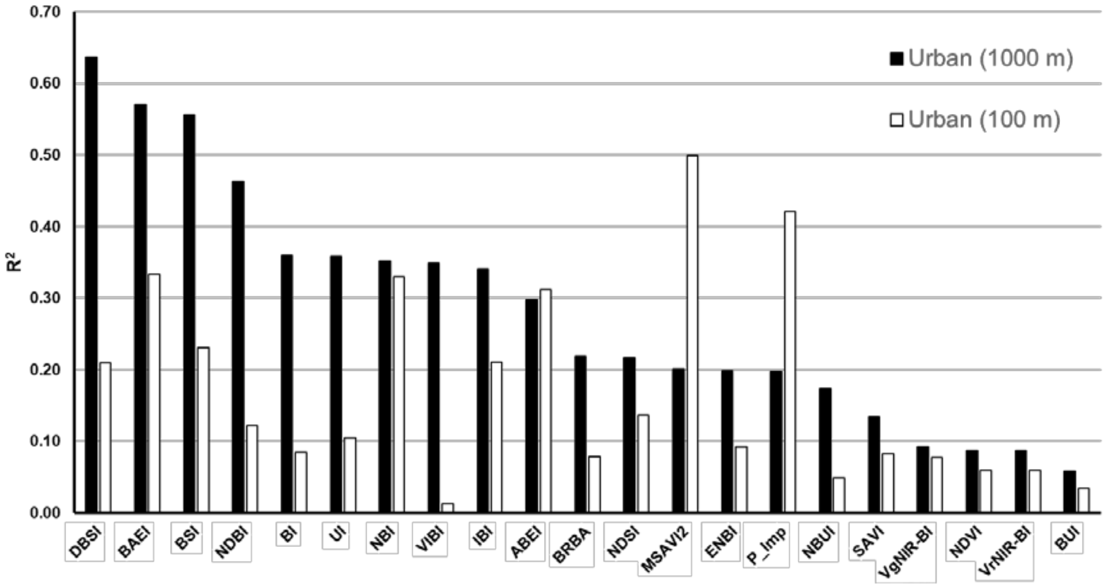


Figure 3. Correlation analysis between observed land surface temperature (LST) and the 21 spectral indices (SIs) calculated for "Urban" class at 1000 m and 100 m resolutions.

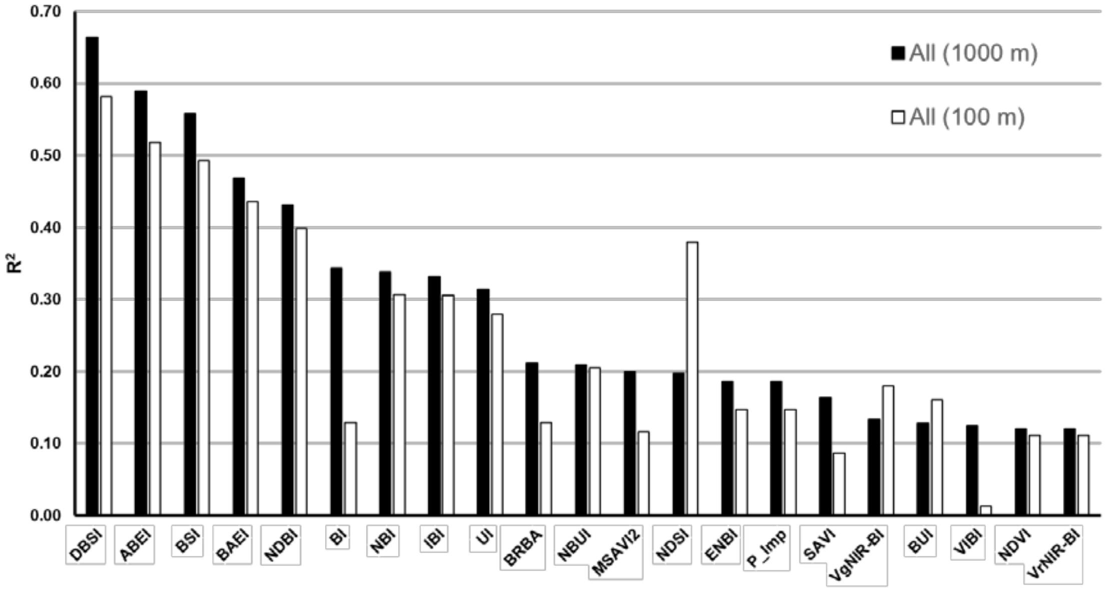


Figure 4. Correlation analysis between observed land surface temperature (LST) and the 21 spectral indices (SIs) calculated for "ALL" class at 1000 m and 100 m resolutions.

Scatterplots of best SIs - LST correlation at scale of 1000 m shown for "urban" class (figure 5) and for the "ALL" class (figure 6).

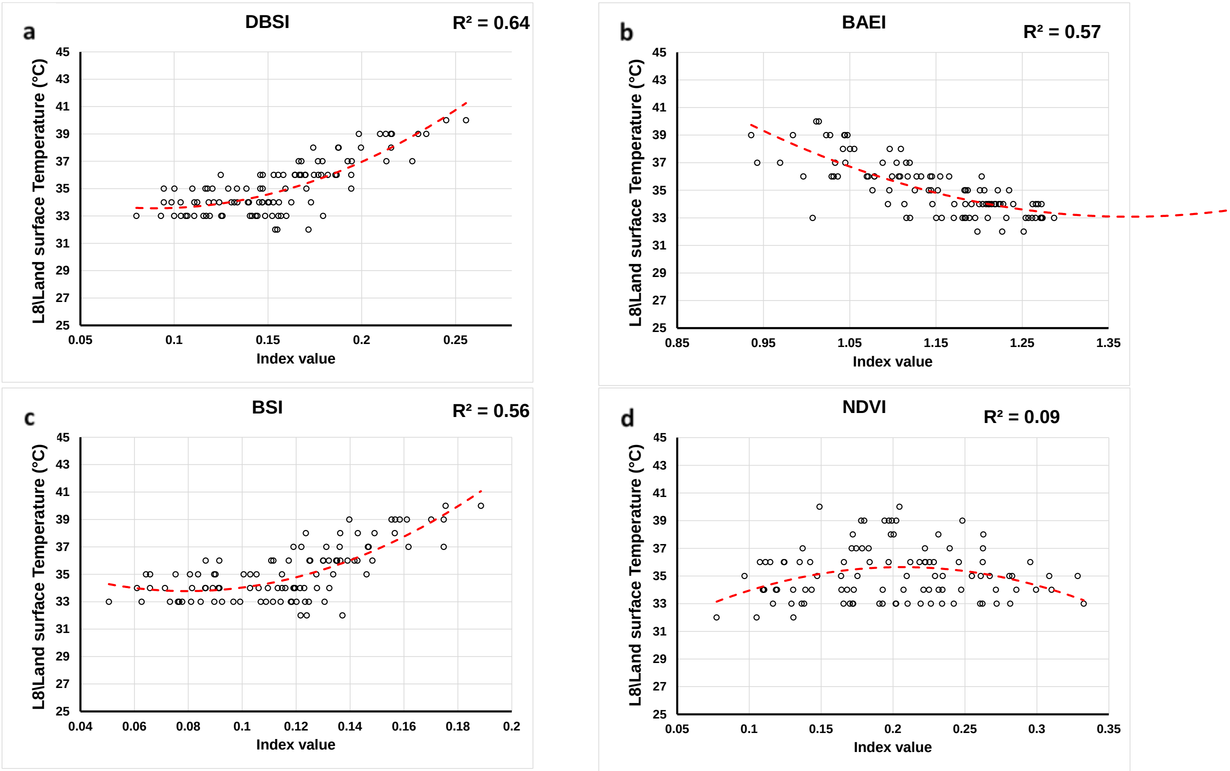


Figure 5. Scatterplots of spectral indices vs observed Landsat 8\land surface temperature for the "urban" class at LR scale (1000 m), using the second order polynomial fitting model.

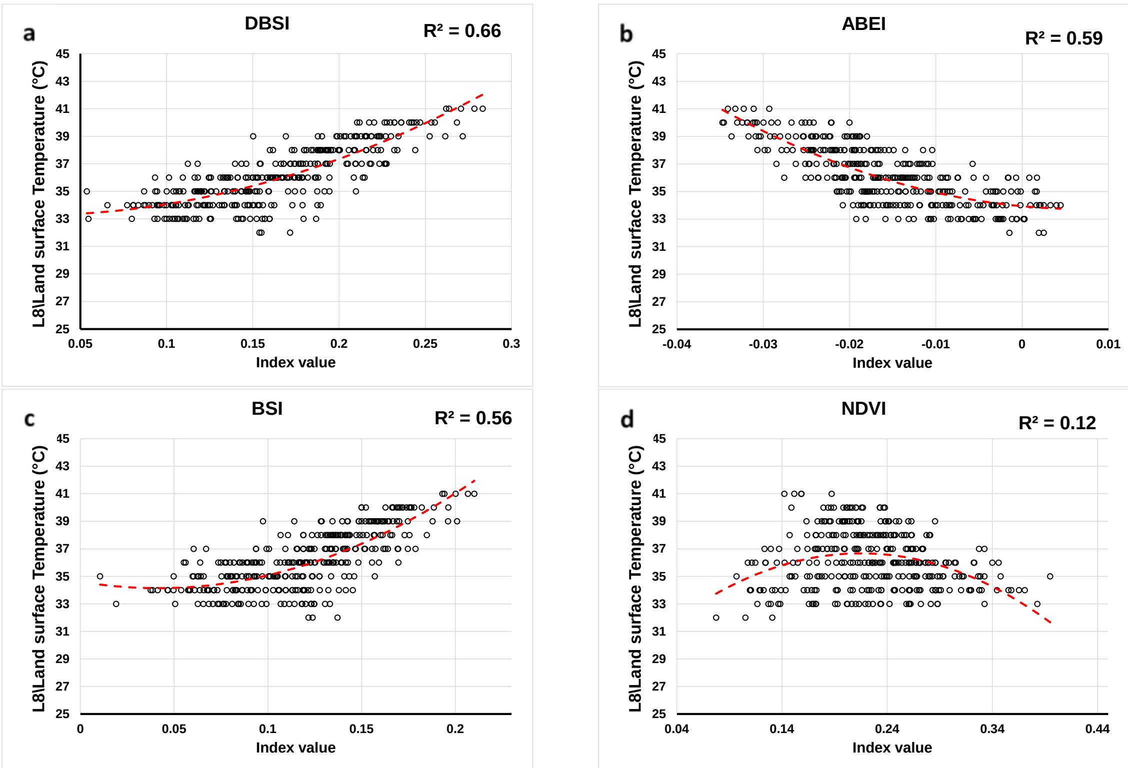


Figure 6. Scatterplots of spectral indices vs observed Landsat 8\land surface temperature for the "All" class at LR scale (1000 m), using the second order polynomial fitting model.

Figure 7 shows the evaluation of sharpening based on spatial correlation analysis (R2 and RMSE error) with coincidence images of Landsat 8\LST image at the downscaled target resolution 100m

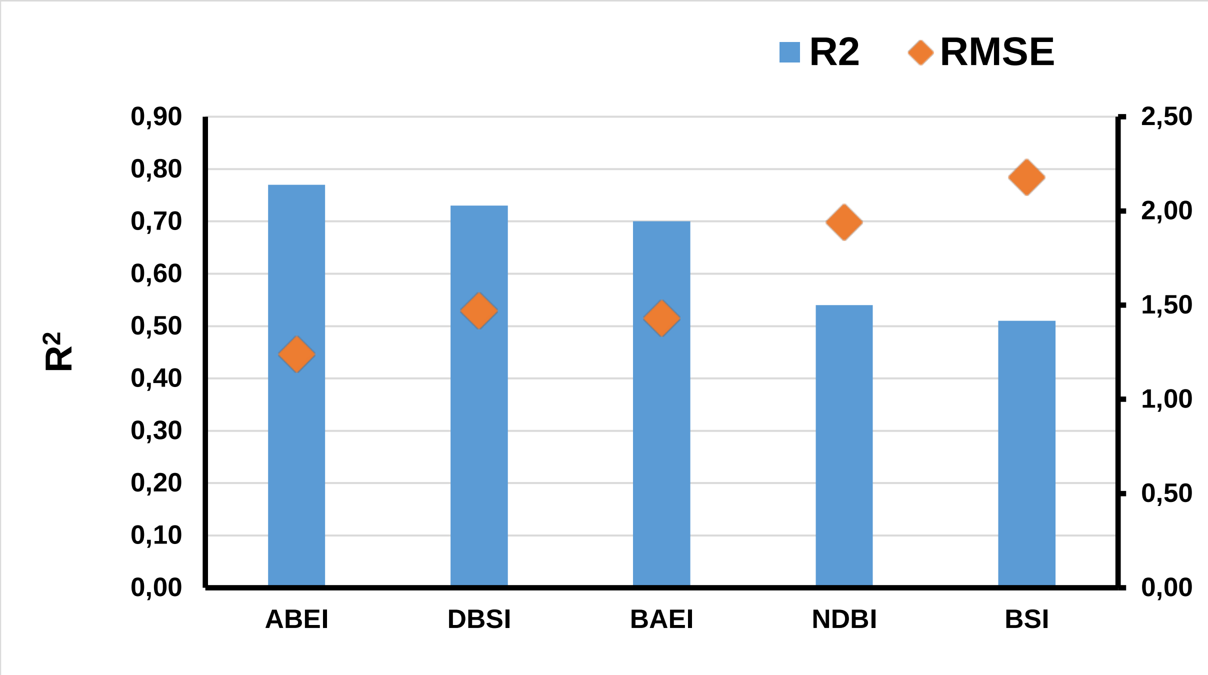


Figure 7. Correlation analysis (R^2 and RMSE) between observed sharpened and observed (LST) calculated for "ALL" class at 100 m resolutions

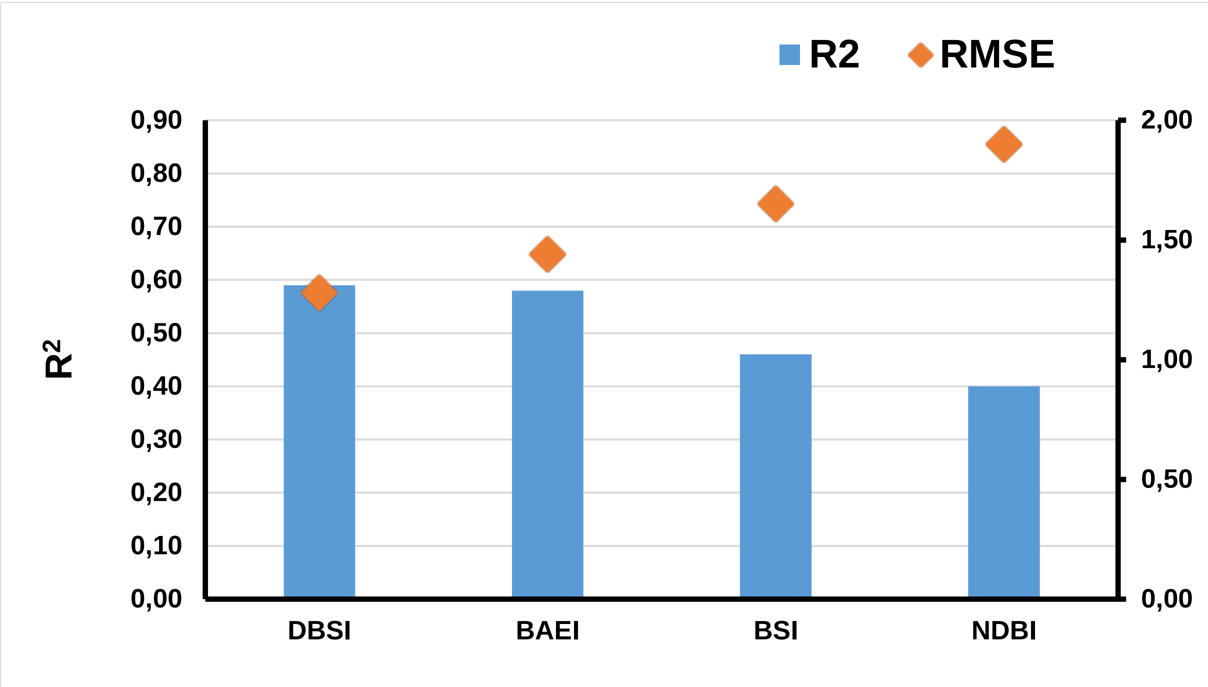


Figure 8. Correlation analysis (R^2 and RMSE) between observed sharpened and observed (LST) calculated for "Urban" class at 100 m resolutions

The best-downscaled products have been evaluated using the absolute error differences, where observed image minus sharpened image is <=2 °C (yellow colour). For "All" class (Figure 9), best absolute error difference is shown for SIs in order; ABEI (90.9%), BAEI (90.7%), DBSI (85.6%), NDBI (85.3%), and BSI (84.2%), and for "urban" class (Figure 10) is in order; DBSI (90%), BAEI (86.5%), BSI (86.5%), and NDBI (81.4%).

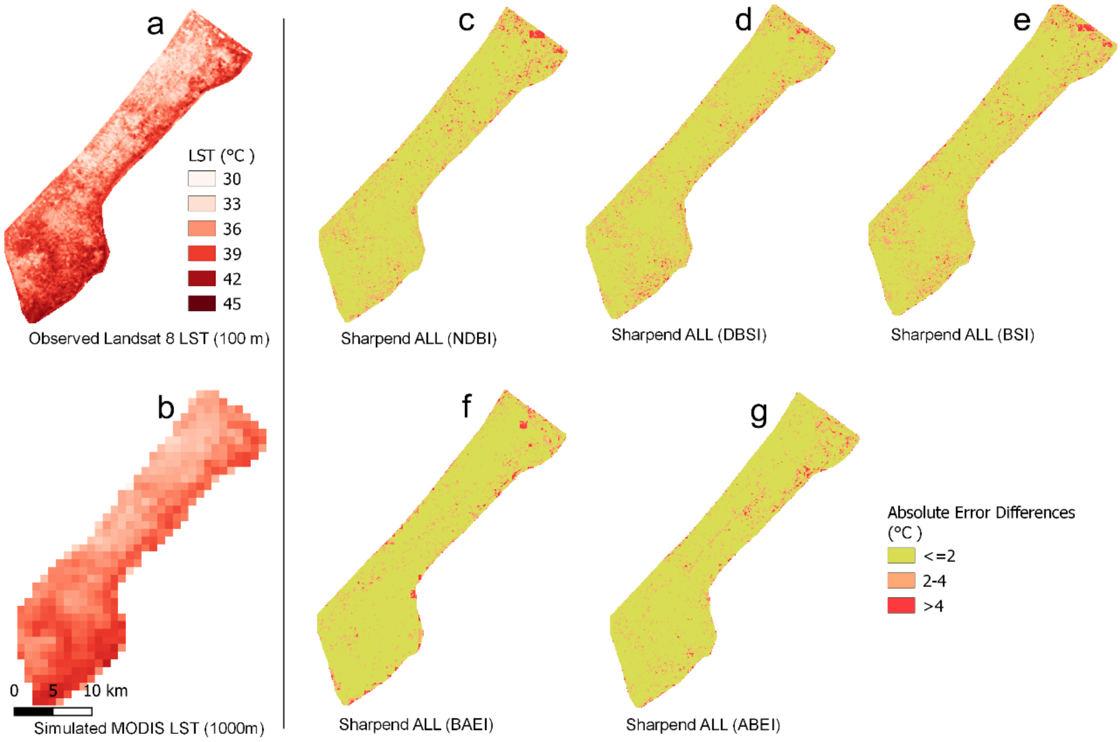


Figure 9. Observed Landsat8\LST-100m (a) and simulated LST-1000m (b) versus the sharpened LST at 100m resolution for the "All" class, based on the indices; NDBI(c), DBSI(d), BSI(e), BAEI(f), and ABEI (g). Absolute error difference calculated by = Observed LST – Sharpened LST using ABEI (h).

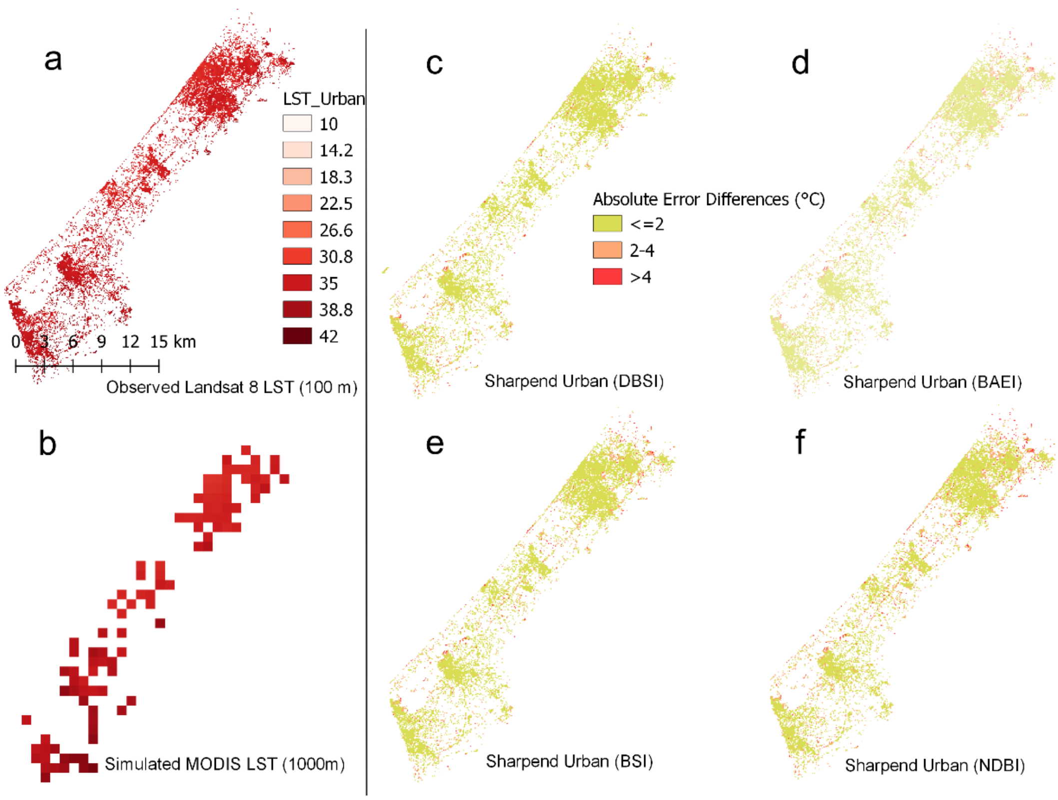


Figure 10 : Observed Landsat8\LST-100m (a) and simulated LST-1000m (b) versus the sharpened LST at 100m resolution for the "urban" class, based on the indices; DBSI(c), BAEI(d), BSI(e), and NDBI (g).

Outlook for the Future

In the future, real observations from MODIS\LST images (1000 m) can be tested and compared with these research findings. In this application, simulated MODIS\LST image was critical to propose the best-case scenario that full coincidence between LST images of both low-resolution image (MODIS at 1000m) and the higher observed LST image and spectral bands (Landsat 8 at 100 m)

This research is limited to the spatial variation of the LST in the daytime during the dry season of an arid and semi-arid climate area. Other temporal variations including seasonal, diurnal might be useful for the validation of SIs - LST relationships within areas have similar arid and semi-arid climate types.

In the "urban" class, although both indices (MSAVI2 and P_imp) have the highest correlation at 100 m resolution, however, a lower correlation ($R2 = 0.20$) at 1000 m resolution, which reveals they are a scale-dependent and may not be useful for downscaling LST from 1000 m resolution. They might be suitable to downscale LST from 100 m to higher resolutions (e.g., Landsat 7 ETM+ 60 m resolution).

Mapping of urban Land Surface Temperatures by the future THRISHNA mission : focus on inversion and sharpening methods

EARSeL Liege 2021
Abstract
Corresponding Author: aurelie.michel@onera.fr

Aurélie Michel[1], Carlos Granero-Belinchon[2], Xavier Briottet[1]

[1] ONERA-DOTA, University of Toulouse, FR-31055 Toulouse, France,

[2] IMT Atlantique, Lab-STICC, UMR CNRS 6285, F-29238 Brest, France

KEYWORDS (5): LST, URBAN AREAS, TES, SHARPENING, TRISHNA

The challenge

CATUT (for mapping of urban temperatures by TRISHNA) was a CNES – funded research project whose aim was to prepare the future multispectral mission TRISHNA by assessing the performances of LST retrieval over urban areas. TRISHNA is assumed to be launched in 2025 and is a joint-mission between CNES and ISRO. The multispectral sensor onboard will cover all spectral ranges from visible to the thermal infrared (in 4 bands) with a 57-m spatial resolution and a 3-day revisit. The mean objects size in urban areas (about 10-m wide), the great spectral variability of surface urban materials, the 3D structure and the LST heterogeneity lead to uncertainties in the LST retrieval. The CATUT project had two objectives : 1/ assess and improve the performance of inversion methods over urban areas, 2/ compare different unmixing methods over urban areas, in order to explore new developments and provide adapted procedures for the future TRISHNA data processings.

Methodology

TRISHNA data was simulated from 4-m airborne images acquired during the ESA DESIREX campaign in 2008 over Madrid. Two radiative transfer codes called "COMANCHE" and "COCHISE" were used to perform atmospheric corrections with atmospheric profiles from the DESIREX campaign, allowing to simulate Top of Atmosphere (satellite) data and recover Bottom of Atmosphere products. The images were then undersampled according to TRISHNA specifications. One commonly used LST retrieval was applied : the Temperature Emissivity Separation (TES) algorithm. This method needs to be calibrated on many materials spectra. A specific urban-oriented database has been developed, in contrast with other studies that use most of the time a large proportion of natural spectra to calibrate the algorithms. Thus, this database was created to maximize the representativeness of urban areas. Once the LST retrieved, several sharpening methods that link the LST with a shortwave index have been used: DisTrad (Disaggregation of radiometric surface Temperature), Thermal Imagery SHARPening, Area-To-Point-Regression Kriging (ATPRK), Adaptive Area-To-Point-Regression Kriging (AATPRK), Urban Thermal Sharpener (HUTS) and Multiple Linear Regressions (MLR). Different spatial resolutions have been simulated to study the performance of the sharpening methods across resolutions.

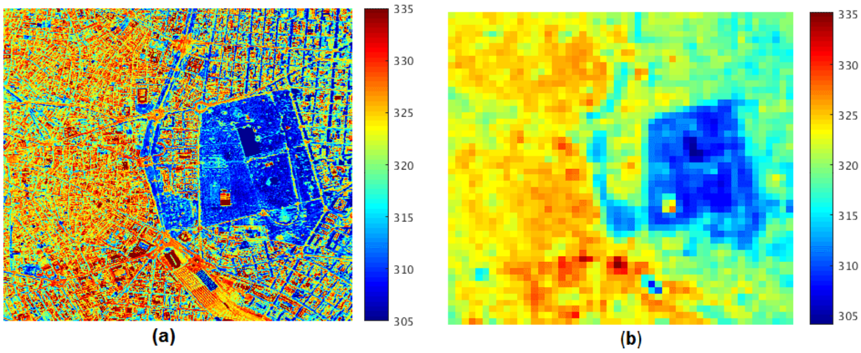
Results

The satellite and airborne configuration are studied to see the impact of the new database. The calibration for the 4-band TES gives a RMSE of 0.016, the validation gives a RMSE of 0.013. At airborne resolutions, the 4-band TES presents a mean difference of around 1K with the reference. Comparison between 4-m and 60-m spatial resolutions gives a good agreement for the mean LST. Errors are due low-emissivity materials (especially metallic surfaces) and the MMD-law that is not optimal for natural materials due to the density of artificial ones. For the sharpening, 20-m LST images were obtained undersampling the 4-m images. ATPRK method gives the best performance for any tested resolution and gives from 60m to 20m a Structural Similarity Index of 0.42 and a RMSE of 2.08K, when NDBI is used as shortwave index. However, very similar performances were obtained with NDVI, indicating the needless of a SWIR band. The hypotheses on resolution invariances used on every sharpening method have been studied, and even if they are not completely matched, the performances of the methods for the study case are not influenced.

Outlook for the future

Future works include improvements and fusions of inversion methods. TES could be hybridized with the Split-Window algorithm. More complex methods in the Bayesian framework could be applied. For the sharpening, the so-called methods were used with sensors that acquire in the VNIR and TIR domains so other methods should be tested for TIR-only sensors. Also, fusion of radar data and/or use of energy transfer models can help to define the 3D structure and lead to correction factors. Eventually, all these results come from the characterization of a mid-latitude city during summer but these methods could be dependant of season and city climate so future research could be done in order to study other cities and generalize to arbitrary urban areas.

Figure 1 - LST in K over the Retiro Park area in Madrid retrieved with the 4-band TES algorithm (a) at a 4-m spatial resolution (b) at a 60-m spatial resolution.



EARSeL Liege 2020
Abstract
Corresponding Author: schoen@ife.uni-hannover.de

MONITORING WATER VAPOUR DISTRIBUTION OVER CITIES USING GALILEO SIGNALS FROM CONNECTED VEHICLES: A FEASABILITY STUDY

Steffen Schön[1], Lucy Icking[1], Gaël Kermarrec[2]

[1] University of Hannover, Institut für Erdmessung, Germany
[2]University of Hannover, Geodetic Institute, Germany

KEYWORDS: WATER VAPOUR, GALILEO, AUTONOMOUS VEHICLE, COPERNICUS, URBAN PLANING

The challenge

Highly populated areas experience high vulnerability to heavy rains. Because these events are expected to increase due to climate change, they need to be accurately modelled and predicted, if possible at the urban island level. However, compared to urban air quality or urban heat island processes, the urban water vapour cycle is less understood and very sensitive to local heterogeneities of surface measurements. Satellite signals from Global Navigation Satellite Systems (GNSS) such as the European Galileo are refracted and delayed in the troposphere thus providing valuable information about water vapour and its transportation. Current GNSS data is however spatially too sparse to provide detailed monitoring and deep insights in the transportation process at urban scales.

Methodology

Taxis, buses and upcoming highly automated vehicles are equipped with GNSS sensors. Besides coordinates, also raw observation data of code and carrier phases can be available. Taking the fact into account that personal vehicles are parked in streets for long periods of the day, they have the potential to act as sensors and provide dense dual-frequency Galileo measurements of tropospheric zenith total delay to be interpolated. This will result in high-resolution water vapour maps, which are of interest for numerical weather prediction, but also for urban planning at high temporal and spatial resolution.

In order to solve this task, two requirements must be fulfilled: (i) The vertical position of the antenna mounted on the vehicles must be known very precisely, i.e. at cm-level. (ii) The urban environment and urban canyons are challenging for GNSS signal propagation. Thus potentially reflected or diffracted GNSS signals must be excluded from the further computations.

In this feasibility study, we will use realistic simulations based on your experiments from real GNSS data in urban environments to evaluate the potentials and shortcomings of the proposed strategy.

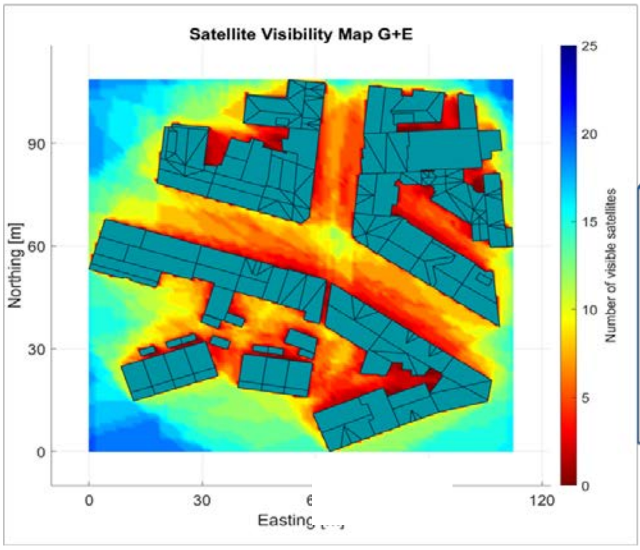
Results

In a first step, taking the example of the city of Hannover, Germany, the undisturbed GNSS signals in typical inner city environment was assessed thanks to freely available 3D LoD2 city models. To this end, the typical parking areas in the streets were identified and rastered in a 2D 1m x 1m grid. For each point the number of directly visible GNSS satellites is computed by an ray-tracing approach in the 3D city model. We will show that shadows of the buildings affect heavily the number of visible satellites (typical values reaches less than three for a single GNSS and up to 12 for a GPS Galileo combination).

In a next step, the estimation of the zenith wet delays is performed. We will show to which extend the quality of the estimates suffers from the restricted satellite visibility and how a connection at the level of urban islands of the different zenith wet delay estimates in a spatio-temporal stochastic process can improve the situation.

Outlook for the future

The results highlight the synergies that will arise from the duality of the navigation problem: for current investigations of connected vehicle for navigation tropospheric delays are important error sources for the GNSS-based navigation while once the positioning problem solved they are valuable information for high resolution water vapour monitoring.



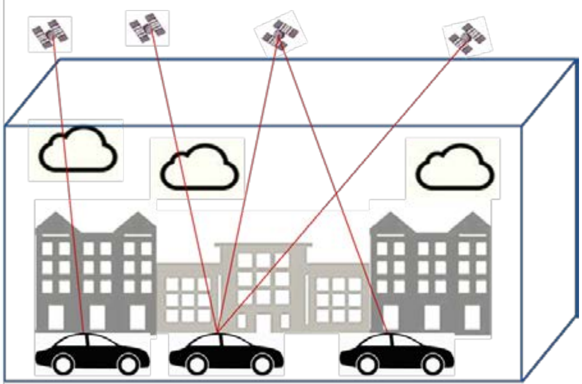


Figure Parked connected vehicles allow the retrieval of zenith total delay with a high spatial and temporal resolutions for urban planning (Left: Satellite visibility for GPS and Galileo in an urban environment in Hannover, Germany, Right: principle idea of the concept)

Early detection of *Heracleum mantegazzianum* (Giant Hogweed) from UAV images using SVM and OBIA

EARSeL Liege 2020
Abstract
Corresponding Author:
sheebalawrence93@gmail.com

Sheeba Lawrence[1], Wietske Bijker[2], Valentyn Tolpekin[3]

[1] eLEAF B.V., the Netherlands
[2] University of Twente, Faculty ITC, the Netherlands
[3] ICEYE, Finland

Keywords: Unmanned Aerial Vehicle, Support Vector Machine, Object-Based Image Analysis, Giant Hogweed, *Heracleum mantegazzianum*

The challenge

Heracleum mantegazzianum is an invasive species that was introduced to Europe in the 19th century as an ornamental plant, which spread through the green spaces of the cities. Early detection and eradication are important because of the health risk (phototoxic burns) for the urban population using these spaces for recreation. Previous studies in remote sensing use Giant Hogweed's umbels to detect the plant during the flowering and early fruiting season (June to August). This limits the period of data acquisition and the time window for eradication measures, because Giant Hogweed depends on seed dispersal (August to October) for its spread. Hence, this research used both pixel-based (SVM) and object-based (OBIA) approaches for an early detection by using the leaves of the plant on UAV images. As a third approach, this study also revealed that UAV images could be used as an input for deep learning based mobile field application (ObsIdentify for plants).

Methodology

The images, acquired from the UAV, are pre-processed and made into orthomosaics. The main goal of the SVM workflow is to determine the optimal hyperplane that maximises the margin between two classes. The OBIA workflow can be divided into two steps: segmentation and classification. Both approaches are carried out for different flying heights. Accuracy assessment showed the degree of success of the classification.

Obsidentify for Plants app was developed to use the photos that are taken in the field. Instead of field photos, the UAV images of all flying heights are uploaded and the 'ID' button is clicked to identify the species.

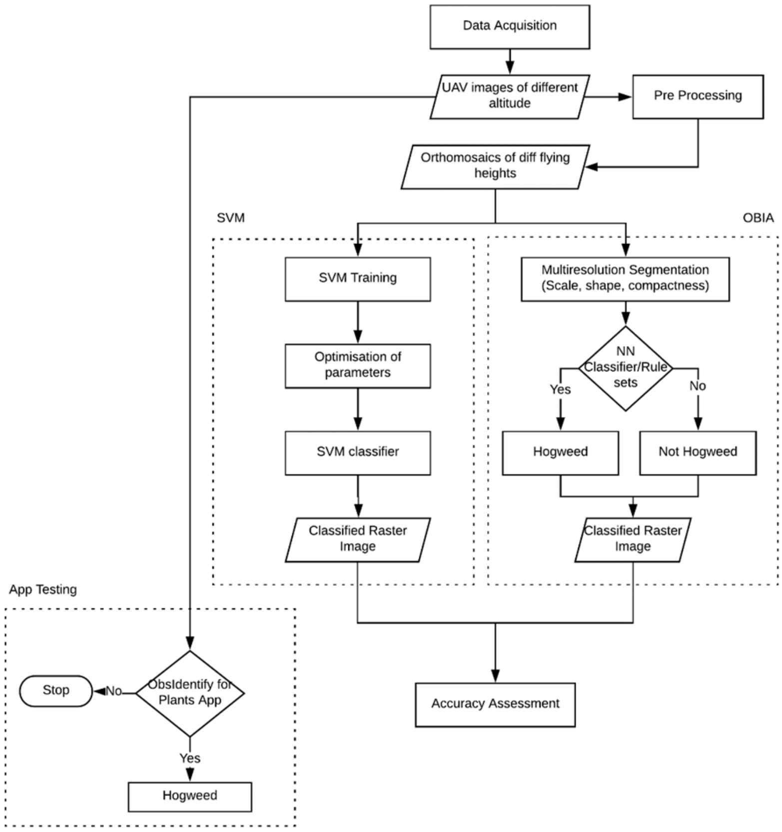


Figure 1 Methodology flowchart

Results

Both methods performed well, but SVM was more time effective even though it produced salt and pepper effect in the resulting map (figure 2). The accuracy of OBIA was less for low flying heights due to the effect of shadow, and in that case, a targeted analysis focusing on the shadow region was carried out to increase the accuracy. A high overall accuracy, between 91% and 97%, which was achieved for both methods, indicating that early detection is possible by using only the spectral information of the leaves of the plant. The app ObsIdentify for plants also showed promising results. The app produced accurate results even where the images are shadow prone.

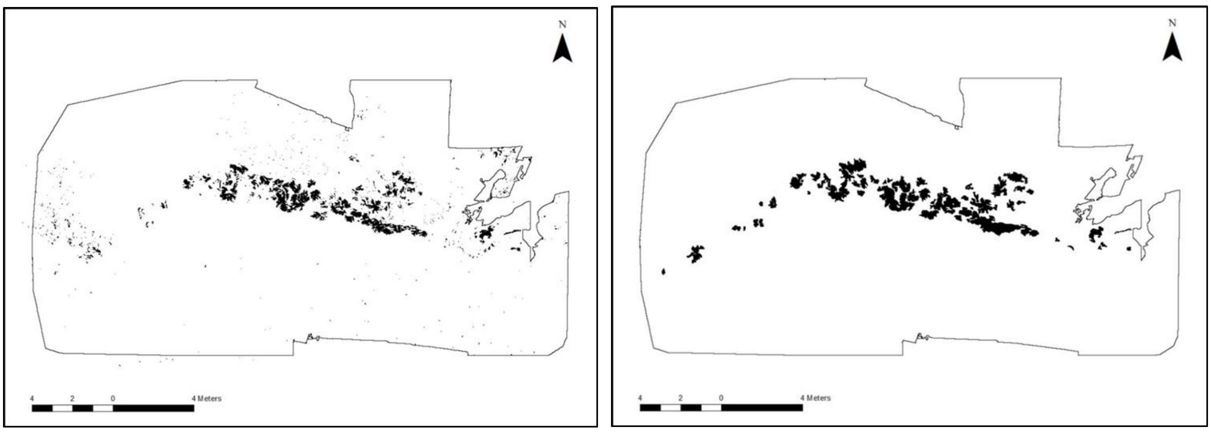


Figure 2 (a) Classified raster image from Support Vector Machine showing salt and pepper effect and (b) classified images raster from Object Based Image Analysis. Hogweed is shown in black and Not Hogweed is shown in white.

Outlook for the future

Further research should determine if there is any plant spectrally similar to Giant Hogweed. In that case, the OBIA method can be used to define a new parameter to further differentiate Giant Hogweed from other plants. In addition, a natural progression of this work would be to find an integrated solution for the effect of shadow rather than separate, targeted analysis. For example, a spatial context can be defined to enable classification of Hogweed image objects from both shadow and sunlit region without segmenting the study area into two separate regions. A further study on using the algorithm from deep learning based app ObsIdentify could be very fruitful research for invasive plant detection.

Mapping of tree species in the city: challenges of the application project

EARSeL Liege 2020
Abstract
Corresponding Author: dkopec@mggpaero.com

Dominik Kopeć [1,2], Jan Niedzielko[1], Adam Kania[3], Justyna Wylazłowska[1], Anna Halladin-Dąbrowska[1], Jakub Charyton[1], Łukasz Sławik[1,4]

[1]MGGP Aero Sp. z o.o., Poland
[2] University of Łódź, Department of Geobotany and Plan Ecology, Poland
[3] Definity Sp. z o.o., Poland
[4] University of Warsaw, Department of Geoinformatics, Cartography and Remote Sensing, Poland

Keywords: Hyperspectral, LiDAR, Airborne, Data Fusion

The challenge

Recent studies have shown that fusion of hyperspectral (HS) and airborne laser scanning (ALS) is a relevant set of remote sensing (RS) data for mapping tree species in urban space. The maps obtained with HS and ALS data fusion are characterized by a large number of map units while maintaining high values of accuracy measures. These features have caused that maps of taxa distribution made using machine learning algorithms are nowadays more and more often chosen by the managers to inventory natural resources. However, the applicability of RS solutions depends on the details of the map legend. The expectation of the end user is to receive a map that identifies all the main taxa of the trees present in the analyzed space. Therefore, urban areas, which are characterized by a very high taxonomic diversity, pose a great challenge for the application of RS. Our goal was to create a map of tree taxa using RS methods for the whole area of Warsaw, which contained 52 specified classes.

Methodology

The research was conducted in the administrative area of Warsaw (the capital of Poland) with an area of 517.24 km2 (1.77 million people). The study area was divided into two, almost equal parts: north-western (NW) and south-eastern (SE). The presented results concern the NW part of Warsaw (area of 243.35 km2) and have been carried out in 2018/2019. The first stage of the project included the acquisition of HS and ALS airborne data and on-ground reference data. The airborne data were obtained in August 2018. HS data were acquired using Hyspex VS-725 sensors, with spectral resolution of 400-2500 nm and spatial resolution of 1 m2. ALS data were obtained using Riegl VQ-780i and Riegl VQ-1560i-DW sensors with cloud density equal to 42 points/m2. In the same vegetation season on-ground reference data for trees were collected, which was necessary for supervised classification. They were evenly distributed in the study area and took into account the quantitative (frequency) and qualitative (taxonomic) variability. The second stage of the project was processing of HS i ALS data and remote sensing analyses. The workflow of these analyses included: tree crowns segmentation, feature selection, legend optimization, and resulting map production. The last stage was to perform field control of the quality of the resulting map in 50 control areas covering different types of urban greenery. The control included checking the map for both segments shape and correctness of classified taxa.

Results

For the purposes of obtaining on-ground reference data, 12,670 samples were collected for trees that belonged to 244 taxa. Representation for individual taxa varied and ranged from 1 to 777.

As a result of the segmentation process, over 2.5 million tree crowns were separated, meeting predefined criteria of minimum height (2.5 m) and area (1m2). Initial classifications with over 140 reference taxa classes reached accuracies of Kappa 0.65, but many individual (especially less represented) classes had scores of 0%, preventing operational use.

An innovative framework for classification-based optimization of combining individual taxa into aggregate units proposed over 50.000 classification models with different settings, which were evaluated.

The final aggregated class legend of the resulting map consists of 52 units, which were created at different levels of taxonomic detail. The global Kappa accuracy was 0.86, with the F1-scores of individual classes ranging from 0.50 to 0.97. By optimizing the legend it was possible to minimize the number of undistinguished ("other trees") class, that constituted only 2.0% of all segments. 7.0 % segments remained unassigned to any class due to various factors like shadow, reduced vitality, sparse crown.

Field control of the resulting map, which validated the correctness of both segmentation and taxa classification, estimated the accuracy of the final product at the level of 77.57%.

Outlook for the future

The presented scheme of tree taxa classification has been developed, tested and accepted within the framework of the order for the Warsaw management units. Today it is a ready-made solution, enabling the implementation of the method in other cities. Further development works will be carried out in the direction of even better automatic optimization of the legend of the result map, which will be adjusted to the needs and expectations of the end user. The challenge for the future will also be to shorten the time needed to prepare the result map and implement actions at the "real time" level.

The project is financed by the Warsaw City Hall.

Copernicus Land Monitoring Service new High Resolution Layer 2015: the Small Woody Features – research, development and production story

EARSeL 2021
Abstract
Corresponding Author :
mailto:amasse@groupcls.com

Antoine Masse[1], Loic Faucqueur[1], Nathalie Morin[1], Pierre-Yves Remy[1], Justine Hugé[1], Fabrice Dazin[1], Carlos De Wasseige[1] and Christophe Sannier[1]

[1] CLS Lille, 61rue de la Cimaise, Villeneuve d'Ascq, France

Keywords: Copernicus, EEA, OBIA, High Resolution Layer, Small Woody Features

The challenge

High Resolution Layers (HRL) are part of the Copernicus Land Monitoring Service (CLMS) pan-European component coordinated by the European Environment Agency (EEA). HRL Lot 5 Small Woody Features (SWF) for the 2015 reference year is a new ambitious product which aims at delivering homogeneous information on small woody features across EEA countries. It includes several structures of woody vegetation, such as linear features (hedgerows, line of trees, etc.) but also small patches of woody vegetation. The main challenges of this major and pioneering mapping exercise are the nature of the object to extract (maximum width of 30m and a minimum length of 50m for linear features and a minimum and maximum area of 200 and 5,000 m2 respectively for patchy features) and the quantity of data to process (Pan-European coverage with approximately 6,000,000 km2 and more than 37,000 VHSR EO data scenes).

Methodology

The workflow designed to produce a harmonised HRL2015 SWF layer for the reference year 2015 includes the following steps: (1) VHSR image preprocessing (radiometric and geometric corrections, pan-sharpening), (2) reference database preparation (extraction of SWF reference from previous reference datasets and automatic verification), (3) automatic supervised classification, (4) internal validation, (5) post-processing (vector smoothing and differentiation between linear polygons, patches or additional small woody features), (6) manual and thematic enhancement, (7) rasterisation of HRL2015 SWF vector layer at 5m spatial resolution and aggregation to 100m resolution, to derive SWF density. The methodology is based on Geographic Object-Based Image Analysis (GEOBIA). It relies on two main components which are feature extraction based on attribute profiles, and a semi-supervised classification using random forest algorithm. The user can easily improve the quality of the training set by providing foreground and background samples, which are needed to comply with the large and heterogeneous area from Iceland to Turkey.

Results

CMLS HRL 2015 SWF vector layer as well as HRL2015 SWF 5m and 100m resolution raster layer were produced successfully over the whole EEA39 area (including French DOMs), except for the areas not covered by the VHR IMAGE 2015 dataset (1.5% of EEA39 area). The 100m raster layer is illustrated in Figures 1 and 2 for a full EEA39 coverage. First results have been published by EEA https://land.copernicus.eu/pan-european/high-resolution-layers/small-woody-features.

Our method was based mainly on open-source solutions, nearly fully automatic. Overall accuracy from internal validation is around 80% aver the whole pan-European area with some parts over 90%.

Outlook for the future

New developments are still in progress to improve the automation and efficiency of the production line. Evolution and adaptation to new thematic mapping will be investigated in the future.

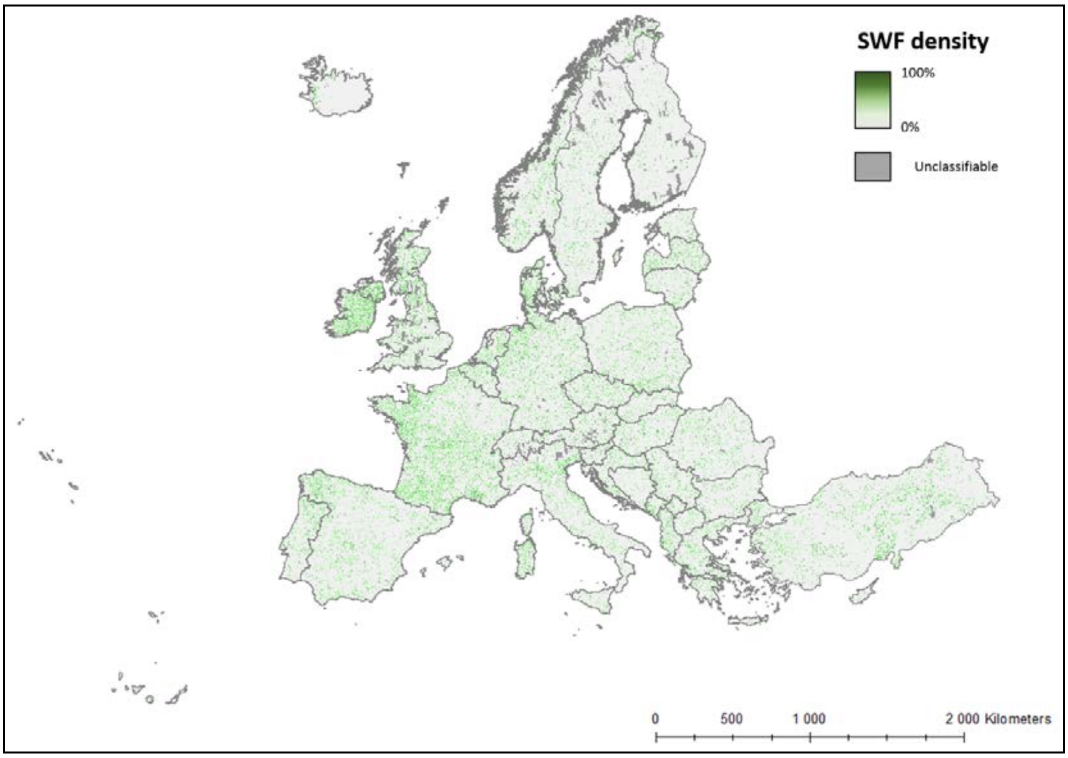


Figure 1 The High Resolution Layer Small Woody features final products (100m raster layer) over continental Europe

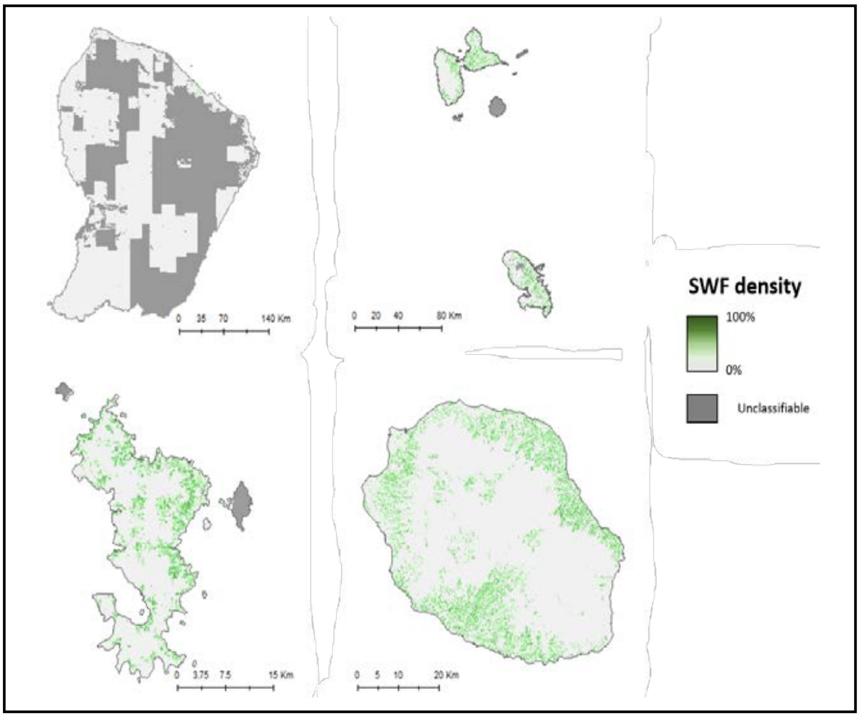


Figure 2 The High Resolution Layer Small Woody features _nal products (100m raster layer) over French overseas

Rapid Country-Scale Inundation Mapping for Urban Planning in Bangladesh Using Copernicus Sentinel-1 Data and Google Earth Engine.

EARSeL Liege 2021
Abstract
Corresponding Author: Lukas.Wimmer@bgr.de

Lukas Wimmer[1], Nicolas Jakob Wagener[1]

[1] Federal Institute for Geosciences and Natural Resources (BGR), Germany

Keywords: Inundation Mapping, Copernicus, SAR, Google Earth Engine, Bangladesh

The challenge

Due to climate change, Bangladesh is experiencing an increase in rural-urban migration movements. Therefore, the demand for safe and cheap building ground is very high. As a result, cities are growing vertically and laterally. Lateral urban growth is limited to suitable building ground. However, eligible areas are often low-lying and therefore prone to flooding during the yearly monsoon season between May and October. Planners and decision makers demand a climate-resilient urban planning including geodata on inundation-prone areas that are reliable, easy to process and easily understandable.

The German-Bangladeshi technical cooperation project "Geo-Information for Urban Planning and Adaptation to Climate Change" aims to strengthen the urban planner's ability in the use and understanding of geodata for selected sites. Google Earth Engine offers an easy-to-use rapid online processing of multi-temporal Copernicus Sentinel-1 data to map the inundation on a country-scale.

Methodology

For the analysis, 174 Sentinel-1 descending scenes from 2015 to 2020 were selected, covering the two weeks of maximum inundation for each year for the entire country of Bangladesh. Using a threshold approach, the inundated areas were extracted from the datasets and exported for mapping.

Results

The heavy rainfalls during the annual monsoon season lead to large inundated areas across Bangladesh. The largest connected affected areas correspond to geological structures or tide-influenced coastal areas: 1. Sylhet depression, west of the city of Sylhet, which is a north-south running regularly inundated basin; 2. Chalan Beel, south-west of the city of Sirajganj, a seasonally inundated marshy inland depression; 3. The delta-region around the cities of Satkhira and Khulna north of Sundarban mangrove forest.

The seasonal inundation leads to a higher river erosion that causes the loss of farmland and pushes the people to migrate to the cities. The data presents an overview on areas that are particularly vulnerable to yearly large-area inundation and on areas that are less regular inundated. Urban planners may use this information to identify less inundation-prone areas as possible space for urban development.

The data processing in Google Earth Engine gives the user a fast and comprehensible opportunity to detect inundated areas on a country-scale using the most recent Copernicus data.

Outlook for the future

Additionally to the country-scale overview of inundation, city-scale inundation maps might show local vulnerabilities and can therefore be useful for urban planning agencies in investment planning and infrastructure development.

Together with additional data (like InSAR for ground deformation patterns, geological maps or land-use information), the inundation data can be used for further interpretation and to detect possible correlations between the different types of data.

With every year of additional data provided by the Copernicus program, the information on regularly inundated areas gains significance. The method is easy to learn and entirely based on free data and free-of-charge software, ensuring a sustainable use and sharing of both.

Acknowledgements

This work was conducted in the framework of the project Geo-Information for Urban Planning and Adaptation to Climate Change, a project of technical cooperation between the Geological Survey of Bangladesh (GSB) and the German Federal Institute for Geosciences and Natural Resources (BGR).

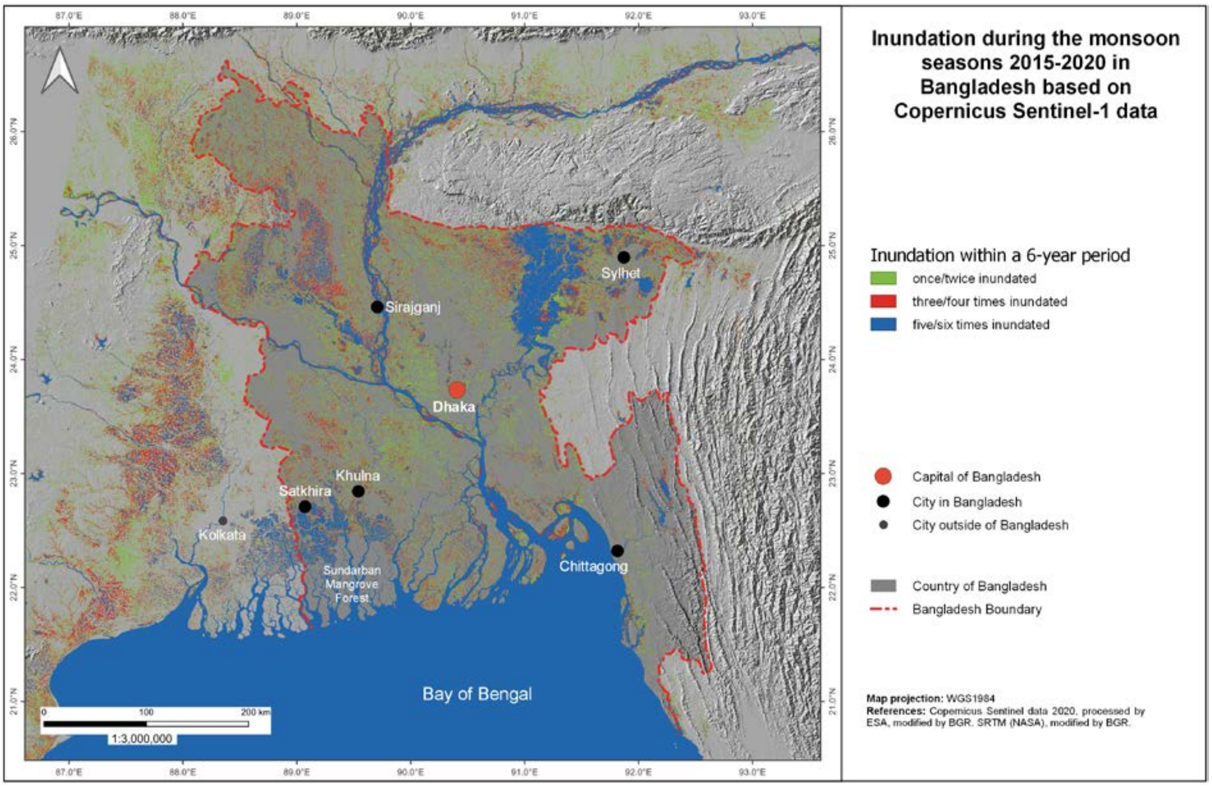


Figure 1 Inundation during the monsoon seasons 2015-2020 in Bangladesh based on Copernicus Sentinel-1 data.

Evaluation of Green Infrastructure Development with High Spatial Resolution Worldview-2 Images in the Baoshan District, Shanghai, China

EARSeL Liege 2021
Abstract
Corresponding Author:
Lars.Gruenhagen@rub.de

Lars Gruenhagen[1], Malte Bührs[1], Matthias Falke[1], Luis Inostroza[1, 2], Harald Zepp[1], Carsten Jürgens[1], Thomas Schmitt[1], Nannan DONG[3]

[1] Ruhr-University Bochum, Geography Department, Germany
[2]Universidad Autónoma de Chile, Chile
[3] Tongji-University, College of Architecture and Urban Planning, China

Keywords : Earth Observation, Urban remote sensing, land-use, Ecosystem Services, Worldview-2

The challenge

Rapid urbanization and population growth in the northern industrial Baoshan district of Shanghai (s. Fig. 2 b) causes tremendous pressure on environmental quality and natural resources in addition to challenges emerging from climate change. The Shanghai municipal government is willing to stop urban sprawl and attempts to enforce a zero-growth strategy in terms of land consumption and population growth. In this political framework, the Baoshan District People's Government 2019 established a general land-use plan for spatial planning of the Baoshan District 2017-2035 with a scale 1:1500. Further, this plan regulates ecological space and the urban development boundary, which aims to stop the urban sprawl. In addition, the land-use plan promotes strategic green infrastructure (GI) to deliver ecosystem services (ES) to sustain human health and wellbeing in Shanghai. The benefits of GI are reflected in the strengthening of multiple ES.

Methodology

The goal was to evaluate land-use (LU) changes, to detect GI and roadside green in Baoshan District. Therefore, very high-resolution Worldview-2 satellite images with 50 cm spatial resolution from 2017 were used. Training areas for different tree species were identified by field visits of the Baoshan District as well as existing GI. Different tree species like camphor tree (Cinnamomum camphora) were identified by onsite visits together with other available Data like OpenStreetMap data (© OpenStreetMap-contributors), due to mapping restrictions in China. Over 10.000 random points were created and buffered. Attributes of the training data were assigned accordingly. Further processing by ERDAS Imagine 2018 was established to acquire data as input for the machine learning classification with the algorithm random forest. A result validation assessment took place in comparison of the image segmentation results with a high accuracy of at least 80 %. This workflow produced a high-quality LU of Baoshan's urban form in terms of GI and built-up areas for the year 2017. Roadside green was extracted from the training pixels to create a city tree cadastre by generalizing onsite samples. To compare these findings with the digitalized LU plan for 2035, the assumed LU in 2035 was calculated and compared with the classification results for 2017. Changes in urban form from 2017 to 2035 will be analysed focusing on the impacts on ES.

Results

The satellite image analysis from 2017 shows that according to the LU plan for 2035 (412 km^2) Shanghai municipality intends to restructure industrial areas and warehouses in the Baoshan district towards GI and residential areas (s. Fig. 1). The detailed LU changes according to the LU plan for 2035 will be these: Industrial area and warehouses - 19% (79 km^2), cultivated agricultural land minus three percent (10 km^2), municipal and commercial infrastructure plus two percent (7 km^2), transportation and freight facilities like roads - railway tracks plus six percent (22 km^2) and GI + 13 % (52 km^2) (s. Fig. 1 a).

This contribution underlines the baseline for the new developments and examines the strategies for the attempted net-zero land-consumption in Shanghai.

Focusing these results on ES of GI, tree species and their composition play an important role. In Shanghai only four mayor tree species are dominant, also called as the “four kings”. Their frequency distribution in Baoshan’s GI ranks them as follows: Camphor (Cinnamomum camphora), London Plane (Platanus x acerifolia), Ginkgo (Ginkgo biloba) and Cedar (Cedrus deodara). By using the classification results of the year 2017, a tree cadastre is a main tool to display the tree-specific ES and disservices, such as CO^2-absorption rate or allergic potential. ES and disservices must be considered in advised future planning regarding the challenge of climate change especially in the urban environment of Megacities.

Outlook for the future

These findings are results from a joint research project “Implementation of the ES framework in GI planning for resilient urban development in the Ruhr and in Chinese megacities” funded by the German Federal Ministry of Education and Research.

Overall, the aim of this project is to establish a method of including ES in the planning of urban areas such as Shanghai to highlight the importance of understanding the benefits and challenges of developing GI towards a still ecologically functional but also beneficial tool. For the future, the main goals are to evaluate future LU and their associated ES with regard to GI and residential environments in the Baoshan District. Therefore, additional earth observation and statistical data will be included to refine and optimize our methods, estimates and results. In addition, the joint research project will look closer to the physical properties of trees as a key element of GI.

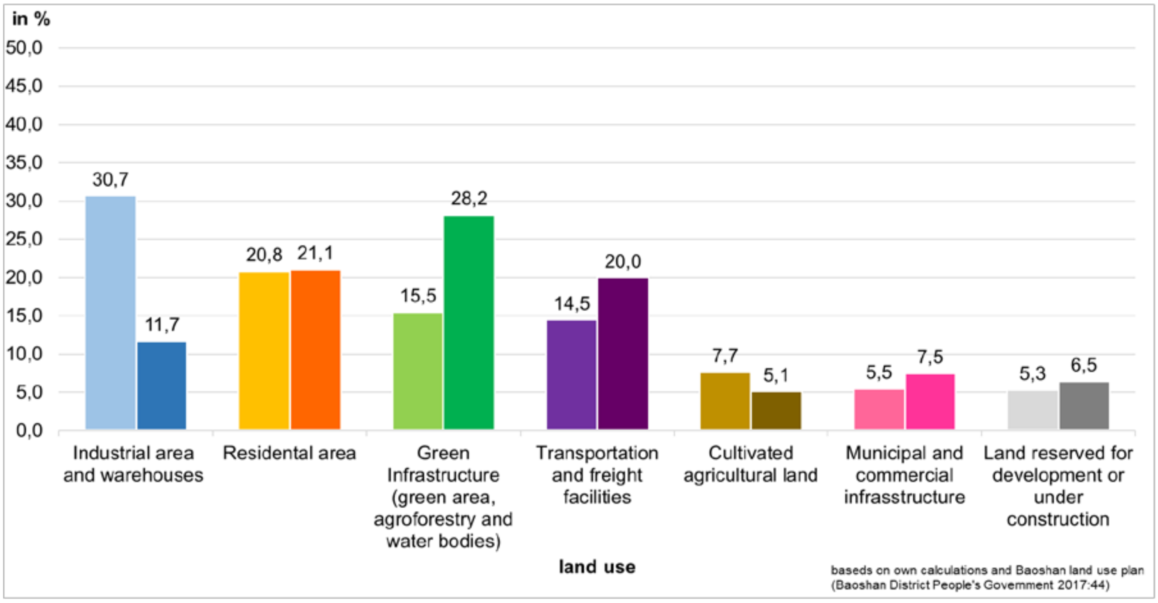


Figure 1 Planned change of land-use ratio for Baoshan District, Shanghai (left bar 2017 and right bar 2035).

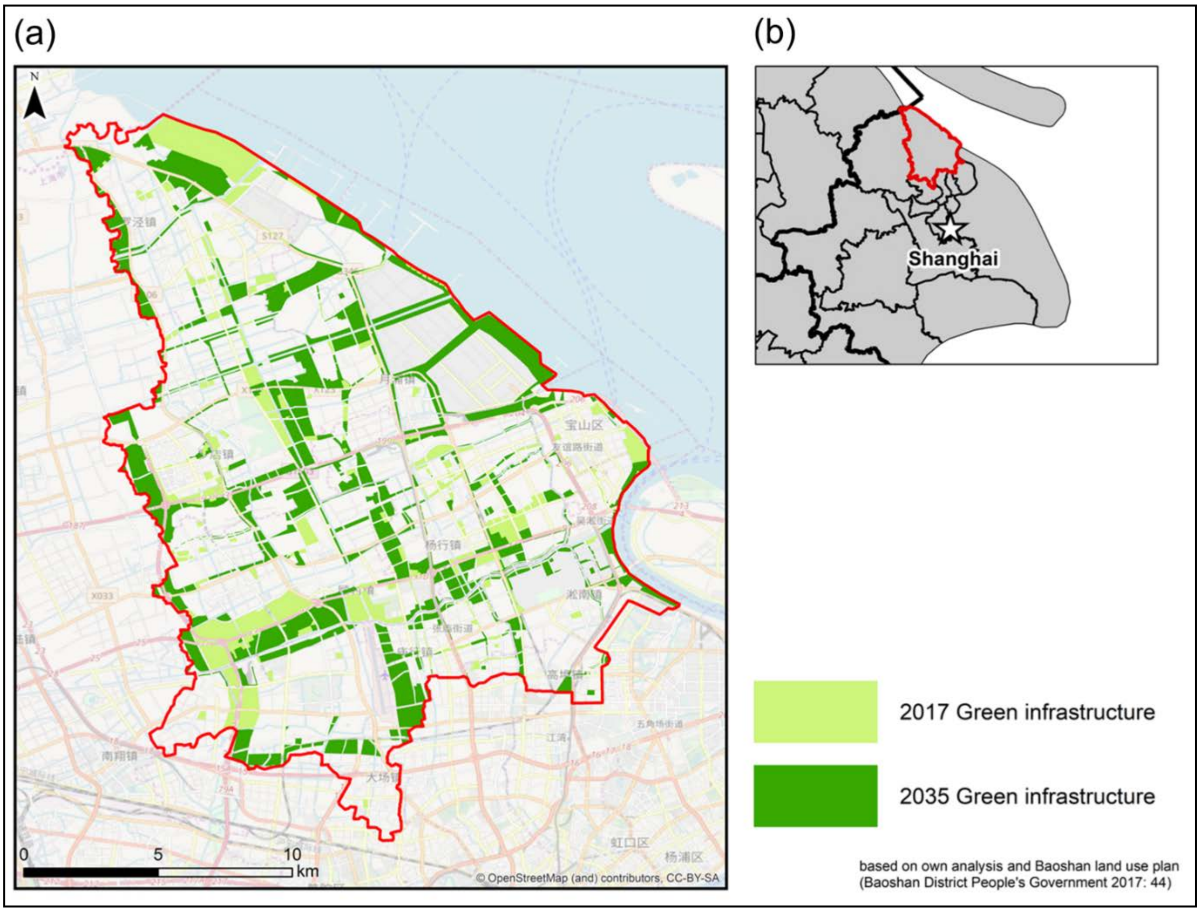


Figure 2 (a) Amount of new GI planned in Baoshan District for 2035 and (b) Location of northern Baoshan district of Shanghai, China.

Keynote Speech – Four-Dimensional Observations of Urban Changes and Environmental Impact Assessments

EARSeL Liege 2020
Abstract
Corresponding Author:
Son.V.Nghiem@jpl.nasa.gov

Son V. Nghiem[1]

[1]Jet Propulsion Laboratory, California Institute of Technology, United States of America

Keywords: Urbanization, Four Dimensions, Radar, Remote Sensing, Environmental Impacts

The challenge

Characterizing and quantifying changes in the urban environment are of the utmost importance as the urban population continues to grow on all continents per the United Nations World Urbanization Prospects. Despite progress in remote sensing of land cover and use change, analyses have primarily relied on satellite images that only account for two dimensions (2D) on the Earth surface. The vertical dimension remains a vital component to comprehensively monitor urban building structures in 3D and to capture socio-economic status mispresented in the 2D confine.

Methodology

Recent remote sensing advances have advanced the ability of Ku-band radar backscatter data acquired globally by satellite scatterometers and processed with the patented Dense Sampling Method (DSM; Nghiem et al. 10.1016/j.isprsjprs.2009.01.004) to monitor urbanization in 3D space (2D lateral extent and 1D vertical build-up) and in 1D decadal time (2000-2009). DSM has been validated in 2D lateral urban expansion (Nguyen et al. 10.1016/j.isprsjprs.2009.01.004) and in 3D building volume (Mathews et al. 10.1016/j.jag.2019.01.004).

Results

DSM provides 3D data products for urban monitoring globally without gaps for cities with different size, shape, and pattern in various climatic and environmental conditions (Mathews et al. 10.1016/j.jag.2019.01.004). This keynote presentation will include results using DSM products to quantitatively capture 3D urban changes to assess both environmental and socio-economic impacts, specifically for Almaty, Austin, Beijing, Dallas-Fort Worth, Hanoi, Ho Chi Minh City, Los Angles, Milan, New Delhi, and Shanghai. DSM products together with urban-climate nested model (e.g. GATOR-GCMOM, Jacobson et al. 10.1029/2018JD029310) and hydrogeology statistical method (e.g. WofE, Stevenazzi et al. 10.1016/j.jenvman.2016.10.057) have found that urbanization can significantly impact air pollution, groundwater contamination, river flow and urban flooding. Socio-economic analyses (e.g. Balk et al. 10.1016/j.landurbplan.2018.07.009) demonstrate that DSM 3D results can capture socio-economic status representing improvements in modern urban living (Figure 1), while other studies using DSM products have illustrated the capability in assessing economic development (e.g. real estate boom), policy change, formation of mega urban agglomeration, and mega urban implementation (such as Jing-Jin-Ji in China).

Outlook for the future

DSM can be modified to process other international scatterometer datasets to extend the time series.

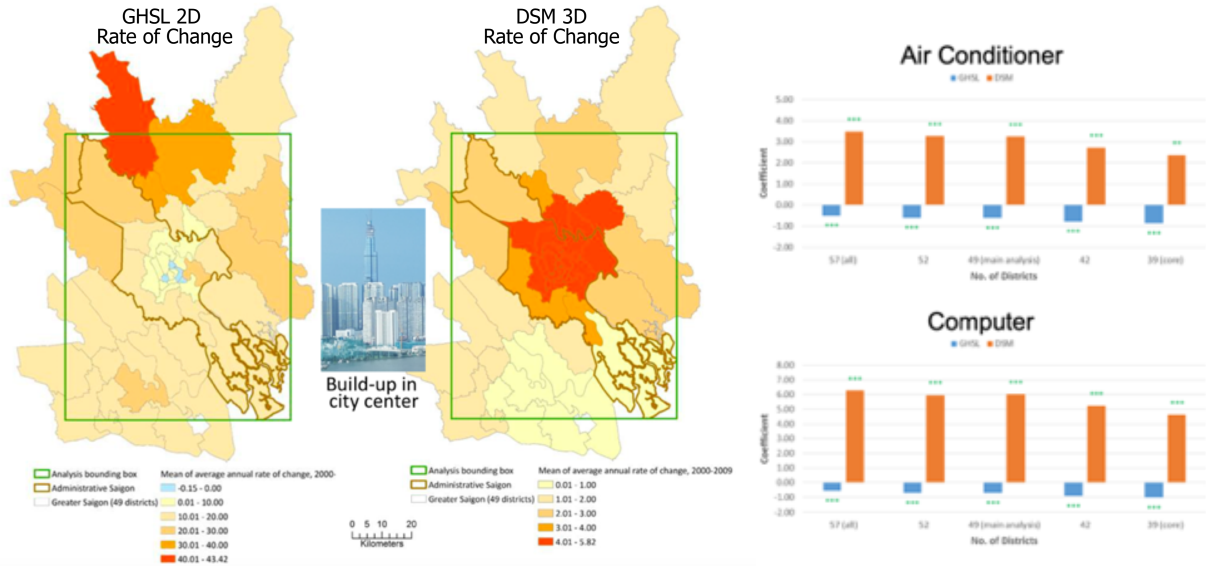


Figure 1. The left two maps show that DSM 3D data product can capture the actual urbanization in the Ho Chi Minh City core with extreme build-up (inset photo) while the GHSL 2D data product unrealistically suggests the urban reduction. The right two graphs illustrate that 3D urban data can correctly represent the increasing socioeconomic status while the 2D result suggests the opposite (Balk et al. 10.1016/j.landurbplan.2018.07.009). In an increasing urbanization trend, the increasing presence in households of necessary amenities such as computers and air conditioners represents a heightened level of socioeconomic status in modern urban living, often in newly developed high-rise buildings found in a dense population centre like Ho Chi Minh City.

Household Wealth in HD: Mapping the Demographic and Health Surveys Wealth Index in Sub-Saharan African Cities with Very-High-Resolution Satellite Data

EARSeL Liege 2021
Abstract
Corresponding Author: sgeorgan@ulb.ac.be

Stefanos Georganos[1], Assane Niang Gadiaga[2], Catherine Linard[2], Tais Grippa[1], Sabine Vanhuysse[1], Nicholus Mboga[1], Eléonore Wolff[1], Sébastien Dujardin[2] and Moritz Lennert[1]

[1] Université Libre de Bruxelles, Department of Geosciences, Environment & Society, Belgium
[2] Université de Namur, Department of Geography, Belgium

Keywords: Wealth Index, Urban, Very-high-resolution, Land Use, Machine learning

The challenge

The high degree of data scarcity in countries of the Global South (GS) hinders systematic evidence-based policy making, particularly with respect to addressing the United Nations Sustainable Goals (UN SDG). At the urban level, up-to-date access to detailed demographic, socio-economic, epidemiological, and bio-physical information is a challenging task. Demographic and Health Surveys (DHS) are a rich source of such information and available in most countries of the GS. Nonetheless, modelling DHS variables for intra-urban analyses is quite challenging as they are randomly displaced to secure privacy. Here, we tackle this issue through the use of satellite derived indicators, machine learning and spatial optimization methods and apply them to model the DHS Household Wealth Index (WI) across several sub-Saharan African cities.

Methodology

Land use/land cover (LULC) information produced for the cities of Dakar (Senegal), Ouagadougou (Burkina Faso), Kampala (Uganda) and Dar es Salaam (Tanzania) are used as input to machine learning in order to predict the DHS WI. The LC maps were initially produced from processing Pleiades and Worlview-3 satellite images at a 50 centimetres resolution through a Geographic Object-Based Image Analysis (GEOBIA) framework while the LU maps are produced at the street-block level, utilizing OpenStreetMap data. All LULC maps are publicly available at Zenodo repositories. To prepare the LULC data for the proposed analysis, we extracted class proportions in buffers around the available DHS survey locations in the 4 cities. To mitigative the effects of displacements with proposed an optimization technique based on random sub-sampling of various locations within the buffers.

Results

Validation of our method in Dakar demonstrated reliable results with or without optimization. The range of agreement between our proposed models and census data at various spatial scales was moderate (correlation coefficient = 0,40-0.59). The relationships between the remotely sensed variables and the WI was mostly non-linear. Notably, LULC classes with a strong socio-economic burden (i.e., street-blocks classified as deprived, or the proportion of swimming pools) exhibited remarkable relationships with household wealth and are semantically interpretable. Consequently, we created predictive DHS WI models for all four cities (Figure 1).

Outlook for the future

A limitation of using satellite VHR information is the increased cost, image-processing knowledge and computational resources needed. Encouragingly, technological advances have allowed for large-scale computing using cloud systems which helps mitigate these issues. Future work should investigate the contribution of open-access satellite data (i.e., Sentinel 1 and 2) for modelling DHS variables, as the transferability potential of our framework will then be truly valorised. Particular focus should be given on secondary cities in the Global South, as they are in the process of rapid transformation and receive most of the current burden of the urbanization increase. Moreover, attempts to model other variables from the breadth and width of DHS information should be encouraged, as the WI is only but a small subset of the potential indicators that can be produced. Finally, the proposed methods and outputs are aimed to enhance evidence-based policy making and help relevant organization, authorities and stakeholders to drive policies and actions in support of the most vulnerable populations.

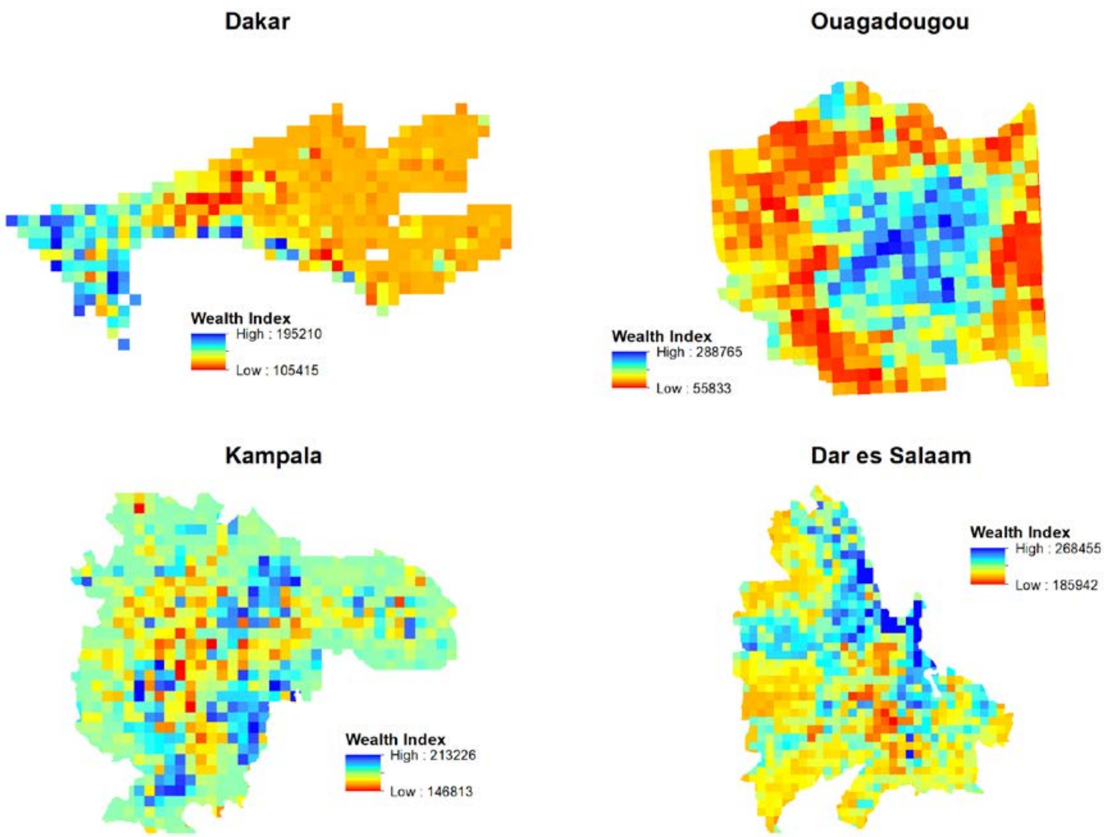


Figure 1. Predicted Wealth Index at a 1-kilometer spatial resolution, across four Sub-Saharan African cities.

Analysing the Robustness of Sampling in Gradient Analysis of Urban Material Mixtures

EARSeL Liege 2020
Abstract
Corresponding Author: ji.chaonan@dlr.de

Chaonan Ji[1,2], Marianne Jilge[1], Uta Heiden[1], Marion Stellmes[3], Hannes Feilhauer[3,4]

[1] German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Oberpfaffenhofen, Germany
[2] Humboldt-Universität zu Berlin, Germany
[3] Freie Universität Berlin, Germany
[4] FAU Erlangen-Nürnberg, Germany

Keywords: Urban, hyperspectral, gradient analysis, robustness, sampling

The challenge

Urban areas contain a complex mixture of surface materials that pose a challenge to conventional mapping approaches that struggle with mixed pixels. In particular for spaceborne hyperspectral image (HSI) with a sufficient spectral resolution to differentiate these materials, the anticipated 30 m spatial resolution (e.g. EnMAP) brings difficulties in finding spectrally pure pixels that are required to map urban materials in detail. Alternate mapping concepts such as gradient mapping are thus required. Gradient mapping is commonly used in ecology to map natural vegetation consisting of a complex mixture of different species and therefore is a promising tool for urban mapping. Jilge et al. (2019) introduced the gradient concept into urban space, successively proving that the gradient exists in urban space and can be linked with spectral mixtures. However, the gradients are determined in a data-driven way, so the robustness of gradients should be analysed.

Methodology

A part of the city of Munich, Germany was chosen as study area. The pre-existing material map was used as ground truth to sample the material mixtures. In order to analyse the robustness of the gradients in urban areas with differing sampling schemes, six systematic and three random sampling schemes were designed containing 153 polygons with a diameter of 100 m. To understand the concept behind and to better compare the different gradient spaces, principle component analysis (PCA) was used to transfer the samples into the gradient space. PCA provides loadings which enable the comparison of gradient spaces obtained from different sampling schemes. The gradient space from Jilge et al. (2019) acted as the primary gradient feature space (Pspace) and was compared to newly determined gradient spaces (Ispaces). Three tests were performed to prove that all gradients determined are robust among different sampling schemes. In the Pspace, all samples from nine sampling schemes were projected onto the Pspace and their distributions were compared regarding their gradient scores. In Ispaces, the loadings extracted from different sampling schemes and the physical significances of the first two gradients were compared to analyze the similarity between Ispaces. Third, Mantel and Procrustes tests were implemented to analyse their similarity regarding sample distributions of the Pspace and Ispaces.

Results

The results show that the sample distributions from all nine schemes were similar in the Pspace. In Ispaces, the correlations of loadings were high. Furthermore, the first gradients generated from different sampling schemes always represent the content of vegetation (deciduous trees and meadow), roofing tiles as well as concrete, and the second gradients are always driven by vegetation (deciduous trees and meadow), roofing tiles and asphalt. Thus, physical meanings of the gradient spaces were similar for different sampling schemes. In the comparison of the Pspace and Ispaces, Mantel test provided rather high statistical values that the permutations of samples from the Pspace and Ispaces are similar with high confidences ($P < 0.001$). Results of Procrustes test showed that the differences between the Pspace and Ispaces are very small. The findings show that a shifted position of the systematic sampling does not affect the extracted gradient information. In addition, neither the systematic sampling scheme nor the random sampling scheme influences the gradient in the study area. Thus, the generalization of gradients among sampling distribution in urban area can be assumed.

Outlook for the future

Gradient analysis enables the identification of characteristic material compositions in very complex spectral mixtures for the first time. The robustness analysis of urban gradients in our study paves the way for the broader application of the gradient concept to urban mapping using spaceborne HSIs. The selection of an ordination method should be consistent with the objective surface material classes and further tested. In addition, the influence of the size and number of samples need to be further analysed. Gradient analysis is a promising approach to tackle urban material mapping using spaceborne HSIs with 30 m spatial resolution, and therefore deserves to be investigated as a possible approach for an improved characterization of urban areas.

Towards a Generic Spectral Library for Urban Mapping Applications

EARSeL Liege 2020
Abstract
Corresponding Author: fpriem@vub.be

Frederik Priem[1], Marianne Jilge[2], Uta Heiden[2], Ben Somers[3], Frank Canters[1]

[1] Vrije Universiteit Brussel, Geography Department, Belgium
[2] Deutsches Zentrum für Luft- und Raumfahrt, Earth Observation Center, Germany
[3] KU Leuven, Division of Forest, Nature and Landscape, Belgium

Keywords: Imaging spectroscopy, Urban mapping, Spectral libraries, Endmember extraction, Library optimization

The challenge

The amount and diversity of urban remote sensing imagery are growing fast. Making useful maps from these images requires high-quality reference spectra of urban cover types. Yet acquiring such spectra is difficult, time-consuming and usually done ad hoc. The GENLIB research project tackles this issue by proposing a common framework for spectral library based urban mapping that relies on the concept of a Generic Urban Library (GUL). A GUL is a multi-site, multi-sensor collection of high-resolution urban spectra, equipped with library management tools enabling dynamic use and enrichment of the GUL. We posit that once a GUL becomes sufficiently representative, it will be able to generate reference data for multi-site mapping at different spatial/spectral scales, thus contributing to the development of automated workflows for urban mapping.

Methodology

The (meta)data model for the GUL is designed by drawing on literature, previous experience and examples of (mostly non-urban) spectral library collections. This model is compliant with the Copernicus EAGLE framework. Spectra are stored in a database intended for interactive and collaborative use, using the SPECCHIO platform. Tools for dynamic use of the GUL are split in a construction and application part (**Figure 1**). Automated endmember selection from available imagery is done through combined use of spectral clustering and pixel purity. New endmember detection compares image endmembers with those already in the GUL, using multiple spectral distance measures. Spectral similarity is also used to support semi-automated labelling. On the application side, tools are developed to automatically select and transform spectra from the GUL, depending on the intended map product and provided image. Particular focus is put on library optimization, i.e. making the selected GUL subset suitable for the intended application and for the image used. For this we draw on library pruning techniques such as IES and AMUSES.

Results

At the conference the GUL concept will be demonstrated for high-resolution hyperspectral mapping at the level of urban materials. Using a GUL containing multi-site spectra of one hyperspectral sensor, transferability of spectra to another site, using imagery from the same sensor, will be tested. Next the experiment will be generalised by including spectra from different hyperspectral sensors in the GUL.

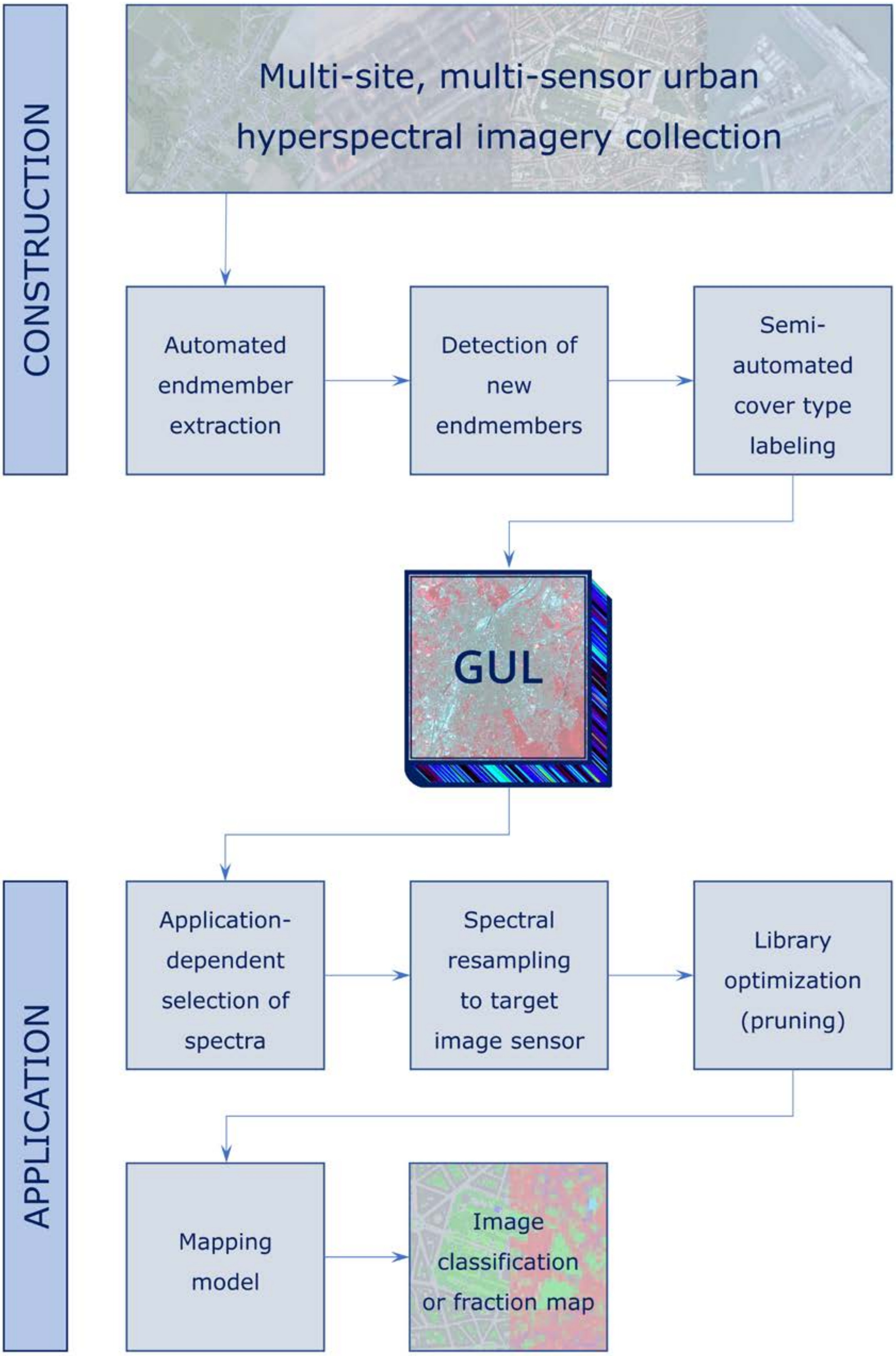


Figure 1 Overview of the proposed framework, including tools for the construction and for the dynamic management and use of the generic urban spectral library.

Settlement Monitoring For Renewable Energy Provision In Indigenous Communities Of The Ecuadorian Amazon

EARSeL Liege 2020
AbstractCorresponding Author:
valerie.graw@uni-bonn.de

Valerie Graw[1], Javier Muro[1], José Jara[2], Leo Zurita[3], Andreas Rienow[4], Esteban Calderón[2] & Richard Resl[3]

[1] University of Bonn, Center for Remote Sensing of Land Surfaces (ZFL), Germany
[2] Tratural, Energía Renovable, Cuenca, Ecuador
[3] University of San Francisco de Quito (USFQ), Ecuador
[4] Ruhr-University Bochum, Department of Geography, Germany

Keywords: renewable energy, tasselled cap, indigenous communities, settlement growth modelling, land use modelling

The challenge

Indigenous communities in the Amazon face high levels of poverty and are usually left behind national action plans such as electrification. Access to electricity implies access to basic services such as illumination, radio communications, powering up appliances for productive activities, and improvements in education and health conditions. Detailed information for isolated communities on demographics or the demand for electricity is not yet captured in national surveys. Also, the settlements are not appearing in any of the global earth observation based products such as the Global Settlement Layer or the Global Urban Footprint. Therefore, we used an interdisciplinary approach to develop a GIS-based renewable energy provision plan for indigenous communities in the Ecuadorian Amazon. Data for this model was based on remote sensing, a multi-variate data approach, participatory household surveys carried out by the indigenous communities themselves and SLEUTH, an urban growth model.

Methodology

Indigenous communities were directly integrated and local indigenous technicians trained during capacity building workshops. Household information from 58 communities and 725 households were collected via the mobile application Geofarmer. This information captured living conditions of these communities with a special focus on energy and included e.g. number of batteries, candles, or gallons of fuel used per month, and their prices.

The location, size and distribution of settlements was determined using multi-temporal composites of the Tasselled Cap components of Landsat images for 1990, 2000 and 2018. These components are expected to show high correlations with the number of houses and infrastructures in each surveyed community. The settlement maps were validated using Very High Resolution (VHR) imagery (SkySat and PlanetDove) and field data from the surveys. Additionally, we used cellular automaton SLEUTH to project with the integrated Urban Growth Model the settlement development until 2030 and four different growth types. This information is needed to calculate the energy demand not only for the current situation but also for the next decade.

The energy demand is estimated using a GIS-based model, which considers the distribution of the settlements and their specific demand. E.g. clustered settlements with a high energy demand will benefit more from a solar minigrid, while sparse settlements with low energy demand will benefit more from e.g. stand-alone panels (Figure 1).

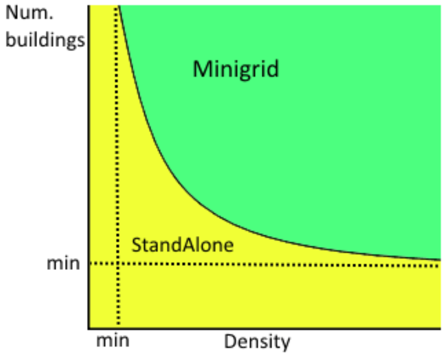


Figure 1: Decision model to choose between solar minigrid or stand-alone solar panels

Results

The community and household surveys allow the estimation of the energy needs and the potential productive uses for the electricity. The collection of data showed interesting results that could also explain deforestation patterns in the region linked to demographic characteristics.

The use of remote sensing imagery for area identification was combined with the household survey to identify settlement areas and improve the classification of the images. The lowest values of the Wetness Tasseled Cap component showed a high correlation (0.75) with the presence of settlements which was used for further settlement mapping in the research area. Also, a hot spot analysis was performed which could identify the locations of the most densely built areas. Figure 2 shows the building density on the left as well as the validation with VHR imagery on the right for comparison. The VHR imagery was used for the identification of the exact distribution of the houses within each community to validate the developed approach.

Combined with the results of the settlement projection based on SLEUTH, the here presented results will be used to plan the distribution of the solar infrastructure in the selected communities.

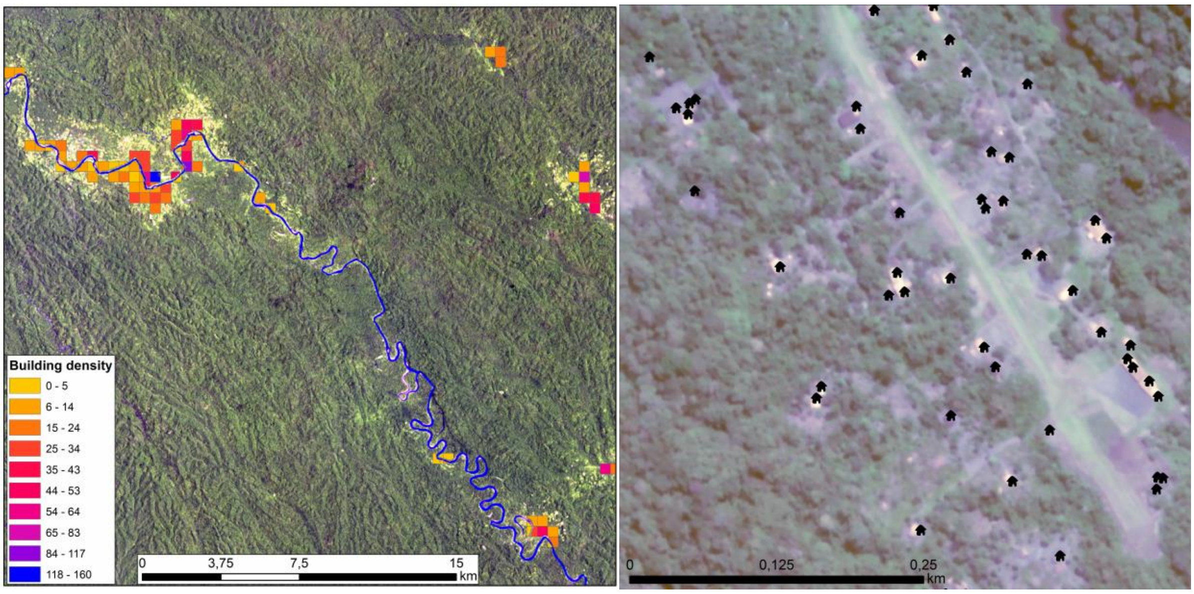


Figure 2: Hotspot analysis of building density (left) and SkySat image with the individual buildings located (right)

Outlook for the future

The developed approach is embedded in a recommended practice with a step by step procedure for indigenous communities and currently transferred to the local technicians. In addition, a number of researchers and stakeholders from Colombia and Bolivia raised their interest to transfer the developed approach to their countries. During the data collection and analysis, room for improvement could be identified for the household data collection to link specific answers to biophysical aspects as derived from remote sensing-based image analysis. The SLEUTH model, initially developed for urban growth, could show its application also in rural areas. Here, we could demonstrate that the level of detail but also an understanding of local conditions and the way of life of indigenous communities is of high relevance to train the model more accurately. The oral presentation will be able to give insights in these aspects by May as the mentioned steps are carried out in January and March 2020.

Regression-based unmixing of urban land cover across multiple cities – Evaluating multi-site libraries and Gaussian Process uncertainties for model generalization

EARSeL Liege 2020
Abstract
Corresponding Author: akpona.okujeni@geo.hu-berlin.de

Akpona Okujeni[1], Sam Cooper[1], Patrick Hostert[1,2], Sebastian van der Linden[3]

[1] Earth Observation Lab, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany
[2] Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys), Humboldt-Universitat zu Berlin, Unter den Linden 6, 10099 Berlin, Germany
[3] Institute of Geography and Geology, Universität Greifswald, Friedrich-Ludwig-Jahn-Str. 16, 17489 Greifswald, Germany

KEYWORDS: URBAN, Hyperspectral, EnMAP, Unmixing, Model uncertainty

The challenge

In times of rapid urbanization, remote sensing has become a valuable Earth observation tool for urban environmental research. Images from multispectral systems like Landsat or Sentinel-2 have been used for describing urban land cover and land use, urban form and function, or urban growth patterns. With the emergence of novel hyperspectral satellite missions like the Environmental Mapping and Analysis Program (EnMAP), timely and globally sampled imaging spectrometer data will complement this rich data pool. Due to the high spectral information content, this new type of imagery appears promising for enhancing large scale urban applications. Along with the progress in sensor technology, however, the need for generalized analysis workflows for repeated and accurate urban mapping across space and time becomes evident.

Methodology

This study presents a workflow for generalizing regression-based unmixing models based on multi-site spectral libraries for vegetation, impervious and soil (VIS) fraction mapping across multiple cities. We use simulated EnMAP data from Berlin, Brussels and Munich and Gaussian Process Regression (GPR) for unmixing. Regression model training relies on synthetic mixtures generated from two spectral libraries from Berlin and Brussels. These are used to develop one generalized model from a combined multi-site library, and two local models from the separate single-site libraries. All models are subsequently either applied to cities that are represented in the model, i.e., known cities (e.g., Berlin model applied to Berlin) or transferred to cities that are not represented in the model, i.e., unknown sites (e.g., Berlin model applied to Brussels). For the Munich constellation, where no spectral library is available, the transferability of all models to an unknown city is accordingly tested. The performances of the GPR models to predict VIS fractions were assessed with independent validation data. Further, GPR uncertainties were used to evaluate the generalization capability and the transferability of the regression models across sites.

Results

For Berlin and Brussels, results indicate that VIS composition is accurately mapped by the generalized model (MAEs of 5.6% and 9.5%) (Figure a). The performance of the generalized model is slightly better than the performances of the local model applications (MAEs of 7.8% and 9.7%). In contrast, local model transfers between Berlin and Brussels lead to a decrease in accuracy (MAEs of 11.9% and 14.0%). These findings are reflected in the VIS maps (Figure b) and underline the use of multi-site libraries for developing generalized regression models for unmixing across multiple sites. Associated GPR average uncertainties and uncertainty maps provide two major insights. First, cities that are represented in the model reveal low uncertainties. Only objects which were not represented in the library stand out in such cases. Second, cities that are not represented in the model show high uncertainty for specific cover types. This particularly applies to vegetation cover and might be explained by the limited inclusion of temporal variability of surfaces in the library. For the constellation where all models are transferred to Munich, the generalized and the Berlin models achieve reasonable map accuracies (MAEs of 12.6% and 12.0%), whereas the Brussels model is less accurate (MAE of 15.1%). Also here, uncertainty maps indicate that impervious surfaces are generally associated with lower uncertainties, whereas vegetated surfaces with high temporal variability show higher uncertainties.

Outlook for the future

This study shows that the strategy of training regression-based unmixing models with multi-site libraries represents a useful framework for land cover fraction mapping across multiple cities. Such generalized workflows are required to make best use of forthcoming hyperspectral satellite data from urban areas, but also for from other existing multispectral sensors. While synthetic mixing presents a great solution for the generation of quantitative training data for regression modelling, successful model development relies on the availability and representativeness of spectral libraries. Follow-up research will, therefore, focus on strategies for developing generic spectral libraries representative for arbitrary urban areas, using GPR uncertainty estimates as indicator for missing spectral information in the library. This way, pre-trained, universally applicable regression models might be generated for automated and repeated urban mapping across space and time.

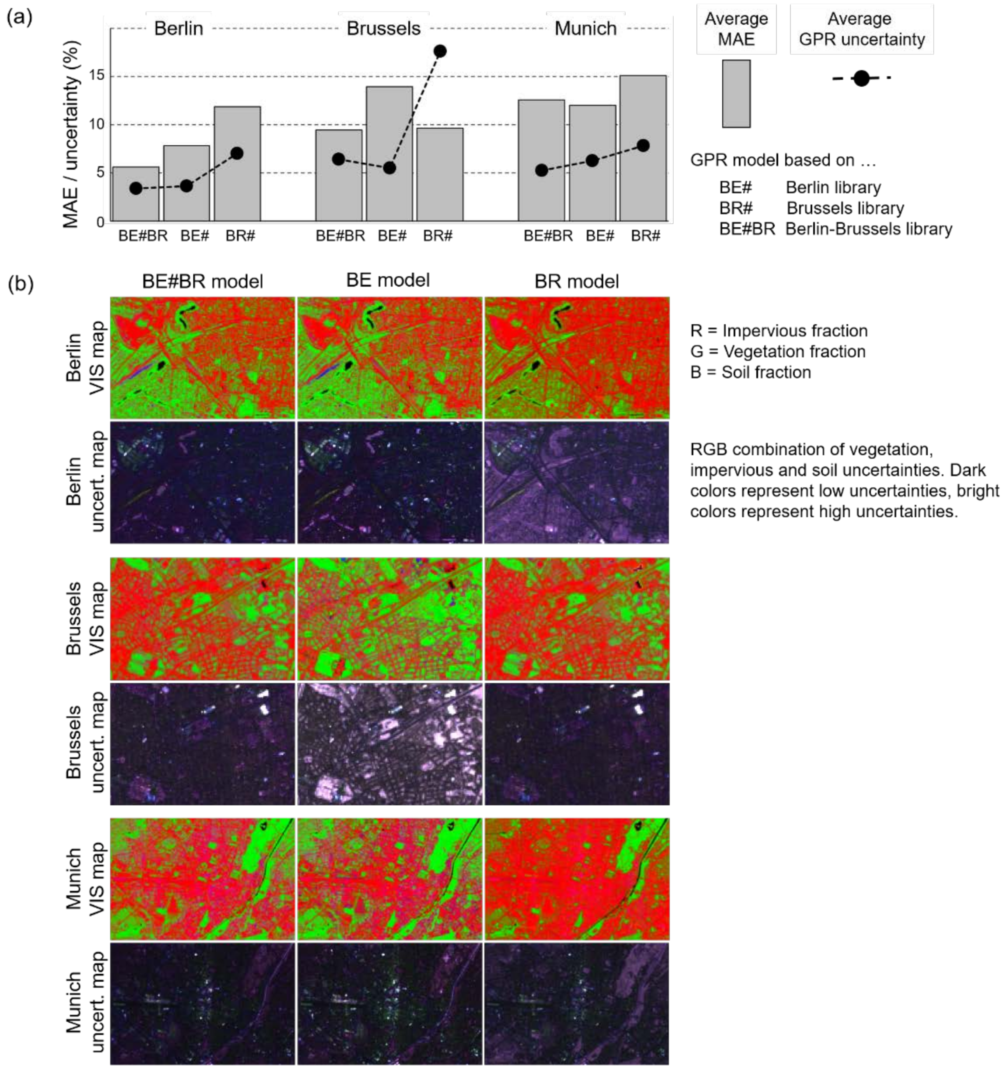


Figure Average MAEs and GPR uncertainties over all VIS categories for Berlin, Brussel, and Munich (a) and GPR-based VIS fraction maps and uncertainty estimates for selected subset within Berlin, Brussels and Munich (b).

Roof Material Mapping: Application Over Liège Using Open-Source Object-Based Supervised Classification Algorithms

EARSeL Liege 2020
Abstract
Corresponding Author: c.wyard@issep.be

Coraline Wyard[1], Benjamin Beaumont[1], Rodolphe Marion[2], Laure Roupioz[3], Taïs Grippa[4], Eric Hallot[1]

[1] ISSeP, Remote sensing and geodata unit, Belgium
[2] CEA, France
[3] ONERA, France
[4] ULB, Institute for Environmental Management and Land-use Planning (IGEAT), Belgium

Keywords: Earth Observation, Urban, Multispectral, Roof Materials, Open-Source, Machine Learning

The challenge

Roof materials can be a significant source of pollution for the environment and can have negative health effects. Analyses of runoff water revealed high levels of metal traces but also polycyclic aromatic hydrocarbons and phthalates. This contamination would result from corrosion and alteration of roof materials. Similarly, the alteration or combustion of asbestos contained in certain types of roofs may allow the emission and dispersion of asbestos fibres into the environment. Therefore, acquiring information on roof materials is of great interest to decrease runoff water pollution, and to improve air and environmental quality around our homes. To this end, remote sensing is a particularly relevant tool since it allows semi-automatic mapping of roof materials using multispectral or hyperspectral data. The CASMATTELE project aims to develop a semi-automatic identification tool of roofing materials over the Liege area using remote-sensing and machine learning for public authorities.

Methodology

For the identification of roofing materials, the use of open-source algorithms and data was favoured. Thus, we have chosen to use the supervised object-oriented classification algorithms implemented in GRASS. These supervised classification algorithms are divided into several steps: (1) Determination of the classes of materials to be identified; (2) Construction of training and validation datasets for classification algorithms; (3) Pre-processing of the images to be classified including building extraction and shadow removal; (4) Image segmentation; (5) Classification; (6) Evaluation of the classification accuracy. Regarding the data, we used multispectral orthophotos (4 bands, RGB+NIR) generated annually and covering entire Wallonia at a spatial resolution of 25 cm. Vector data, in this case PICC (the Walloon reference building GIS database), were also used to extract building footprints and roofs from orthophotos. As the use of certain roofing materials is sometimes characteristic of certain periods, we also used the years of construction of the buildings provided by the Cadastre. A spectral library of roofing materials encountered in Wallonia has also been created using an ASD FieldSpec 3 Hi-Res spectrometer to identify the main classes of roofing materials.

Results

The development of the spectral library made it possible to define 13 classes of roof materials: black, brown and orange ceramic tiles, black and white membranes, natural slates, artificial slates in asbestos cement, corrugated asbestos cement sheet, metal, gravel, vegetation, solar panels, and another class including plastic roofs, roof windows, and rare materials such as thatch. About 2000 roof samples were collected within our 25 km² study area. 100 samples per material class were used to train the classification algorithms, the remaining samples were used for validation. Roofs were then extracted from the orthophotos using PICC as mask. The shadows were then removed from the images. After segmentation of the images, the resulting segments were finally classified into the 13 classes previously identified. The results are promising since more than 80% of the orange tile roofs and green roofs are correctly identified while more than 70% of the solar panels, white membranes and AC corrugated sheets are correctly identified by the classification algorithms. The integration of the NIR band produces the most significant improvement, classification overall accuracy improving by +6%. Still, overall accuracy peaks at 64.9%. Various elements help to explain these results such as the large number of classes, the poor quality of some input data. There is thus considerable room for improvement.

Outlook for the future

The prototype developed in the Liege region will have to be optimized and improved before considering any implementation on the scale of the Walloon territory. The prototype could benefit of new open-access regional data such as the new Walloon DSM and the WALOUS project building mask which will soon be made available.

These initial results have already generated considerable interest from several public authorities. For instance, a Walloon map of roofing materials would be useful for asbestos inventories, for monitoring the development of solar panel installations, for monitoring roof renovations and the energy performance of buildings, for firefighters' interventions in the event of roof fires as special measures has to be taken if the roof contains asbestos.

The project's applications are thus numerous and highlight the relevance of regional mapping of roofing materials as well as its updating.

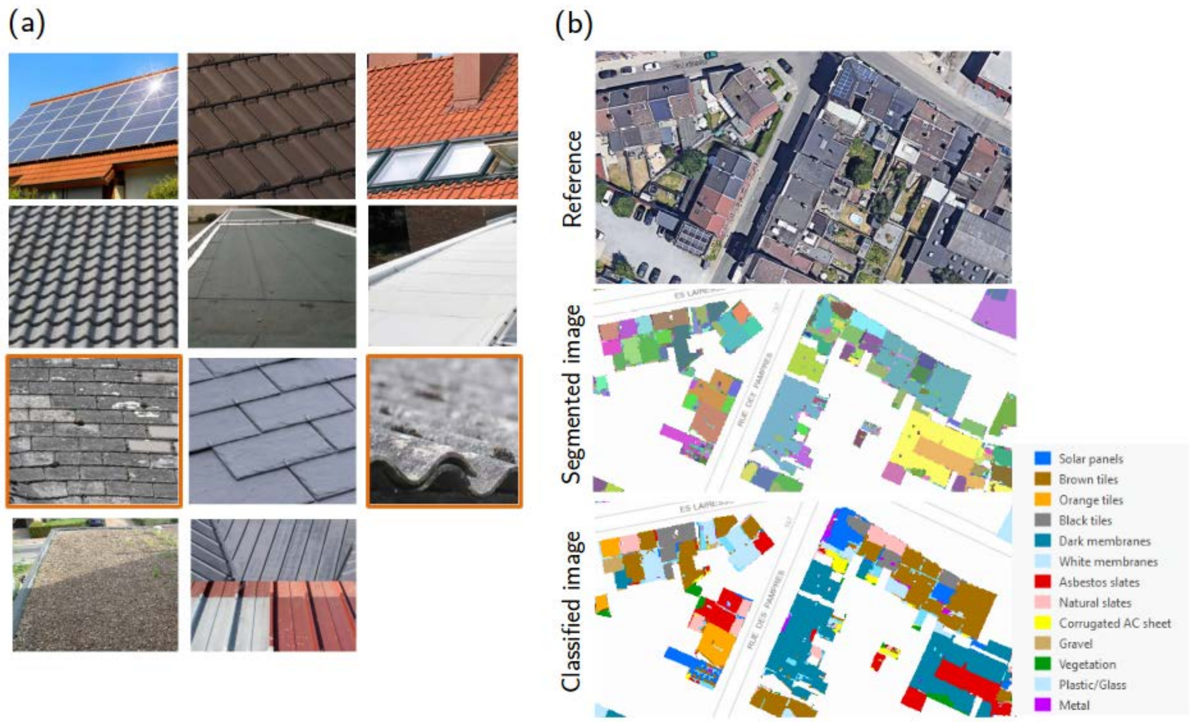


Figure (a) Overview of the main roof materials used in the Walloon region; and (b) example of classification result using RGB bands and support vector machine algorithm.

The Garden Monitor (Garmon) : What is a garden ? Technically…

EARSeL Liege 2020
Abstract
Corresponding Author:
jo.vanvalckenborgh@vlaanderen.be

Jo Van Valckenborgh[1], Stijn Van der Linden[1], Ben Somers [2] Jingli Yan [2] Veerle Strosse [3]

[1] Informatie Vlaanderen, Program Earth Observation Data Science, Belgium[2]University of Leuven, Belgium

[3] Departement Omgeving, Belgium

Keywords: Earth Observation, Garden, Land Use, Land Cover, Airborne Data, Regional data

The challenge

Being a substantial part of local green in living environments worldwide, gardens are strategic spaces for local environmental quality of life. Gardens are relatively inaccessible and challenging for systematic data collection. Region- or nation-wide spatially explicit baseline data for referencing representativeness of data is often missing. To support garden research and policy, there is a clear need for more detailed information on monitoring of garden cover, use and management. The aim of this project Garmon (a BELSPO application project for earth observation STEREO III) is the development of a proof-of-concept of a garden monitor that is able to collect data on the ecosystem. The study focuses on the development of a garden monitor through the integration of existing remote sensing techniques. Both airborne and spaceborne (e.g. Pleiades) remote sensing technologies will be combined. In this presentation the delineation of gardens from a technical point of view will be discussed.

Methodology

The goal is to explore image processing techniques to extract in a spatial explicit way the location and area of gardens and area of (and ratio's between) different garden cover components (e.g. trees, grass, low green, sealed surface, and water). The steps taken are :

- delineation of gardens from a technical point of view through the use of available regional data the use of official census GIS data layers such as Grootschalig Referentiebestand (GRB) and Agricultural Land Parcel Information, …;
- adding information on different garden components to delineated gardens, e.g. calculation of area of and ratio's between different garden cover components (trees, low green, sealed surface, …) based on the regional land cover map based which is in itself based airborne data based as baseline to compare with garden characterisation of satellite data (e.g. Pleiades).

Results

Dataset (map) of garden parcels in Flanders with baseline garden component information and thematic (land use) information of the study areas and/or Flanders.

Outlook for the future

The current lack of a (regional) garden monitoring system and inquiries from potential users about more detailed garden use and cover information and the monitoring of garden management induced policy makers to draw up a development of applications project on combining remote sensing and citizen techniques. Within the frame of Garmon (a BELSPO application project for earth observation STEREO III) the aspect of delineation of a garden and the use of remote sensing (airborne data) allows remote characterization of garden land covers. This baseline is within the application project further used to compare with garden parameters characterization through available satellite data as additional and a way for more frequent monitoring. Next to this, the result can also be used a baseline for regional and local authorities to setup collecting spatially explicit garden meaning, design and management data through crowd sourcing (citizen science) or terrain data.

Figure % green in delineated garden parcels per parcel blocks in the city of Leuven (study area).

Corresponding Author: ingunn.burud@nmbu.no

Blue-green microstructures - Detection of geometrical and permeability features of microstructures.

Agnieszka Kuras[1], Øivind Due Trier[2], Thomas Thiis[1], Vetle Odin Jonassen[3], Niki Gaitani[4], Christian Rogass[5], Ingunn Burud[1]

[1]Norwegian University of Life Sciences, Faculty of Science and Technology, PB 5003, 1430 Aas, Norway
[2]Norwegian Computing Center, Section for Earth Observation, Oslo, Norway
[3]Terratec AS, Vækerøveien 3, 0281 Oslo, Norway

[4]Norwegian University of Science and Technology, Department of Architecture and Technology, Høgskoleringen 1, 7491 Trondheim, Norway

[5]Helmholtz Centre for Environmental Research, UFZ, Permoserstraße 15, 04318 Leipzig, Germany

Keywords: Urban, Hyperspectral imaging, airborne lidar, roads, blue-green microstructures

The challenge

During urban flooding, the flow path of water depends to a large extent on microstructures such as gutters and curbs, and the permeability of the surfaces. Good road design can deflect and drain water before it penetrates into sensitive constructions. In urban flood applications, a digital terrain model (DTM) is crucial to extract street depressions in the surface, and prediction of flow direction, and velocity. LiDAR provides time-efficient precise DTM for larger areas. However, automated classification of exact borders based on lidar data is proved difficult due to its limited spatial resolution and inability to differ complex urban structures. Material detection in the urban area can be achieved using hyperspectral data. Thanks to recent advances in deep neural networks and increased computing power fusion of hyperspectral airborne images with LiDar data of an urban area will be used to retrieve exact borders and potential drainage lines in small scale urban topography.

Methodology

Hyperspectral and lidar data were acquired simultaneously by airplane on 24 August 2019 under cloud-free conditions over Bærum municipality near Oslo, Norway. The HySpex VNIR-1800 (400 -1000 nm) and HySpex SWIR-384 (1000 – 2500 nm) sensors acquired images with 0.3 m and 0.7 m spatial resolution, respectively. Lidar data were acquired using Riegl VQ-1560i, with five emitted pulses per m^2. In the georeferencing of the hyperspectral images, the hyperspectral signatures were preserved using nearest neighbor interpolation.

The U-Net deep neural network will be used for semantic segmentation of the hyperspectral data in order to extract road surface areas. The U-net architecture has been proven to be applicable on hyperspectral data as it can reduce the number of input bands to a much smaller number of non-linear principal components that represent distinct separable information. Additinally, existing road vector data will be used to produce road masks, for areas where no changes have occurred.

In the lidar data, object height may be extracted for buildings, trees, cars, etc. (Figure 1d). By using a vegetation index, obtained from the hyperspectral data, separate masks for buildings and trees may be generated. The tree mask will be used to remove areas covered by trees from the road mask. The building mask will be used to remove buildings from the detection result.

The modified road mask will be used to extract training, validation and test data for the U-net.

Results

The purpose of the proposed method is to detect and map microstructures along the roads in the urban environment. With an exact delineation of the curb of the asphalt and classification of the neighbouring materials it is assumed to enable modelling of the water runoff along the roads.

The method will be evaluated by comparing results for old roads with existing correct vector data and field work in selected areas.

The airborne data will be divided into non-overlapping parts called ‘training’, ‘validation’ and ‘testing’, with 70%, 20% and 10%, respectively. The U-net internal parameters will be optimized using the training data. The validation data will be used to select the best set of internal parameters so far. The test data will be used to evaluate the detection performance.

The first expected result will be the detection of all roads clearly visible in the hyperspectral data (Figure 1a). The method will be evaluated by comparing user’s accuracy (how many of the predicted road pixels are in fact road surface) and producer’s accuracy (how many of the true road surface pixels were predicted as road surface).

Based on the road maps a first version of a water runoff model will be estimated and presented.

The method will also be tested in an area with known new roads not covered by the vector data. This will be a qualitative evaluation, with examples of successful and unsuccessful detection of new roads.

Outlook for the future

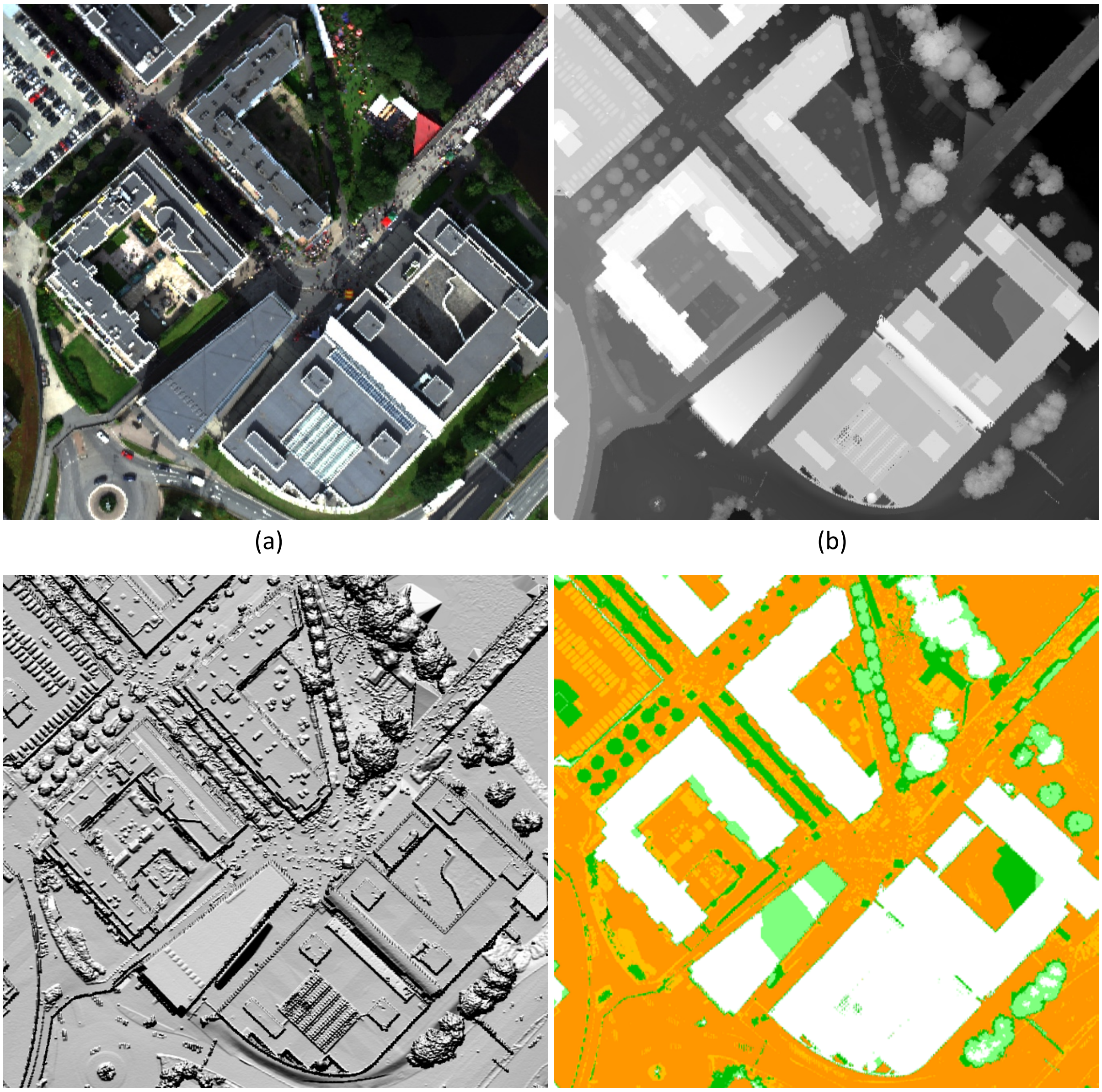
The next step in this study is a differentiation between various surface materials in road analysis, e.g. asphalt, gravel, cobblestone, as well as gutters and curbs. Various materials have different physical properties and geometrical characteristics that affect the microclimate and water runoff. The classification of the materials and characterization of terrain surface properties (as roughness, infiltration, evapotranspiration, thermal inertia etc.) will feed numerical urban climate simulation models to minimize the effects of extreme climate events.

Further research will also explore how the combination of hyperspectral and lidar data can be utilized to determine the microtopography along the roads, which is also crucial for modelling the water flow paths. These described approaches will also be evaluated on data acquired in 2019 from two different regions in Norway, Hønefoss and Hamar areas.

Acknowledgments

This research is part of a project on machine learning in map revision, financed by: Regional Research Fund Viken, Bærum municipality, Terratec AS and Geovekst.

The project has just started and the data is already available; however, the work is progressing rapidly and the results will be available at the workshop.



(a) (b) (c) (d)

Figure 1 A 216 m by 203 m part of the urban area in Bærum, Norway. (a) Three channels in natural colours from hyperspectral data. (b) Digital surface model (DSM) from lidar data. (c) hillshade visualisation of DSM. (d) Object height from lidar data, colour coded as: 0.0-0.1 m = orange, 0.1-2.0 m = yellow, 2-5 m = light green, 5-12 m = green, > 12 m = white.

Potential of green roofs in the East bank of Liege, Belgium

EARSeL Liege 2021
Abstract
Corresponding Author: mjoshi@uliege.be

Mitali Yeshwant Joshi[1], Simon Rohon[1], Gilles-Antoine Nys[2], Jacques Teller[1]

[1] University of Liege, LEMA, Department of Urban and Environmental Engineering, Belgium

[2] University of Liege, Geomatics unit, SPHERES, Department of Geography, Belgium

Keywords: Green Roofs, Buildings, Cadastre, LiDAR, GIS

The challenge

The government of Walloon region in Belgium aims at sustainable development with a focus on urban renewal and revitalisation. Green roofs can be considered as an alternative to providing green spaces in urban areas. Researchers suggest that green roofs can be beneficial in sustainable development and overcoming the adverse effects of urbanisation. Therefore, considering the lack of green spaces (figure 1) and abundance of impervious surfaces in core urban areas, we focus on assessing the potential of green roofs in the east bank of city of Liege in Walloon region of Belgium. We identify the potential of green roofs in this region with three different criteria, namely, area and slope of the roof and structure of the building. The results suggest that there is a significant potential to develop green roofs in this region. The total area of flat roofs in the region is 96 hectares, from which around 73 hectares of roofs can be developed as green roofs.

Figure 1 Existing green spaces in the study area

Methodology

The criteria to identify the potential of green roofs are selected based on state of art. We used LiDAR point cloud to map the slope of roofs. To process the LiDAR point cloud, we used the RANSAC algorithm as it is computationally more efficient. For simplicity, only the roofs with a slope less than 10º are considered to be flat. Considering the obstructions such as chimneys and elevator shafts, mobilizing a green roof on a roof size less than 10 m^2 can be challenging. Thus, while processing point cloud, we considered planes with a slope less than 10º and an area greater than 10 m^2. The results for each building provided the percentage of flat area in a building footprint. The roof's area is mapped using the PICC (Projet Informatique de Cartographie Continue) data by the Public Service of Wallonia (SPW). Simultaneously, based on the building standards in Europe and Belgium since 1900, we determined the reserve structural capacity of the building to accommodate green roofs. The structure of the buildings was indeed according to the norms that were in force during the period of construction. The buildings constructed before 1977 have reserved strength as they were built according to old standards, which were more conservative given their lower accuracy. An analysis of three buildings demonstrated that there is a reserve capacity in these structures. The Eurocode was proposed in 1977, after which the buildings were built with the exact strength and capacity. It is not possible to develop green roofs on these recent buildings without significant structural changes. The year of construction of a building was used from the cadastre data. Figure 2 illustrates the flow of the methodology.

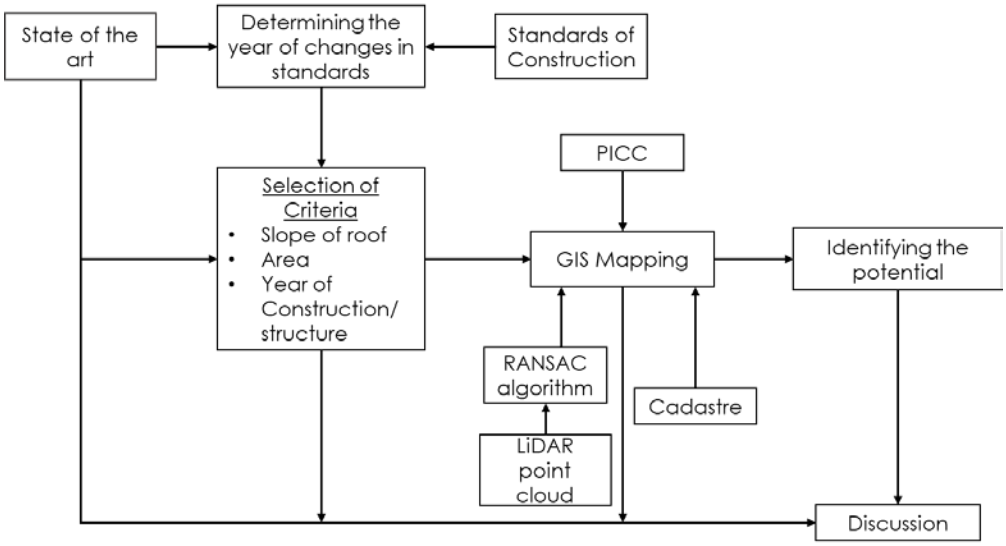


Figure 2 Methodology flowchart

Results

There are 96 hectares of flat roofs in the study area of 450 hectares with 161 hectares of built-up. Around 73 hectares (45% of the built-up, 4547 buildings, 28% of total buildings) of flat roofs are on the buildings that were constructed before 1977 which have the reserved structural capacity for mobilizing green roofs on them. Figure 3 (a) shows the spatial distribution of the potential roofs for mobilizing green roofs. The buildings with complete flat roofs consist of around 48 hectares of area. The buildings with more than 50% of the roof area being flat are around 22 hectares. Thus, there is a significant potential for constructing green roofs in the current scenario. Green roofs can be built on larger roofs easily as compared to smaller roofs. The roofs greater than 200 m^2 with a reserved structural capacity, constitute of 52 hectares of area. Although the number of potential roofs with area greater than 200 m^2 is less, the area of potential roofs is significantly large (Figure 3(b)). Thus, implementing green roofs on these roofs can deliver a significant impact. With advanced technologies, the smaller roofs also can be mobilized with green roofs. Apart from this, the identified roofs for green roof development are spread throughout the region indicating a scope for even distribution of green spaces (Figure 3(a)).

Outlook for the future

Analysis suggests that there is a significant potential for developing green roofs to address the lack of existing green spaces. During October 2013 to July 2014, 64 existing green roofs could be counted in the study area indicating a development of public's initial interest in green roofs. Besides being an alternative for green spaces, researchers have suggested that green roofs can be beneficial in mitigating urban heat island, retaining stormwater runoff, and enhancing biodiversity. Although study uses only three parameters, it still points out that there is a significant potential to develop green roofs in the East bank of Liege. However, further research on additional parameters such as structures of the building and orientation along with people's perception about green roofs can direct better implementation of green roof.

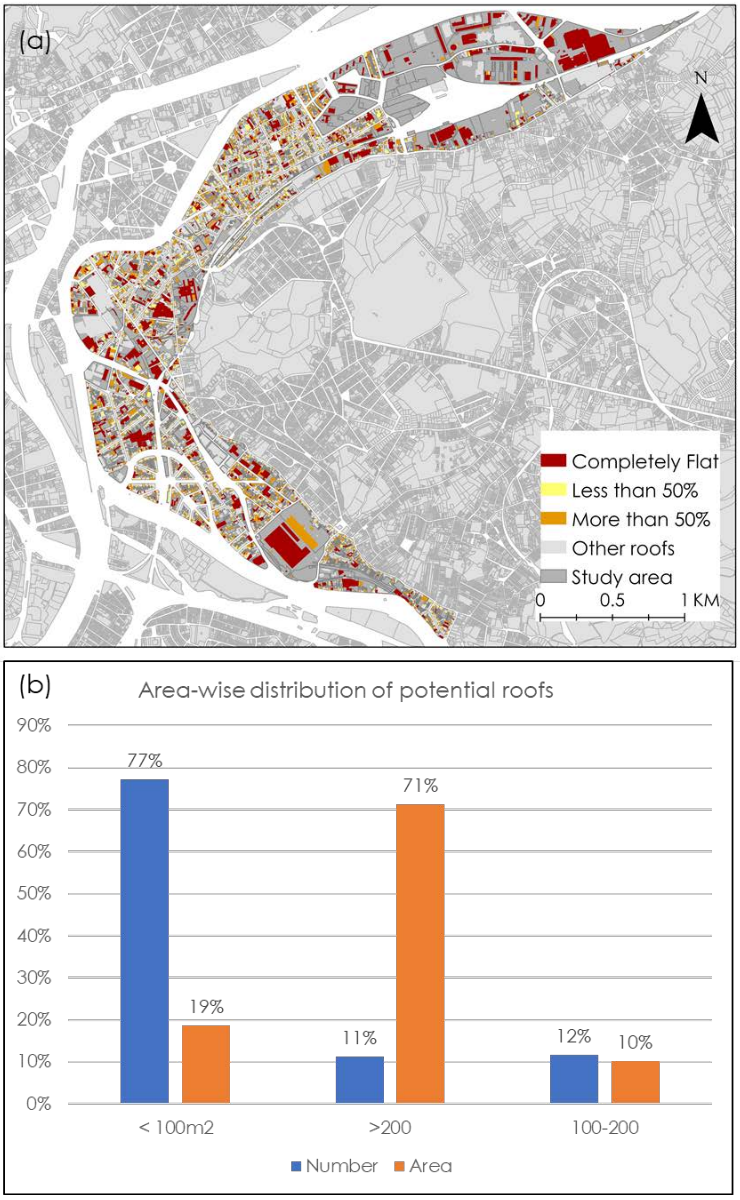


Figure 3 (a) Spatial distribution of potential of green roofs (b) Percentages of potential levels of green roofs

Continental-scale mapping and analysis of 3D building structure

EARSeL Liege 2020
Abstract
Corresponding Author: mengmeng.li@vu.nl

Mengmeng Li[1], Elco Koks[1], Hannes Taubenböck[2,3], Jasper van Vliet[1]

[1] VU University Amsterdam, Institute for Environmental Studies, the Netherlands
[2] German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Germany
[3] Julius-Maximilians-Universität Würzburg, Institute for Geography and Geology, Germany

Keywords: Urban Form, Land Use Intensity, Building Height, Urban Density, Settlement System

The challenge

Monitoring urban extent has been prominent in earth-observation studies for decades, resulting in various products available from local to global scales. However, the retrieval of an urban vertical profile based on remote sensing remains challenging. Building height has been retrieved thus far based on a number of different remote sensing data sources: conventional optical images, stereo optical images, LiDAR, and SAR, among which LiDAR is widely acknowledged as the most robust source. However, applications of LiDAR-derived data are highly constrained in their coverage, as data is scarce and scattered. In this study, we aim to map the 3D building structure, i.e. footprint, height and volume, at a continental scale using a large number of explanatory datasets, including both radar and optical satellite imagery, as well as other spatial data.

Methodology

We train three random forest (RF) models to predict building footprint, height, and volume, respectively, using reference data for different locations within the study areas. Subsequently we use these trained models to estimate the same variables for all other locations within the study areas. These study areas are mainland Europe, the conterminous US, and mainland China (including Hong Kong and Macao, hereafter referred to as China). Our approach consists of four parts: 1) the collection and pre-processing of spatially explanatory data to produce ready-to-use inputs for the model using the Google Earth Engine (GEE); 2) collection and pre-processing of the reference data, including both readily available 3D building data and manually classified of building properties based on Very High Resolution (VHR) imagery and street view; 3) training, optimizing, and validating the RF models to produce maps of 3D building structure maps; 4) spatial analysis of 3D building structure in the three study regions and the differences between these regions.

Results

The distribution of building footprint, height and volume at a 1 km^2 resolution for our three study areas is presented in Figure 1. In general, the spatial patterns are correlated: high values for all three variables are concentrated around the larger urban areas, such as Paris, New York and Shanghai. However, the correlation between building height and building footprint for all regions combined is only 0.66, indicating the need to map these properties independently. There are notable differences across the three study regions. For example, China has more locations with a relatively large building footprint as well as a high building height, while the US has more pixels with a low building height, typical for suburban sprawl. Specifically, China has the highest average building height at 10.35 m. In Europe, the average building height is 7.37 m, and in the US this is 6.69 m. Consistently, China has more areas that have a very high building volume, while the opposite is true for the US.

The RF model trained on the combined reference data set of all three continents yields a very high accuracy for building footprint, density, and volume, as indicated by R^2 values of 0.90, 0.82, and 0.88 for the median results, respectively. The analysis of variable importance reveals that the GUF is most valuable for estimating building footprints, while SAR data are most valuable for estimating building height. Both have a relatively high value for estimating building volume.

Outlook for the future

Urban land plays an increasingly important role in global land use change, and impacts of urban expansion have been widely reported in scientific literature. Consequently, increasing urban land use intensity could be a way to reduce urban expansion and thus alleviate the global competition for land. Building characteristics as presented in this paper offer an option for characterizing built-up areas more elaborately and also characterize urban land use intensity. The approach presented in this paper therefore complements population density as a measure for urban land use intensity, and covers all types of human settlements regardless of their size. The results of this study, the first continental-scale 3D building dataset, can be used for further analysis of the urban environment, spatial planning, and land use projections. Mapping 3D building structure is as of yet constrained by the availability of ground truth in other areas.

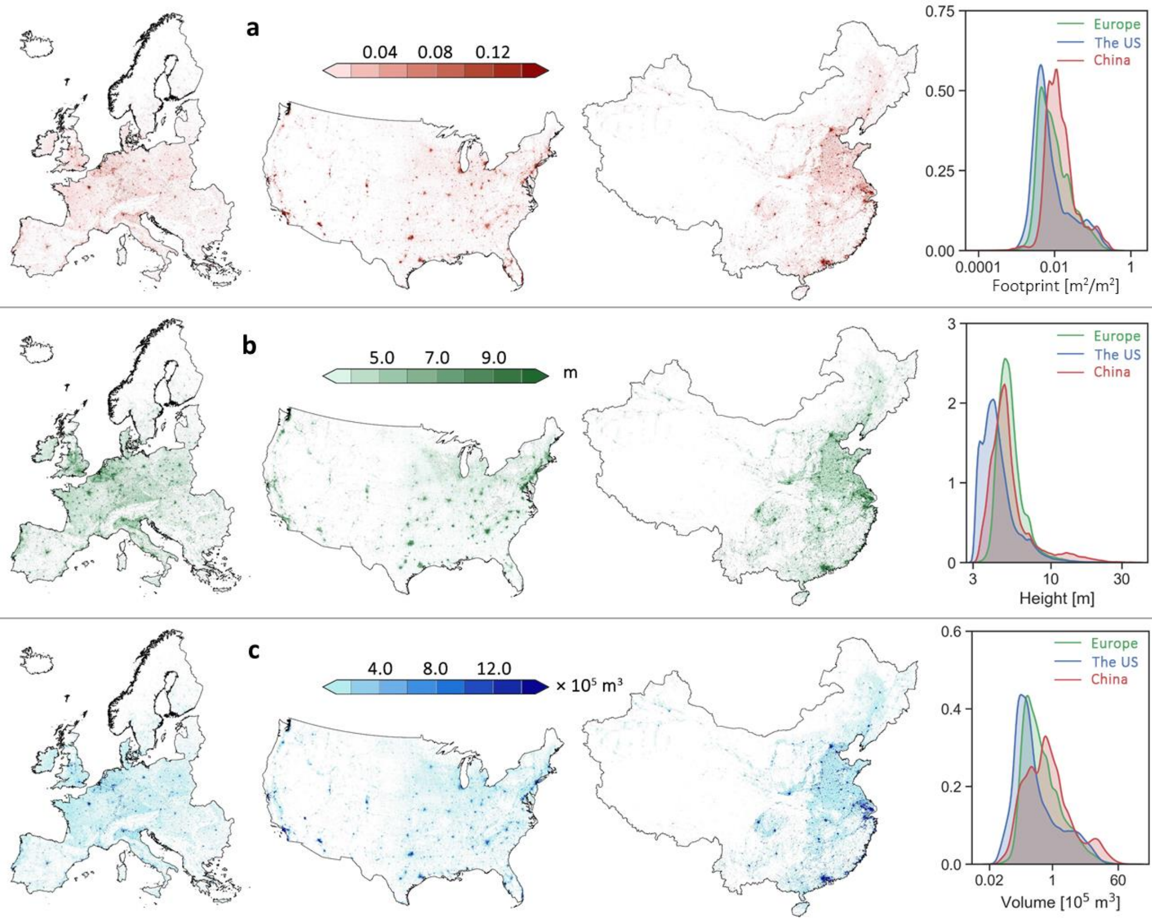


Figure 1. Distribution of building footprint, height and volume in three study regions. a) building footprint; b) building height; c) building volume. The graphs on the right, i.e. the kernel density estimations, are plotted based on 100,000 randomly selected points for each region, of which the x-axis is scaled using a logarithmic function.

Using multiple color spaces of orthophotos and computer vision method for building segmentation and change recognition

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Abstract
Corresponding Author: lingli.zhu@nls.fi

Lingli Zhu, Heli Laaksonen, Jani Kylmäaho, Juha Vilhomaa, Juha Hyyppä, Mikko Sippo

National Land Survey of Finland, Opastinsilta 12C, 00521 Helsinki, Finland

Keywords: Orthophoto, building segmentation, building change recognition, computer vision, color spaces

The challenge

Building change recognition has been one of the major tasks in national mapping agencies. At present, in most countries, this task is processing by the stereo model operators. It is labor-intensive and time-consuming. From literature, although many methods have been published, most of them were still far from practical use. The main reason might be that some methods were developed by using many different data resources, which are hard to be obtained in practice. For example, Some researchers utilized both aerial images and Lidar for building change detection. However, in most of the countries, Lidar data were acquired in a longer period than aerial images. In Finland, the updating period of aerial images is two to three years, while the first round of Lidar data covering the whole country took more than ten years (in the future, it will be shortened to six years). Thus, it is hard to get both data from the same time for map updating. Therefore, it is practical to use a single type of dataset for change detection. Due to the frequent updating of aerial images, in this paper, we focus on exploiting orthophotos for building change recognition.

Typically remote sensed imagery is represented by RGB color space because it is intuitive for the human visual system. With the advancement of various physical devices, i. e. image and video capture systems, printers, and monitors, different color spaces were defined and adopted by digital forms. These color spaces have different combinations of luminance and chrominance. Therefore, detecting different color buildings from different color spaces become possible.

Methodology

In this experiment, we explore different color spaces (e.g. Gray, CIELAB, HSV, and YCbCr) of orthophotos and exploit the computer vision method to segment the images and recognize the buildings. By comparing building locations and colors from orthophoto datasets of different years, the new buildings, demolished buildings, and rebuilt buildings are recognized.

Figure 1 shows the workflow of building detection and changes recognition. From the HSV color spaces, the shadows of images can be segmented. The green objects (e.g. vegetations) can be separated by increasing the color differences and detect the green objects. From orthophotos, we first remove the shadows and vegetations. Then by different color spaces, we can obtain white, red, blue, and other dark buildings. Buildings extracted from orthophotos of different years are compared. The comparisons between buildings from the new dataset and old dataset were performed in the following ways: i) compare all buildings from the new dataset with ones from the old dataset to find the new buildings; ii) compare all buildings from the old dataset with ones from the new dataset to find the demolished buildings; iii)compare the building color by color to recognize the rebuilt buildings.

The computer vision method was applied in the process of image segmentation. By the thresholds of the area, shape, and solidity for the color space image, noise and unwanted objects can be removed. Thus, the new buildings, demolished buildings, and rebuilt buildings (color changed) can be recognized.

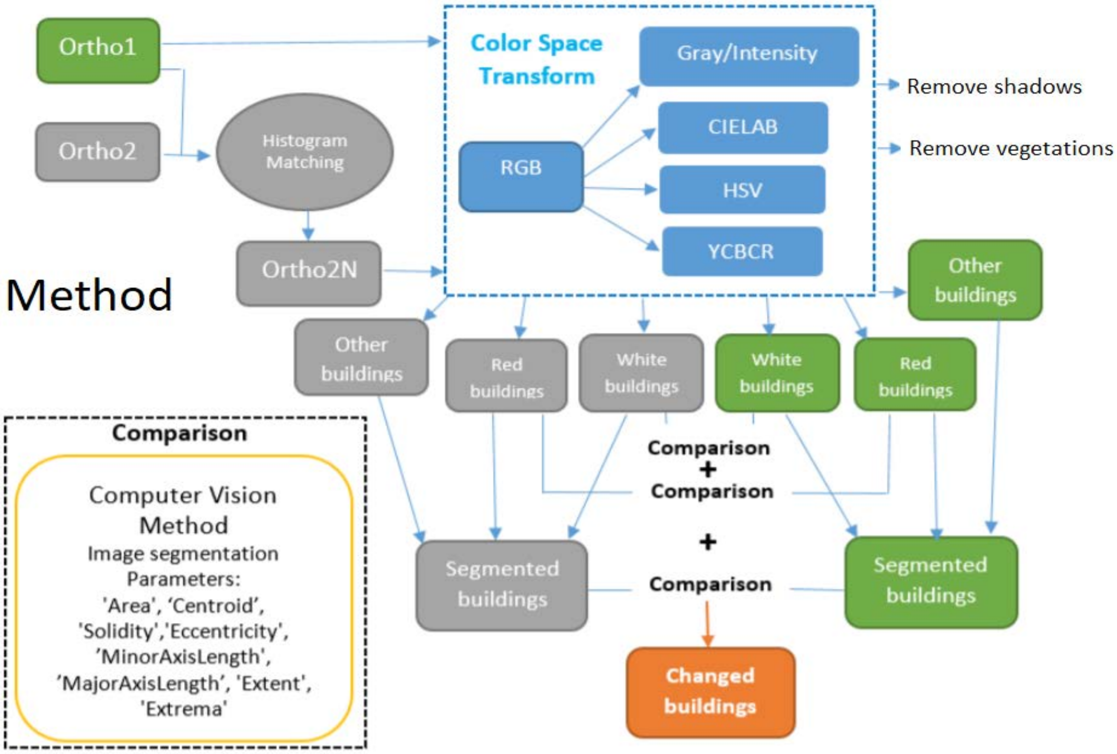

Figure1 Workflow of the method development

Results

The proposed method has been tested in five areas of orthophotos from the datasets with different time, space, and resolution. The test datasets were from the period of 2011 to 2020, with a resolution of 30cm to 50cm. The results have been validated and analyzed. It is quite promising. Our method is full automation and beneficial for reducing manual operation in finding building changes. Fig. 2 and Fig.3 show the results from orthophotos with different resolutions and covering different sizes of the areas. The figures include the original orthophotos, building extraction, and the changed buildings (new buildings, demolished buildings, and rebuilt buildings).

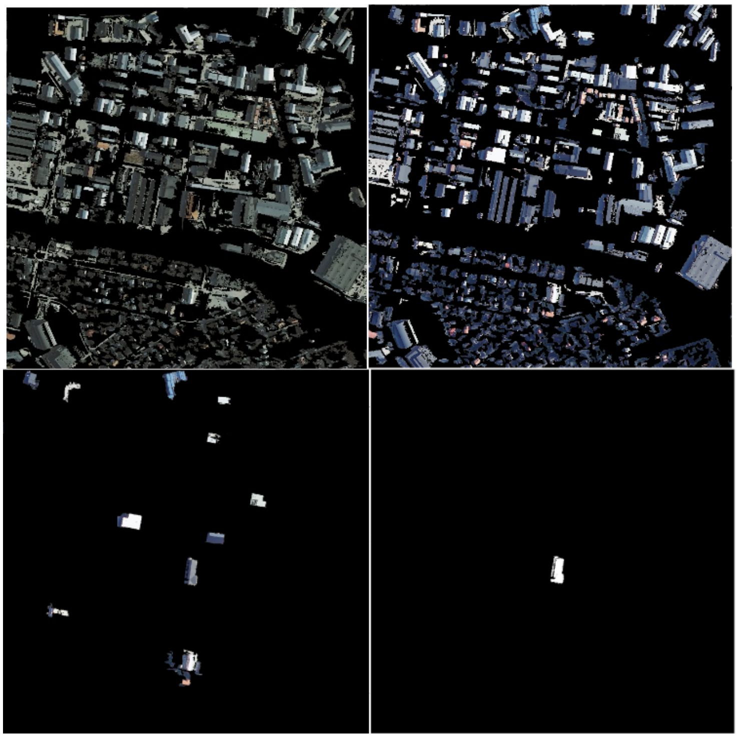

Figure 2. An example of the result of building extraction and change recognition from 1km*1km orthophoto with 30cm resolution (the lowest figure from left to right: new buildings and rebuilt building)

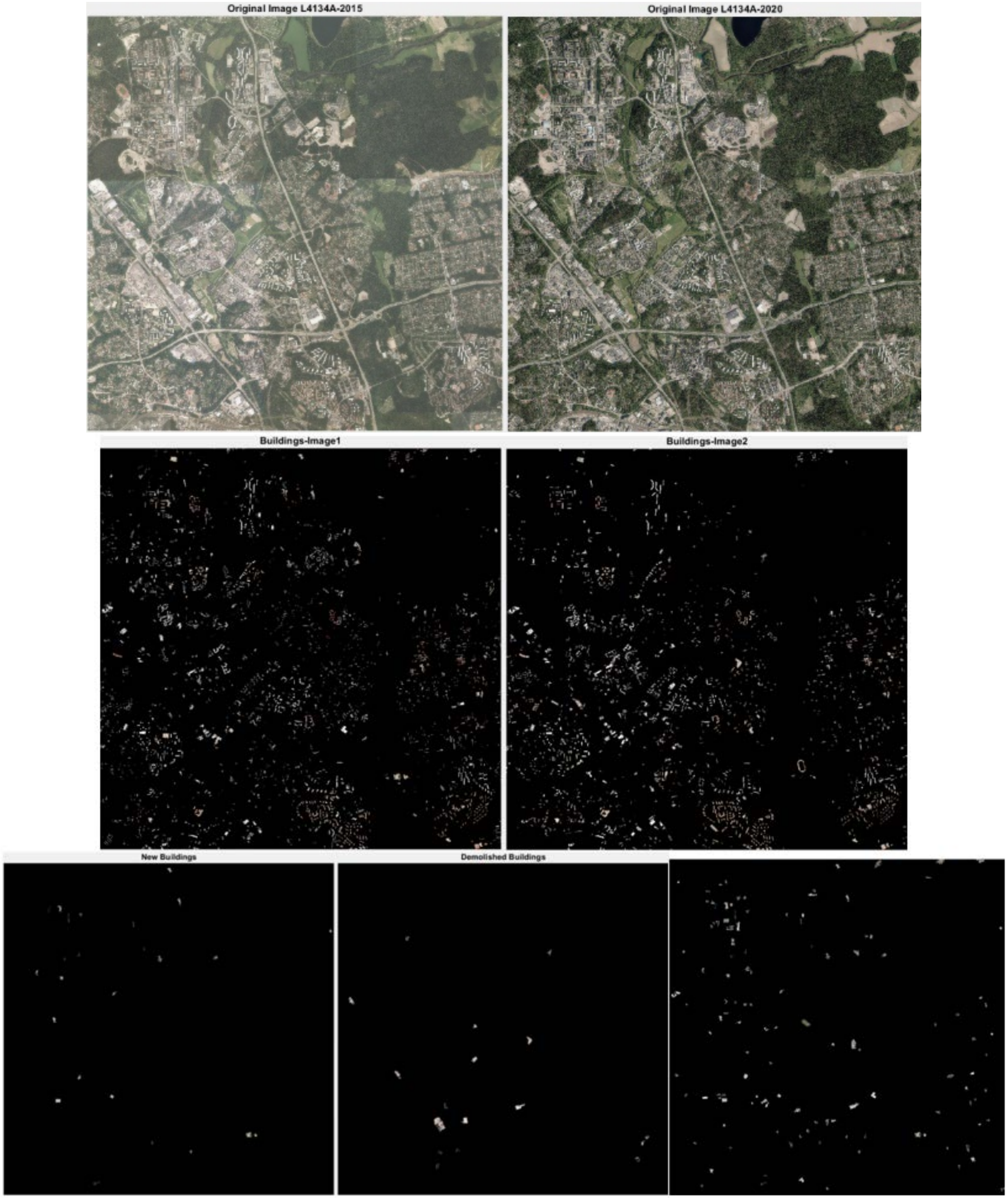

Figure 3. An example of the result of building extraction and change recognition from 6km*6km orthophoto with 50cm resolution (the lowest figure from left to right: new buildings, demolished buildings, all changed buildings)

Orthophoto based method for building change recognition has the following advantages and disadvantages: it is beneficial for rich information in color spaces; there were mature theory and methods support in image processing; an orthophoto has a small size with large coverage; object segmentation is color-dependent (using rgbn image is helpful); shadows affect object segmentation; it is co-existing of small buildings and noise (a balance needs to be kept);

Outlook for the future

In the future, the method can be continuously updating and improved when high to very high resolution data are acquired. And also, photogrammetric point clouds or DSM from the aerial images might help in detecting the building height changes. Thus, the buildings rebuilt with the same colored roofs but in different heights or morphologies can be recognized.

3D data on regional scale: what are the main mapping products and associated users?

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Abstract
Corresponding Author:
liege2020@earsel.org
y.francois@student.uliege.be

Yohann François[1], Nathalie Stephenne[2], Philippe Lejeune[1], Adrien Michez[1]

[1] University of Liège, Gembloux Agro-Bio Tech, Belgium
[2] Service Public de Wallonie (SPW), Geomatic Department, Belgium

Keywords: Earth Observation, 3D modelling, LiDAR, Land Use, INSPIRE, Walloon georeferential

The challenge

Our study aims to synthetize the existing publically available 3D mapping products in Wallonia (Southern Belgium) and their actual and potential users. Moreover, our study also intends to gathering requirements from these users in order to increase the appropriation of these data. The INFRASIG Walloon decree which transposes European Union INSPIRE directive adopts an operational plan and proposes a Walloon Georeferential. This dataset should include the main reference geodata such as orthophoto coverage and relief information required in Annex II of INSPIRE. To respect the EU obligation of assessing geodatas needs, this paper analyses the requirements in 3D information and compares the different products available in Wallonia.

Methodology

This paper classifies the specific Walloon 3D dataset in relation to the users' needs. While 3D information is also taken on the field through topographic instruments to be integrated in the PICC, this paper focuses on Walloon coverages by LiDAR and photogrammetry from which are derived digital elevation models over the complete territory. A qualitative analysis of Walloon requirements based on a user story survey has been conducted by the SPW. Each user combines 3D geodatas available in Wallonia. Companies, public services and universities want high quality of elevation information. The growing interest in this type of data is linked to the expected smart land use management and UN development goals.

In Wallonia, LiDAR and photogrammetry technologies have been used to build several models for relief measurement and mapping. In 2013-2014, LiDAR provided a directly usable 3D cloud points (3DCP) from which were derived 2 models at 1m resolution: a digital terrain model (Li DTM) and a digital surface model (Li DSM). A digital surface model (pDSM) has also been produced by photogrammetry from the 25cm orthophoto coverage acquired by regional administration in 2018-2019. All these products can be used in different ways. For example, in vegetation monitoring purposes, Canopy height models derived from lidar data and photogrammetric canopy height models (pCHM) have been created in 2006-09-12-15 and 2016. In addition, combinations of these 3D products are created to satisfy some needs

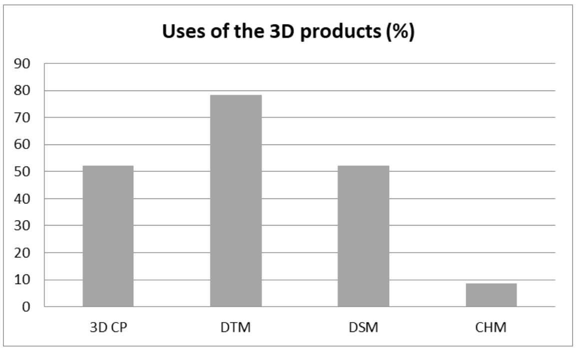
Results

Comparative tables between the different existing models present their advantages and disadvantages, as well as their uses for various Walloon projects. Criteria include budget of acquisition but also time needed for the complete coverage, processing techniques and time, weather impact, data and resources needed for the quality check. These tables allow identifying the potentially improved specifications or the essential products for most of the users. It reveals the common technical requirements of 3D products such as number of points / m², update frequency, accessibility, type of derived products, … Some validation studies have been carried out on each dataset. Most of them make use of the topographic measurements taken by the SPW for the PICC. Comparison of these techniques and recommendations about quality control process to be applied for the next products is proposed. In comparison to Wallonia, Flanders and Brussel regions have acquired denser lidar datasets to derive higher resolution elevation models. Comparison of these applications and technical specification have inspired the Walloon administration for defining the current lidar acquisition.

Outlook for the future

A new LiDAR data acquisition campaign will start in early 2020 with higher point density (3pts/square m) and full wave form signal storage. The synthesis carried out in this paper will attempt to answer this central question: Will this technology evolution help to create the reference dataset which meet most of Walloon users' needs, as requested by the INFRASIG decree? Moreover, geomatics and remote sensing are fast evolving domains where new solutions can quickly rise. Combining multi-source data can produce specific models better suited to certain situations or needs. For example, projects can integrate Sentinel satellite optical imagery with these 3D regional models to increase the quality of the classification through seasonal information, i.e. in land cover map production. This analysis of current needs will help to develop these specific models with new technologies such as artificial intelligence.

Users	Data/Models	Uses
Catholic University of Louvain	DTM	Detection of faulde areas in forest to quantify the carbon stock in Walloon soils
SPW / Archaeology Department	DTM	Better visual perception of archeological vestiges on the ground
SPW / Data Integration Department	3D CP	Obstacles detection around aerodromes
SPW / Non-navigable Watercourses Department	DTM	Flood forecasting and prevention
Catholic University of Louvain	DTM	Predict location and intensity of concentrated runoff to propose mitigation measures
Sireal	3D CP,DTM	Optimize hydrological modelling by reducing DTM errors and uncertainties
University of Liège - Gembloux Agro-Bio Tech	3D CP,DTM,DSM,CHM	Estimate the height of forest stands, and indirectly, the wood production
SPW / The granting of agricultural aid Department	DTM,DSM	Classify and delineate the structural elements of landscape as precisely as possible
Catholic University of Louvain	3D CP,DTM	Mapping, automatic classification, ecotope delimitation (lifewatch)
University of liège - Geomatic unity	3D CP	3D building representation with high geometric and/or visual representativity
SPW /Industrial, Geological and Mining Risks Department	DTM	Geological mapping and natural risk management
SPW / DGO3 DAFoR	DTM,DSM	Rural land use planning (new and existing infrastructures)
ISSeP	3D CP,DTM,DSM	Land use / land cover mapping (automatisation)
University of liège - Geomatic unity	3D CP,DTM,DSM	Theoretical issues and perspectives in 3D data acquisition
IGN	3D CP,DTM,DSM	Improve the accuracy of the IGN altimetry dataset
AWaP	3D CP,DTM,DSM	Patrimonial interest sites detection and 3D reconstruction
Computer centre of Brussels region (CIRB).	3D CP	Semi-automatic 3D reconstruction of buildings or bridges
SPW / Geomatic Department	3D CP,DTM,DSM	Produce and distribute reference data (INFRASIG decree)
University of Liège	DTM	Geology, geomorpholgy and landslides areas identification
ISSeP / CASMATTELE	DSM	Semi-automatic characterization of roofing materials by remote detection
ISSEeP / E04LULUCF	DSM	Inventory of land use, land use change and forestry in Wallonia for Kyoto reporting (Climate change)
ISSeP / SARSAR	DTM,DSM	Combining optical and radar imagery for automatic monitoring of brownfields
University of Liège - Gembloux Agro-Bio Tech	3D CP,DTM,DSM,CHM	Mapping the evolution of bark beetle attacks in Walloon spruce forests



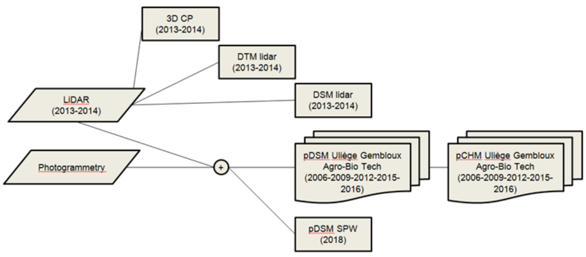


Figure Example of comparative table derived from the SPW survey

Mapping Urban Population Distribution In Data-Scarce Countries

EARSeL Liege 2021
Abstract
Corresponding Author:
catherine.linard@unamur.be

Catherine Linard[1]

[1] Université de Namur, Belgium

Advances in satellite remote sensing techniques and crowdsourcing data availability offer effective solutions for mapping settlements and monitoring urbanization at different spatial and temporal scales. Moreover, remote sensing data have a great potential to map and predict intra-urban variations in population density or socio-demographic characteristics because they provide information on the morphology of different residential patterns that can be linked to different population densities and socio-economic variables. With a particular focus on sub-Saharan African cities, the presentation will summarize latest research in satellite-based population modelling techniques, will highlight the added-value of recent data and techniques, and will show some application examples for intra-urban health risk mapping.

The complexity of cities in the Global South from Space

Corresponding Author: m.kuffer@utwente.nl

Monika Kuffer[1]

[1] University of Twente, The Netherlands.

Many regions of the global South are rapidly urbanizing, showing complex spatial dynamics of urban morphologies. However, spatial patterns and dynamics are insufficiently explored and understood due to a chronic lack of data, which is also reflected by the challenges in local reporting of the urban Sustainable Development Goals (SDGs) indicators. Spatial dynamics include urban transformation processes, e.g., changes in deprivation levels of neighbourhoods. However, data that reflect the complexity of urban morphologies, and their dynamics, in the Global South are commonly unavailable or inaccessible. Innovations in Earth Observation (EO) methods and data are required, e.g., developing transferable and scalable methods, the inclusion of secondary cities, and the provision of more accurate and timely population estimates. Data are needed in support of tracking local and policy goals, which calls for the integration of EO and local data, in particular community-based data. This will allow bridging the large data gaps. For local policy support or managing humanitarian crises (e.g., COVID-19), data integration innovations are key to produce data in a responsible manner that supports societal progress

The Potential of SAR and OPTICAL Sentinel Images for the Automatic Monitoring of Redevelopment Sites

EARSeL Liege 2020
Abstract
Corresponding Author: s.petit@issep.be

Sophie Petit[1], Mattia Stasolla[2], Wyard Coraline[1], Gerard Swinnen[1], Odile Close[1], Benjamin Beaumont[1], Christophe Rasumny[3], Xavier Neyt[2], Eric Hallot[1]

[1] Remote Sensing and Geodata Unit, Institut Scientifique de Service Public, Belgium
[2] Signal and Image Centre, Royal Military Academy, Belgium
[3] Land Planning, Housing, Heritage and Energy, Service Public de Wallonie, Belgium

Keywords: Sentinel, Synthetic aperture radar (SAR) data, Optical images, Change detection, Redevelopment sites

The challenge

The Walloon Region is managing an inventory of abandoned sites, called "Redevelopment sites" (RDS). These sites are former industrial, commercial, social, real estate (housing excluded) areas whose current condition is against the good management of the site or represents a deconstruction of the urban canvas. Fully updating the inventory of more than 2000 sites on the territory is costly and time consuming, but essential in order to provide up-to-date information and more particularly to avoid leaving old RDSs in the publicly accessible database. As it is estimated that less than 10% of RDS are likely to "change" each year, the inventory update time could be reduced by allowing investigators to examine only the RDS where there are indications of change. The aim of this project is to develop a tool to perform the automatic monitoring of RDS using synthetic aperture radar (SAR) and optical images in order to detect changes that can then be confirmed and refined by on-site visit.

Methodology

Sentinel-1 (S1), acquiring C-band SAR images, and Sentinel-2 (S2), carrying a multi-spectral imaging system are used for retrieving information from two complementary sources of information. On the one hand, SAR being sensitive to variations in height shape and water content, it allows to acquire information on the physical parameters that might have changed between the acquisition dates. On the other hand, optical data, thanks to their multi-spectral capabilities, provides the capacity to identify and classify changes in land cover/land use. In addition, their frequent revisiting time and their open-access made them relevant tools for change detection.

As S1 images are more frequently available than S2 ones, data fusion cannot be performed following a strict combination scheme, but is adapted according to the availability of the sources. The overall idea is to create a multi-dimensional feature vector of variable size that is populated with a set of temporal features extracted from the available data. The obtained multi-dimensional feature vector is then input into the processing block that is in charge of the change detection. To quantify and classify changes into different types, a rule-based classifier is applied. Finally, a confidence parameter is given to help the user finalizing the decision and prioritizing the sites to be checked.

Results

Different possibilities are currently explored. As far as SAR data is concerned, the backscattering coefficient (sigma nought) obtained from different viewing angles and polarizations has been used.

Regarding optical data, a combination of several spectral indices (NDVI, BI, BI2, SBI, BAI and NDWI2) is used to emphasise specific aspects of land cover by analysing the RDSs spectral signatures. In order to emphasise changes limited to specific areas of each site, segmentation with ancillary data and/or with a grid is implemented.

This leads to the detection and the classification of changes, such as building demolition or construction, vegetation cut or growth…, as well as an estimation of their magnitude. Moreover, this highlights the specific times at which the change occurred, called "Changepoints".

The automatization of the process, which is still a work in progress, is developed in Terrascope, the Belgian contribution to the Sentinel Collaborative Ground Segment. This virtual research environment provides data from the Sentinel missions integrated with computing power.

Outlook for the future

The first important step will be the validation of changes detected by the rule-based classifier. Two specific tools will be used. The first is an inventory that was manually established where each of the 2000 sites have been remotely-sensed mainly by aerial photography (SPW Orthophotos) and analysed by an operator. It is a semi-qualitative inventory of changes observed between four dates (2013 / 2015 / 2016 / 2018) and focuses on buildings, vegetation and artificial ground cover. The second tool will be based on the observation and processing of Pleiades images. These images are requested every 2 months for the duration of the project for two test areas having a very high density of RDS (e.g. Liège and Charleroi).

The results and findings of the project will be properly documented and training sessions on how to use and maintain the tool will be specifically organised for the Walloon Region.

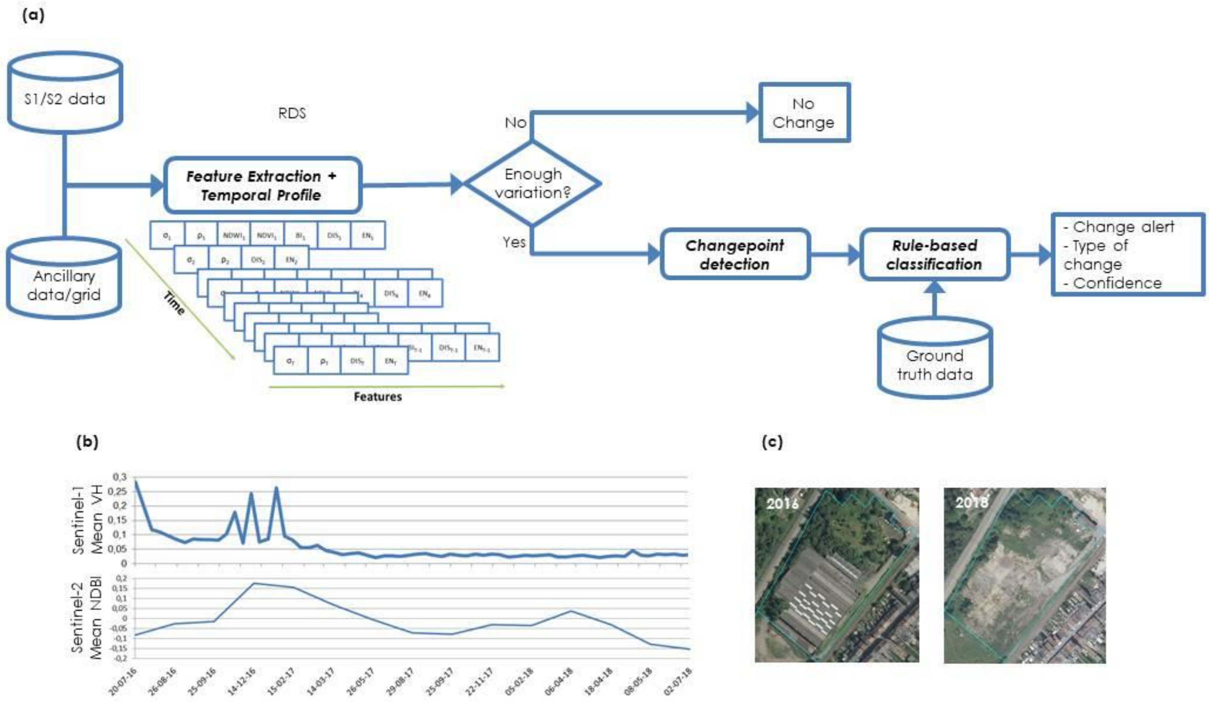


Figure (a) block diagram presenting the technical process, (b) temporal profile of "Ets Linotte" site and (c) ortho-photo of "Ets Linotte" site

Assessing the Capabilities of Sentinel-1 and 2 for Citywide Slum Mapping with Machine Learning

EARSeL Liege 2021
Abstract
Corresponding Author: sabine.vanhuysse@ulb.be

Sabine Vanhuysse[1], Taïs Grippa[1], Monika Kuffer[2], Stefanos Georganos[1], Nicholus Mboga[1], Eléonore Wolff[1], Moritz Lennert[1].

[1] Université libre de Bruxelles (ULB), Department of Geosciences, Environment and Society, Belgium
[2] University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), The Netherlands

Keywords: Slums, Sub-Saharan Africa, Sentinel-1, Sentinel-2, Machine Learning

The challenge

Sub-Saharan African cities are faced with considerable development challenges, as rapid urbanisation leads to the proliferation of deprived areas lacking basic services, often referred to as slums. There is a need for consistent and regularly updated citywide spatial data on the location and extent of deprived areas for supporting local and national policies, and fostering progress towards global development goals (e.g., SDG 11), but such data are generally missing. To date, Earth Observation has not been used as an effective policy support tool in this respect, and most remote sensing studies tend to develop site-specific approaches on small areas. In this research, we assess the potential of free Sentinel-1/2 imagery and ancillary open data for mapping slum-like deprived areas in a scalable manner, using free open-source software (FOSS), and focusing only on the morphological aspects of deprivation.

Methodology

The methods are showcased for the city of Nairobi, Kenya. As Sentinel-2 (S2) availability is affected by frequent cloud cover over tropical and equatorial regions, we use an atmospherically corrected S2 cloud-free multitemporal composite covering a period of 3 months. A series of 10 Sentinel-1 (S1) IW SLC datasets acquired during the same period, is used to produce temporal averages of VV and VH intensity, and interferometric coherence with SNAP. Ancillary open datasets consist of the World Settlement Footprint layer (10m resolution), void-filled SRTM GL1 v3 data (30m resolution), and selected OpenStreetMap features that have a good global coverage. Training and validation samples are produced by visual interpretation of very-high resolution optical imagery in QGIS, according to an 8-class land-use/land-cover (LULC) scheme that includes 2 classes of deprived areas. Processing is carried out in 50 x 50m grid cells using mostly GRASS GIS modules in a Jupyter Notebook and R, and OTB to a lesser extent. A large number of spectral, spatial, land-cover and ancillary features are extracted, and feature selection is performed prior to Random Forest classification in view of building simple and parsimonious models that maximize accuracy, reduce computational costs and increase the potential for transferability across cities. Different feature combinations are assessed and their performances are compared.

Results

For each combination, feature selection with the Variable Selection Using Random Forest (VSURF) algorithm considerably reduced the large initial feature set, which is an asset for the potential replicability of the method. The assessment of the Random Forest classifications focused on the two classes of deprived areas, namely (i) type 1: very compact deprived areas without structured road network and (ii) type 2: compact to mid-dense deprived areas with a more structured road network. It indicates that using S2 features produces better results than using S1 features, and that the joint use of S1 and S2 features further improves the accuracy. Adding ancillary features derived from the WSF, SRTM terrain morphometry and OSM roads, railways and city centre location to any of these combinations also brings a substantial improvement. The combinations that involve S2 or S1/S2, with the addition of ancillary features (Figure 1), obtain the highest accuracies, with F1 scores over 85%. It appears from visual assessment that larger deprived areas of type 1 are particularly well captured. Our results demonstrate that S1/2 imagery complemented with free global open datasets in a FOSS workflow offer good opportunities for developing Earth Observation products in support to pro-poor policies in sub-Saharan African cities.

Outlook for the future

A similar methodology will be implemented for processing low-cost SPOT 6/7 images and results will be compared to those obtained with S1/2 to draw conclusions on their respective merits and limitations. Besides, as the publication of maps of deprived urban areas with hard labels could lead to misuses and ethical concerns, we will investigate alternative solutions for meeting the requirements of different categories of users, e.g., gridded morphological deprivation probability maps. Domain adaptation strategies will also be explored in view of proposing a heavily automated method that is not only scalable, but also transferable to other sub-Saharan urban environments, with a reduced workload of manual sampling.

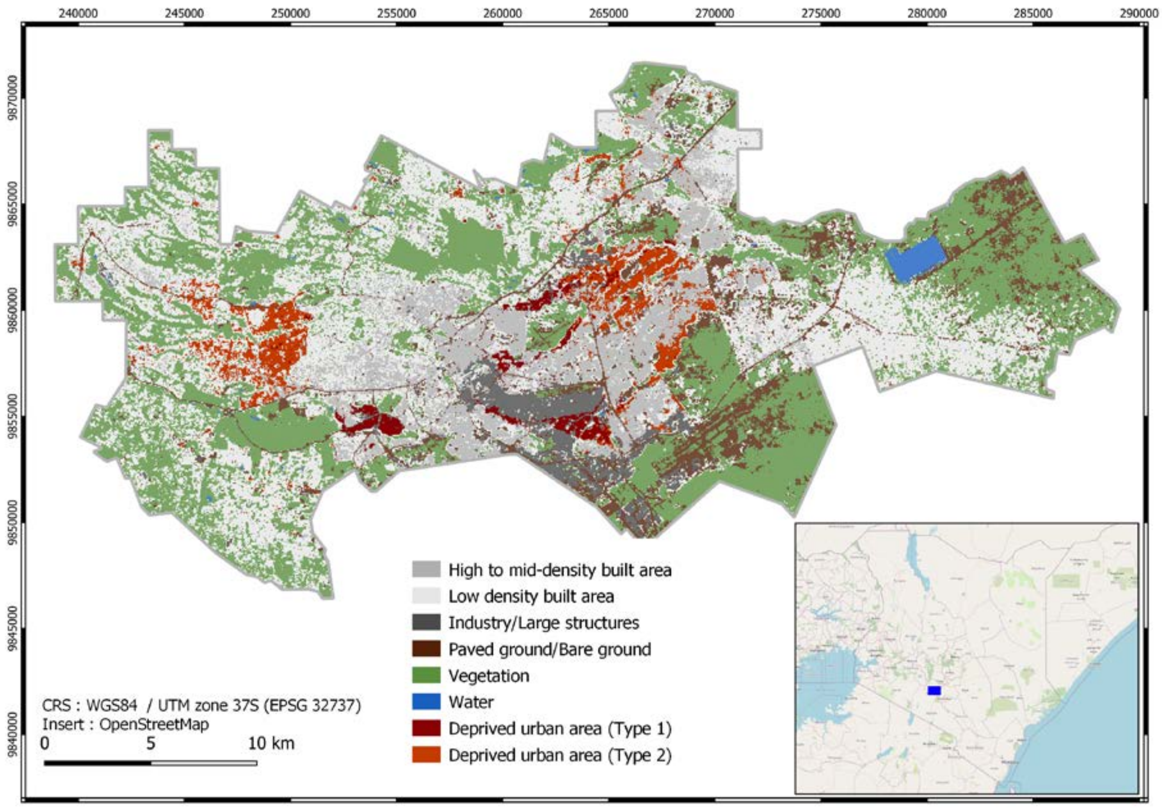


Figure 1 Citywide map of Nairobi, Kenya, with two types of deprived urban areas. Input: S1, S2 and ancillary (i.e., WSF, SRTM and OSM) features. Resolution: 50 x 50m.

Citizens and Satellites – Multisource Monitoring of Urban Sprawl in Context of Climate Change Adaptation based on Remotely Sensed Time Series and Crowdmapping in German Metropolitan Regions

EARSeL Liege 2020
Abstract
Corresponding Author: andreas.rienow@rub.de

Gohar Ghazaryan[1], Francis Hugenroth[2], Carsten Jürgens[3], Sarah Sticksel[3], Birte Trampnau[3], Anke Valentin[2], Andreas Rienow[3]

[1] University of Bonn, Center for Remote Sensing of Land Surfaces (ZFL), Germany
[2] Science Shop Bonn (WiLa Bonn e.V.), Germany
[3] Ruhr-University Bochum, Department of Geography, Geomatics Research Group, Germany

Keywords: Urban Growth, Impervious Surfaces, Climate Adaptation, Multisensor data, Citizen Science

The challenge

Germany was among the three top countries affected by extreme weather events in 2018. With the continuously increasing urban population and their footprint, the need to assess, map and quantify the dynamics of the urban environment and the impact of these changes increases. Coupled with climate change impacts, improving the climate adaptation competence of cities is essential. Land use and consequent soil sealing are particularly high in urban areas and this can induce conflicts of use: the demand for housing, business, and economy is enormous, but at the same time it is essential to maintain and improve the quality of life through a network of green spaces. With the help of remote sensing and crowdmapping, the change of urban areas can be observed and quantified over time. In this study we develop a framework for analyzing urban growth degrees of imperviousness in terms of soil sealing in North Rhine-Westphalia (NRW) from the 1980s to date while integrating citizens for developing climate adaptation strategies at once.

Methodology

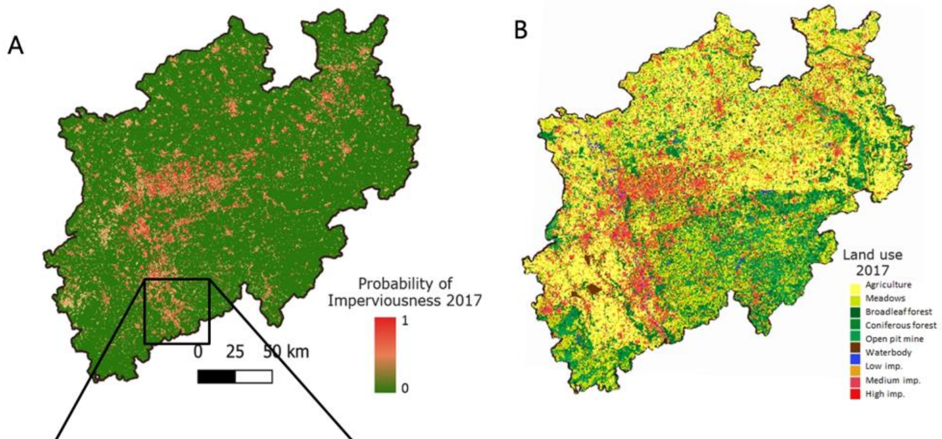
Particularly, the study examines to which extent Landsat and Sentinel, as well as coarser scale MODIS data can be used in order to monitor and analyze urban change. As a primary data, Landsat time series were selected due to the availability of long-term time series. Following the preprocessing of the images (e.g. cloud masking) several indices were estimated, and composites were calculated for growing season and full-year for 2017, 2015 to 1985 for every five years. For the initial 2017 time step Atkis data were extracted in order to gather data for training. For retrospective classification the output of this classification and information based on radiometric bi-temporal change detection was used for preceding years. For 2017, Sentinel-2 based classification was carried out as well. Besides spectral bands, several indices such as NDVI, NDMI, and Tasseled cap indices were calculated and several aggregates were created, such as minima, maxima, median over the year and growing season which was used as an input for Random Forest classification.

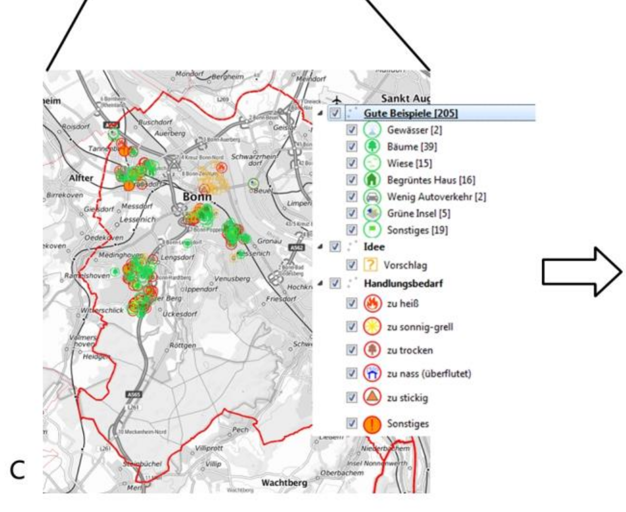
Results

The combination of these metrics provided information on three imperviousness classes, helping to minimize misclassifications through minimizing seasonal effects and changes. A producers accuracy of 0.82 (low imperviousness), 0.89 (medium imperviousness), and 0.91 (high imperviousness) could be achieved. According to our results, the imperviousness areas continuously grew from 1985s to 2017, with a high imperviousness area growth by more than 100.000 ha. In addition, MODIS and Landsat data were used to estimate recent trends in land surface temperature and identify the hotspots of increased imperviousness and LST. A mean LST increase of 2-3 °C could be observed; ubiquitous in the whole state, in urban as well as in rural areas. But since 71.6% of the inhabitants live in cities, the satellite-based analyses were further combined with in-situ information gained by crowdmapping in the Rhine-Ruhr metropolitan. Crowdmapped data enhanced the extensive land use information with point by point information. It is shown, how citizen science can help not only by gathering people's knowledge acting as data collectors but also by letting them participate in research and regional planning.

Outlook for the future

The examples of Rhine-Ruhr metropolitan region demonstrate how local knowledge of people is integrated in a multisource remote sensing framework to detect calls for actions, potentials, and best-practice examples related to climate adaptation of growing urban systems. With the help of Science Cafés, workshops, and summer schools scientific methods and paradigms are again imparted to the citizens and discussed. The integration of "sensors" and "citizens" will enforce the development of regional climate adaptation strategies, increase the resilience of cities, and help to analyze spatio-temporal urban dynamics within the coupled human-environmental system of urban areas.





Type	Count
Good Practice examples	
Waterbodies	2
Trees	40
Meadows	15
Vertical Green	16
Reduced Traffic	2
"Green Island"	5
Others	19
Need for Action	
Too hot	34
Too sunny	16
Too dry	12
Too moist	3
Too stuffy	5
Others	9
Ideas	
Suggestions	27

Figure (A) Probability of imperviousness in NRW 2017; (b) Land use map NRW 2017; Good practices, needs for action, and ideas mapped by citizens

Copernicus for Urban Resilience in Europe: The CURE Project Idea

EARSeL Liege 2020
Abstract
Corresponding Author: zedd2@iacm.forth.gr

Nektarios Chrysoulakis[1], Zina Mitraka[1], Mattia Marconcini[2], David Ludlow[3], Zaheer Khan[3], Brigitte Holt Andersen[4], Tomas Soukup[5], Andreas Walli[6], Alessandra Gandini[7], Jürgen Kropp[8], Dirk Lauwaet [9], Christian Feigenwinter[10]

[1] FORTH, Institute of Applied and Computational Mathematics, Remote Sensing Lab, Greece
[2] DLR, Deutsches Zentrum für Luft- und Raumfahrt, Germany
[3] University of the West of England, Bristol, United Kingdom
[4] CWare ApS, Denmark
[5] Gisat S.R.O., Czech Republic
[6] GeoVille Informationssysteme und Datenverarbeitung GMBH, Austria
[7] TECNALIA, Fundacion Tecnalia Research & Innovation, Spain
[8] PIK, otsdam Institut fuer Klimafolgenforschung, Germany
[9] VITO, laamse Instelling voor Technologisch Onderzoek N.V., Belgium
[10] Universitaet Basel, Switzerland

Keywords: Urban Resilience, DIAS, Thermal Comfort, Air Quality and Health, Urban Flood and Subsidence Risks

The challenge

A major challenge for the urban community is the exploitation of the Copernicus products in dealing with the multidimensional nature of urban sustainability towards enhancing urban resilience. The recently funded H2020-Space project CURE (Copernicus for Urban Resilience in Europe) aims to synergistically exploit Copernicus Core Services to develop an umbrella cross-cutting application for urban resilience at several European cities. CURE is expected to provide the urban planning community with spatially disaggregated environmental information at local scale. It uses DIAS (Data and Information Access Services) to develop a system integrating this application, capable of supporting operational applications and downstream services across Europe in the future. Furthermore, CURE is expected to provide scenarios on how the developed system could potentially be integrated into the existing Copernicus service architecture addressing also its economic feasibility.

Methodology

The innovation potential of CURE lies on the exploitation of the Copernicus offer in the domain of urban resilience. CURE develops cross-cutting applications combining products from CLMS (Copernicus Land Monitoring Service), CAMS (Copernicus Atmospheric Service), C3S (Copernicus Climate Change Service) and EMS (Copernicus Emergency Service) with third-party data, and a system for integrating these applications, enabling its incorporation into operational applications and downstream services across Europe in the future. An active co-creation process, involving potential users, enables an effective and dynamic knowledge exchange to ensure that demands and needs are addressed. 11 cross-cutting applications (Figure) reflecting specific urban sustainability dimensions (climate change adaptation and mitigation, healthy cities and social environments, energy and economy) are developed, as parts of the CURE umbrella cross-cutting application. These are based on state-of-the-art methods developed in past projects, which are improved and adapted to Copernicus in CURE. Each application is developed and evaluated for one or more of the CURE front-runner cities (Berlin, Copenhagen, Sofia and Heraklion). The CURE system is developed as a DIAS Service, including the hardware components set-up (processing units and storage), and the software design (interaction between those components, information provided by the platform and the deployed applications in a cloud computing environment).

Results

CURE is expected to lead to more efficient routine urban planning activities with obvious socioeconomic impact, as well as to more efficient resilience planning activities related to climate change mitigation and adaptation, resulting in improved thermal comfort and air quality (societal benefit), as well as in enhanced energy efficiency (economic benefit). In a broader context, mitigation and adaptation actions that enhance the resilience of cities need to be based on a sound understanding and quantification of the drivers of urban transformation and vulnerability, as defined in SDGs and the New Urban Agenda. An ever-growing number of European cities is putting environmental sustainability at the core of their urban development strategies (e.g., Covenant of Mayors). Local authorities benefit from the development of tools such as the CURE system, to streamline environmental data collection and management and to facilitate the exchange of information and best practices at all levels. Therefore, CURE is able to support the implementation of these polices, because it provides analysis at different scales, facilitating the comprehension of the underlying mechanisms that drive environmental problems in cities. This will benefit from a site level perspective and thus support the identification of priorities for policy intervention at the city level.

Outlook for the future

In the future, urban areas need to be resilient, sustainable, inclusive, safe, resource-efficient and innovative, incorporating a circular economy and smart infrastructure. Hence, a better understanding of local scale interactions between urban form and function is needed for resilience planning. To this end, the Copernicus Services with potential to monitor and evaluate resilience building efforts might play a crucial role. Given that the existing Core Services are not specifically designed for urban environment, it is expected that precise requirements related to the spatial, temporal, spectral and angular characteristics of EO data, along with the respective technological limitations and barriers will be analysed and documented. This analysis will lead to possible scenarios on how CURE can be used as a basis for an enhanced Copernicus Urban Service development in the long term and recognize priorities for future scientific advancements, technological improvements and EO missions.

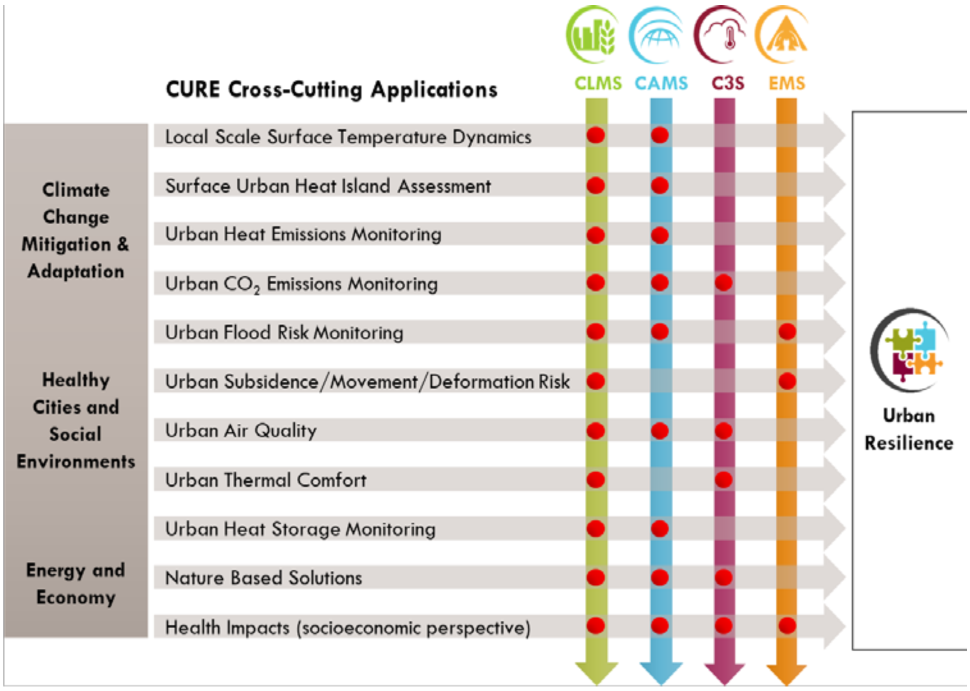


Figure The cross-cutting applications across Copernicus Core Services that are developed in CURE

Multinomial logistic regression and Cellular Automata for modelling of urban sprinkling

EARSeL Liege 2020
Abstract
Corresponding Author: lucia.saganeit@unibas.it

Lucia Saganeiti[1], Ahmed Mustafà[2], Beniamino Murgante[1], Jacques Teller[3]

[1] School of Engineering, University of Basilicata, Potenza, Italy
[2]Urban systems lab, the new school, New York, USA
[3] LEMA, Urban and Environmental Engineering Department, Liège University, Belgium

KEYWORDS: URBAN DENSITY, CELLULAR AUTOMATA, MULTINOMIAL LOGISTIC REGRESSION, URBAN SPRINKLING, BASILICATA REGION.

The challenge

We applied an integrated approach based on the multinomial logistic regression (MLR) and the cellular automata (CA) for urban sprinkling modelling. Our case study is the Basilicata region, in southern Italy, which is affected by urban sprinkling. Urban sprinkling has been here defined as a decoupling between demographic dynamics, which may be negative, and the expansion built-up areas. Built-up density maps were created on the basis of three regional building datasets (1989, 1998 and 2013). These sources were used for calibrating and validating the model as well as for future simulation of urban sprinkling. The transition probability for the first time period (1989-1998) has been calibrated with MLR for the built-up causative factors and with multi-objective genetic algorithm for CA neighbourhood effects. The causative factors consider the physical, socio-economic, proximity and existing building constraints in the study area. The calibrated map was then used for the simulation of the 2013 map which was compared with the actual map of 2013 (validation). We then used our calibrated model to simulate urban growth in the year 2030.

Methodology

In order to generate built-up density maps we used the regional technical map, by regional geo portal (https://rsdi.regione.basilicata.it/servizi-in-linea) in a vector format. Three maps have been rasterized at a 2x2 m pixel resolution for the years 1989, 1998 and 2013. The rasterized maps have been aggregated to a 100x100 pixel resolution in which every pixel has a range density values from 0 to 2500 (counting the 2x2 m pixels within each 100x100 m pixel). We then classified the urban density continuum into four classes: non built-up, low density, medium density and high density. Two components were considered for the calculation of the transition potential from one density class to another. (i) Built up development causative factors were calibrated using the MLR for the expansion and densification processes. The factors considered were: elevation and slope (physical factors), Euclidian distance to railway station, different type of street, large size city and medium size city (proximity factors), population density and employment rate (socio economic factors) and zoning (land use policies). (ii) The second causative factor is the CA neighbourhood effects that have been calibrated using a multi objective genetic algorithm (MOGA) as in (Mustafa et al., 2018). The transition potential was calibrated for the 1989-1998 time period and the calibration outcomes were used to simulate the 2013 map. We then validated our model by comparing the simulated 2013 with the observed 2013. The validation results are used to predict the 2030 map. The robustness of MLR has been evaluated with the Receiver Operating Characteristic (ROC) index. The Fuzzines index has been used for evaluating the validation process accuracy.

Results

The results show that the most influential causative factor for the expansion process is the distance from local roads while, for the densification processes, it is the slope. Another important factor for the expansion process is the positive correlation with proximity factors from medium and large cities. This means that there is a trend to build far from cities and therefore from existing services, increasing social and environmental costs of urbanisation. This is directly related to sprinkling phenomenon prevalent in the study area. On the opposite, densification occurs close to existing large cities (negative correlation). The ROC values of the MLR outcomes are 0.85 for the expansion process and 0.91/0.95 for the densification process. Since the amount of change was very low, the densification process for class 1 to 3 has not been considered. The optimization process returned a set of Pareto front solutions (Yijie and Gongzhang, 2008) among which the optimal solution has been selected. The calibrated map of 1989-1998 has been used for the validation of 1998-2013 map. The accuracy rates for the validation process are 0.55, 0.34 and 0.22 for class 0 to 1, 0 to 2 and 0 to 3 respectively. The results of the 2030 prediction show a 0.17% loss of non-urbanized territory. The greatest variations concern class 1 (low density) that represent the sprinkling of urban cells in the territory.

Outlook for the future

Modelling future scenarios of urban sprinkling through the causative factors that regulate its mechanisms, help to understand the spatial model in action in a given territory and help, for example, the policy makers to adopt policies aimed at sustainable land consumption. The aim of this work is to predict future scenarios in low-density settlements in order to control and regulate the processes of urban transformation. The future research directions of this work will concern the application of the model to predict the variation of the sprinkling index, expression of urban dispersion in low density settlements.

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Leveraging IDP sites as pseudo-administrative boundaries for improved gridded population mapping

Hannah Rosenblum
Abstract
Corresponding Author:
hannah.rosenblum@census.gov

Hannah Rosenblum, John T. Fitzwater, Derek Azar, Joshua Comenetz, Arthur Desch, Nicholas John

U.S. Census Bureau, Population Division, United States of America

Keywords: Internally displaced persons, Random forests, Human settlement, Population distribution, Remote sensing

The challenge

Recent population data are essential for monitoring issues such as poverty, disease burden, and displacement, serving as the denominator for a variety of metrics. To be useful, such data must be current and spatially precise. However, these data are often unavailable in areas with conflict or limited financial resources. Satellite imagery can be used to produce gridded population datasets at a finer scale than available census data and closer to the present day.

The complex humanitarian crisis in South Sudan has caused extensive instability, substantially affecting the population distribution since the 2008 census. A dispersed and mostly rural population, with large numbers of internally displaced persons (IDPs) required a novel approach to gridded mapping that accounted for local human and physical geographic context.

Methodology

We used binary thresholding, unsupervised classification, and supervised classification techniques and Sentinel-2 imagery (10 m) to produce a 2017 human activity layer for South Sudan. We then used the human activity layer, 2017 population estimates, and several other human and physical geography datasets as inputs into a random forest model to generate a gridded population weighting layer. To account for the local context of a substantial proportion of the population living in internally displaced persons camps and Protection of Civilian sites, we linked population estimates to corresponding geographic areas and then subtracted the population estimate for each IDP site from its respective administrative area. We used a dasymetric method to disaggregate subnational population estimates to create a gridded population dataset for 2017. We applied this method using census data to create an additional gridded population dataset for 2008.

Results

We found that villages and water facilities were predictive covariates for both the 2008 and 2017 models. The most predictive covariates for 2008 were distance to villages, distance to health facilities, distance to educational facilities, distance to water facilities, and distance to roads. For 2017, the most predictive covariates were distance to built landcover, distance to cropland, distance to water facilities, distance to human activity, and distance to villages. The gridded population datasets reflect that much of the population of South Sudan lives in villages along rivers. The 2017 model performed well, with 86% of variance explained, and the 2008 model was able to explain 79% of variance. The high variance explained suggests that both datasets are appropriate to use as a weighting layer in a dasymetric approach.

Outlook for the future

As with all modeled population distributions, having population data for smaller geographic areas improves the disaggregation precision. For South Sudan, geographically detailed data are particularly important given the weak signal in the remotely sensed data due to a largely rural and dispersed population. In particular, being limited to second-order administrative divisions for 2017 affected the spatial refinement of our model and necessitated our use of IDP camps.

Further research is needed regarding modeling the population dynamics of adjacent areas or areas with similar physical and human geography. These methods could be especially useful in data-scarce areas. For example, if neighboring countries have higher quality census data, it is possible that those models could subsequently be applied to data-scarce regions to improve the accuracy of the population density model.

(a)

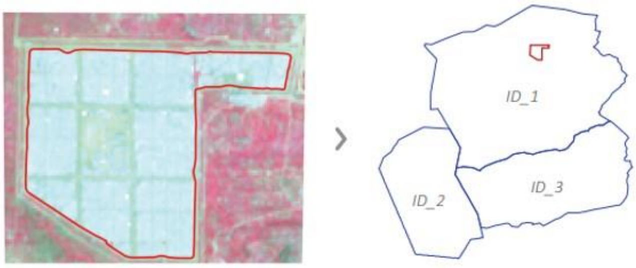

Figure (a) delineation and union of IDP sites with ADM 2 boundaries to account for the substantial IDP population.

The utility of gridded mapping systems to capture deprived urban areas in low-income country (LMIC) cities

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Abstract
Corresponding Author:
m.kuffer@utwente.nl

Michael Malkin[1,2,] Monika Kuffer[2], Jon Wang[2]

[1] Karlsruhe Institute of Technology, BGU, Germany
[2] University of Twente, ITC, The Netherlands

Keywords: Earth Observation, Deprivation, Slums, Informal Settlements, Machine Learning

The Challenge

Pixel-based outputs, which are commonly used mapping approaches of slums or informal settlements (here referred to as deprived areas), have much less user potential (due to their noisy nature) as compared to more aggregated mapping products. However, different aggregation unit's pros and cons are not well understood when using low and free cost Earth Observation data. This study shows for the example of Ouagadougou in Burkina Faso the differences of gridded versus street block mapping outputs and compares free cost Sentinel-2 and low-cost SPOT data. The conclusion that gridded mapping outputs in combination with Sentinel-2 data are providing the most accurate results is of key importance for the development of an integrated deprivation area mapping system that aims at scalable and transferable methods across African cites.

Methodology

For both the Sentinel-2 (10 m) and the SPOT-7 (1.5 m) imagery, textural features (e.g., GLCM) and vegetation indices (e.g., NDVI) were computed in addition to the four RGB-NIR bands. Furthermore, land cover features were created using a pixel-based approach for the Sentinel data and an object-based one for SPOT. The land cover features combined with the texture and spectral features were used as input to land use classification. For the generation of street blocks as the first aggregation level of land use data, road network data was extracted from OpenStreetMap and cleaned topologically to remove sliver polygons, while a grid of 100 m side length was generated as a second aggregation level. Segmental statistics were computed for each input layer, giving a total of around 120 features per satellite product and aggregation. Random Forest classifiers were applied to obtain land use information using six classes (i.e., water, vegetation, bare land, industry, planned residential, unplanned residential), thus pointing out the deprived areas as a separate class.

Results

Generally, the Sentinel-2 data showed a higher overall accuracy (Table 1) than the SPOT-7 imagery, while the gridded approach performed better than the street blocks.

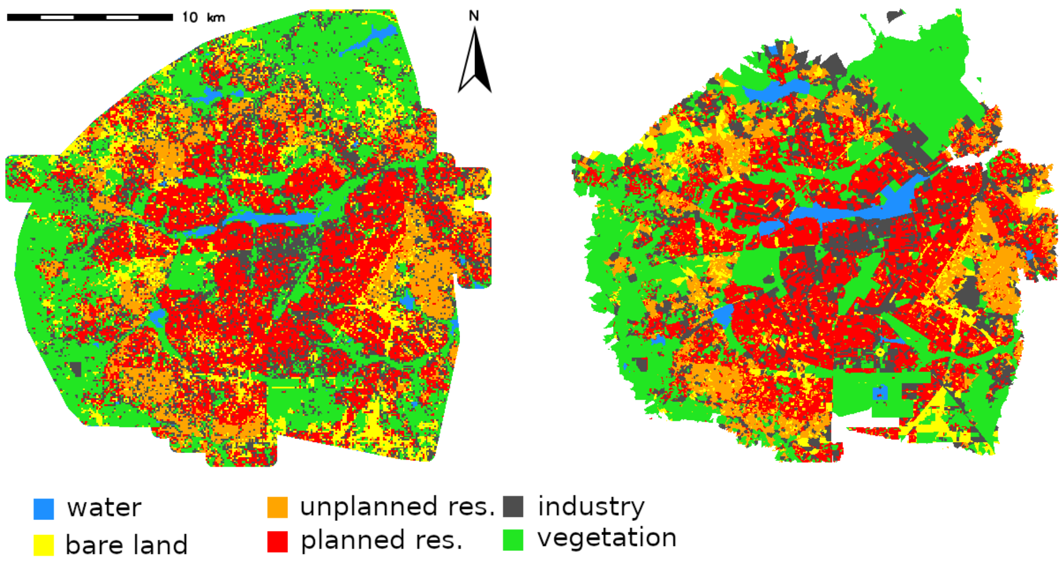

Figure 1: Land use classification - grid and street blocks.

Table 1: Accuracies of land use classification, comparing Sentinel-2 and SPOT-7 (aggregated at street blocks and 100 m grids).

RF Accuracy, Kappa, important features	Sentinel-2	SPOT-7
Grid	0.92, 0.9 Land Cover, NDVI	0.86, 0.83 Land Cover, NDVI
Street blocks	0.83, 0.77 RGB, NDVI	0.72, 0.64, RGB, Land Cover

The highest overall accuracy of 92 % was achieved for the Sentinel imagery with a grid aggregation, which points out the suitability of freely available Earth Observation data for mapping the location of deprived areas at city scale.

Outlook for the future

Flexible, transferable and low-cost mapping systems are required to produce maps of deprived urban areas supporting evidence-based local and global spatial policies. We are presently combining experiments on several cities to develop such a mapping system that will provide routine and accurate maps on the extent, location and dynamics of deprived urban areas with a focus on Sub-Saharan African cities, where data are chronically lacking. The combined knowledge generated within SLUMAP (http://slumap.ulb.be/) and IDEAMAPS (https://ideamapsnetwork.org) will be used to provide spatial data to satisfy diverse user needs.

A spatial assessment of low-income housing estate programs in the periphery of Mexico City using remote sensing and census data

EARSeL Liege 2020
Abstract
Corresponding Author: andres@igg.unam.mx

Stéphane Couturier[1,2], Adrian Flores[3], Roberto Huerta Luna[1], Richard Sliuzas[2], Monika Kuffer[2]

[1]National Autonomous University of Mexico (UNAM), Geography Institute, Laboratory for Geo-spatial Analysis (LAGE), Mexico
[2]University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), The Netherlands
[3]University of Anáhuac, Mexico

Keywords: Urban sprawl, impervious surface, deprived population, housing estate, Landsat imagery

The challenge

Market-driven housing programmes, backed by public mortgage schemes for about 25 years, offer the possibility of legalized homeownership for the growing urban low income population in the global South. In Mexico, however, these planned estates often compound tiny, easily overcrowded single-family houses in the periphery of metropolitan zones. Furthermore, many of them have been reported with caveats such as poor quality housing materials and basements, insufficient basic infrastructure, in contradiction with the ones advertised, and sometimes very remote or exposed to severe environmental hazards. In such under-serviced and unhealthy habitats, insecurity is not uncommon, and there have been cases of massive abandonment of houses. Despite advances in urbanization concepts, a quantitative assessment of these housing public policies in the megalopolis of Mexico City is still lacking, in part because of the unavailability or inconsistency of the data at metropolitan scale.

Methodology

Considering the unavailability of consistent and spatially explicit information on population numbers actually involved in the low-income housing programmes, we propose net population density (population per unit of built-up area) as a surrogate for the detection and assessment of overcrowding and abandonment in housing estates and in other urbanization types such as peripheral informal settlements.

Housing compounds constructed between 2000 and 2010 in the Mexico City Metropolitan Zone (MCMZ) were manually delineated after an exhaustive search of their approximate location on official estate company sites.

A cartographic representation was built over the MCMZ between 2000 and 2010, years of population census at neighbourhood level (approximately the size of individual housing compounds). The built-up area distribution was approximated by impervious surface extraction from Landsat imagery, using a decision tree classification strategy. The classification is separated per population density strata and has been previously assessed in a contiguous metropolitan zone of the Mexican central region with reasonable accuracy (about 70%) in the lower density stratum. Hotspots of low and high net densities were finally identified and analysed.

Results

The impervious surface distribution in MCMZ compared well with respect to global urban area coverage products such as the Global Human Settlement Layer (GHSL) and the Global Urban Footprint (GUF). Our method implied the supervision of classification results at two stages (more human labour intensive than global products) but our representation tended to include more dispersed settlements than the global products in the near periphery, although it underrepresented impervious surface in the far periphery.

On the one hand, possible abandonment of housing compounds has been detected in 8 municipios (counties) of the MCMZ (net densities between 2 and 65 inhab /ha). Notorious cases are the compounds “Hacienda Las Misiones”, “Santa Teresa I”, “Urbi Villa del Rey” and “El Dorado Huehuetoca”, at 40 km North of Mexico City.

On the other hand, possible overcrowding in housing compounds has been detected in 4 municipios (net densities over 300 inhab /ha): Acolman, Ixtapaluca, Chicoloapan and Chalco at distances of 10 to 20 km East of Mexico City.

Further analysis, using sources like newspaper reports, on a case by case basis, is needed to complement this preliminary study in order to confirm the hypothesis of overcrowding presented here.

Outlook for the future

This research offers a first step towards spatially explicit analysis of metropolitan scale public housing programmes in Mexico. Due to interest from the regional urban planning and citizen science communities, a spatial data infrastructure making this urban baseline cartography available online is under construction. A comprehensive database on the expected population per housing compound in MCMZ (from the sites of the estate companies) will be built to refine the analysis of this study and relate possible factors of success / failure of these projects in terms of the actual numbers of inhabitants. Additionally, a probabilistic accuracy assessment of the impervious surface extraction and quantitative comparison with global urban area products are the next steps of this research.

Building on those assets, our research is being extended to the central altiplano region level, and then to the National Urban System which was the scale of implementation of the entire housing programme.

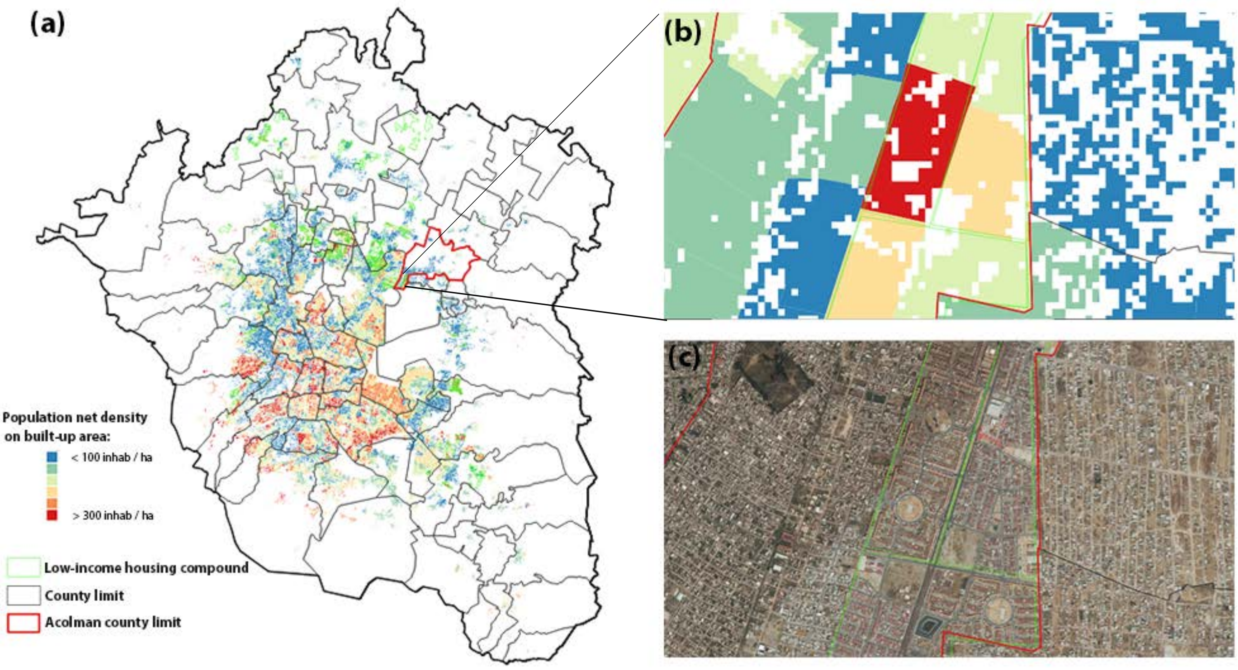

Figure (a) Mexico City Metropolitan Zone (MCMZ), distribution of net population density (inhab / ha of built-up area, neighbourhood spatial unit) for year 2010;
(b) Zoom-in to a high net population density hotspot in the Acolman Municipio (county), corresponding to a low-income housing estate;
(c) Bing aerial coverage of the same area: low-income housing compounds contrast with low density surrounding popular neighbourhoods and rural-urban fabric.

EARSeL Liege 2020
Abstract
Corresponding Author: liege2020@earsel.org

Keynote speech for Session "RS and Urban Social Science Applications"

Urbanization and sustainability under global change and transitional economies: Synthesis from Southeast, East, and North Asia (SENA)

Peilei Fan[1]

[1] Michigan State University, USA

Keywords: Urbanization, sustainability, transitional economies, Asia

This talk will introduce urban social science applications of using remote sensing data through a recently NASA LULUC funded project "Urbanization and sustainability under global change and transitional economies: Synthesis from Southeast, East, and North Asia (SENA)" (NNX15AD51G, 2015-2018). This project is to synthesize the data and knowledge on urban sustainability to the socioeconomic transformation and changing climate in transitional economies in Southeast, East, and North Asia (SENA), including Cambodia, Laos PDR, Myanmar, Vietnam, China, Mongolia, and the Asian part of Russia (Siberia). Main research activities and findings in four categories will be introduced, including 1) urban LCLUC: patterns, characteristics, & methods; 2) drivers and spatial determinants; 3) impacts of urbanization; and 4) synthesis at sub-regional level.

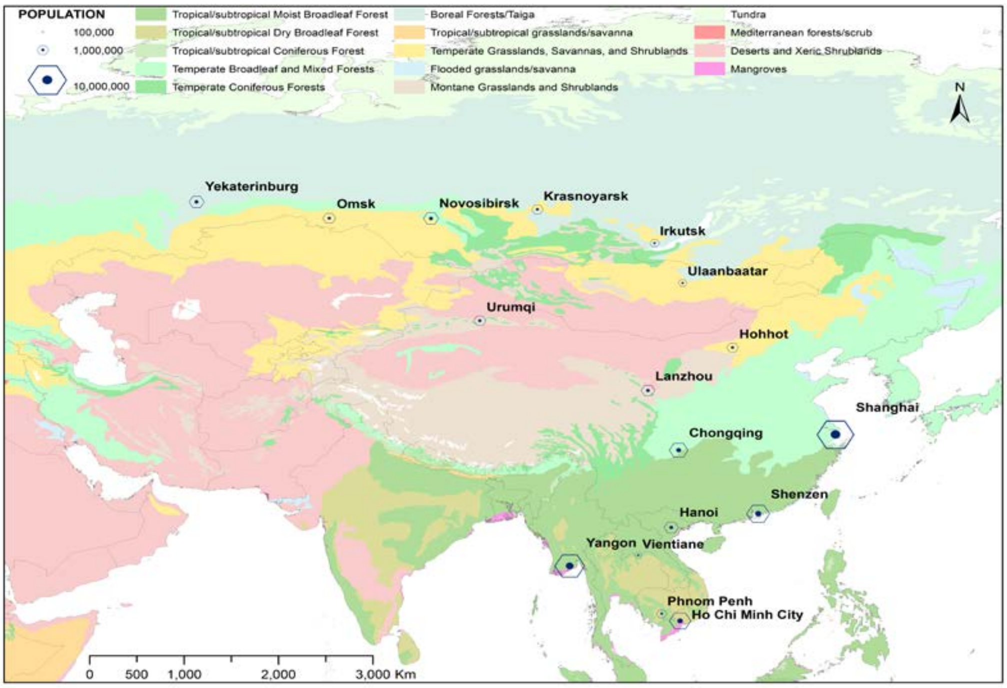

Figure 1. Study area: 17 urban systems overlaid on the Ecoregion coverage (8 biomes in 7 countries)

Knowledge gaps in Earth Observation-based mapping of human settlements: from an ontological perspective.

EARSeL Liege 2021
Abstract
Corresponding Author: m.kuffer@utwente.nl

Jiong Wang[1], Monika Kuffer[2]

[1] Department of Physical Geography, Faculty of Geosciences, Utrecht University, Princetonlaan 8A, Utrecht, 3584 CB, The Netherlands
[2] Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, P.O. Box 217, 7500 AE, Enschede, the Netherlands

Keywords: Earth Observation, Ontology, Settlements, Boundary representation, Uncertainties

The challenge

Earth Observation (EO) imagery forms a vital source of knowledge regarding geographic phenomena. The growing amount of knowledge derived from diverse sensors along with various algorithms is subject to major criticisms: lacking *interoperability*. Insufficient *interoperability* among derived knowledge exists, e.g., in terms of semantic heterogeneity and topological inconsistency, which hinders exchange and reuse of knowledge. Despite many efforts in grounding geographic phenomena through primitive symbols (e.g., polygons) from an ontological point of view and *interoperability*, we argue that deriving knowledge from EO images is difficult. In this study, we examine the difficulties through the mechanisms of knowledge flow from human conceptualization of the real world to information extraction by artificial intelligence (AI) from EO data. We use human settlement mapping to focus on fundamental issues such as conceptualization and representation of regions, boundaries, and dynamics.

Methodology

We acknowledge the *duality* of conceptualizing geographic phenomena on the ground and that in EO images (Figure 1), and treat this *duality* as a major frame governing knowledge flow. Thus knowledge gaps are eminent in representing geographic phenomena showcased by human settlements. In examining these gaps, an ontological approach is adopted to study knowledge derivation. For human settlement mapping, we revisit representative literature and particularly consider human-reality, human-AI, reality-imagery, and AI-imagery as critical interfaces where gaps exist in knowledge flow and transition (Figure 1). The role of AI in deriving knowledge of image pixels is highlighted, which contrasts existing studies on only implicitly drawing upon the issue of knowledge transition from human-reality to AI-imagery interface. We conclude that: (1) existing primitives (geometrically and semantically) have not been fully utilized to represent our understanding of the on-ground reality, (2) meaningful knowledge can only be derived conditioned on the tight connection between domain-specific semantics and input data during the processing of data. Remedies are proposed in the form of conceptual and technical solutions in capturing the dynamics of geographic phenomena. For the example of mapping human settlement, we develop an improved conceptualization of geographic regions and objects for EO-based mapping. Then we propose an EO-implementation of an improved workflow of deriving target knowledge.

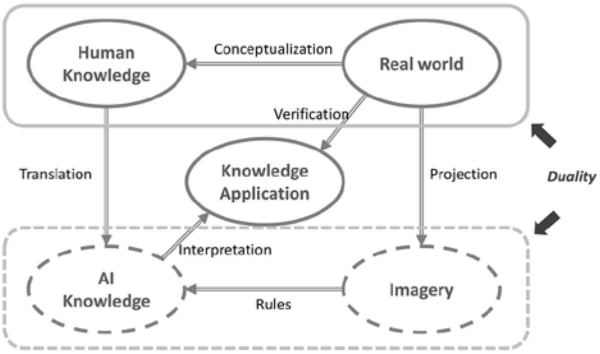

Figure 1. Knowledge flow within the *duality* of conceptualizing geographic phenomena.

Results

The results show the progress in EO based derivation of geographic knowledge illustrating envisioned remedies to the gaps throughout knowledge derivation. Existing studies display that our current conceptualization of geographic phenomena on the ground already exhibits fuzziness due to, for instance, changes in the spatio-temporal extent (4D ontology) (Figure 2(a;b)). Such conceptualization, when fed into the AI as the input knowledge triggers uncertain output from the AI. However, with the fast development of AI in deriving knowledge, it becomes less controllable to obtain interpretable results derived from the AI, for instance, the automatically generated features from representation learning algorithms such as deep learning. When the knowledge derived from the AI-imagery interface is brought back and is compared with human-reality, large gaps between the derived and human conceptualized knowledge are often shown. In the study case of human settlement mapping, we require improved ontological objects that improve capturing geographic phenomena on the ground, as compared to the crisp area objects (e.g., polygons). Such theoretic reasoning is technically implemented as new GIS features other than points, arcs and polygons. Objects can be represented as a combination of 1-dimensional arc and 2-dimensional regions, which form new types of training data for AI (Figure 2(c)). Such digital representation also improves the characterization of real geographic phenomena on the ground.

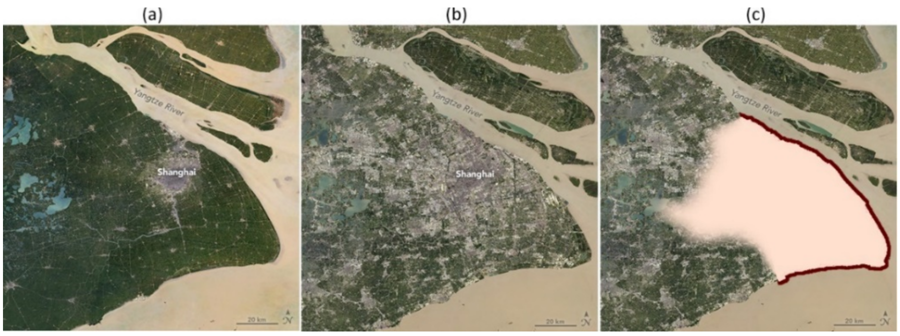

Figure 2. Shanghai, China (a) in 1989 and (b) 2019 on the ground captured by the EO, and (c) represented by proposed conceptualization for the AI.

Outlook for the future

In this process, we summarize the strength and weaknesses in our current EO based mapping of geographic phenomena, and envision the future direction of EO based knowledge derivation in the context of machine learning and AI. From the perspective of an ontology, this discussion touches many fundamental and practical aspects of EO based mapping activity including knowledge representation, exchanging, and application. For example, training and validation strategies will benefit from the developed ontology that captures the fuzziness of geographic phenomena, linking better human vision and AI-based information generation.

Identifying human settlement growth types using Symbolic Machine Learning and Geographic Information Systems: Assiut Governorate as a case study

EARSeL Liege 2020
Abstract
Corresponding Author: m.m.abdelkader@utwente.nl

Mahmood Abdelkader[1,2], Luc Boorboem[1], Richard Sliuzas[1], Jaap Zevenbergen[1]

[1] Faculty of Geo-Information Science and Earth Observation (ITC), Department of Urban and Regional Planning and Geo-information Management (PGM), University of Twente, The Netherlands
[2] Faculty of Engineering, Department of Architectural Engineering, Assiut University, Egypt

Keywords: Symbolic Machine Learning, Built-up extraction, MASADA 1.3, Human settlement growth types, Spatial metrics

The challenge

Nowadays, urban planning and management promote innovative approaches for effective growth, such as smart growth and sustainable urban development. However, their implementation relies, in part, on the availability of information that describes human settlement growth (HSG) dynamics. Although there are many available data sources and open-source tools that facilitate HSG dynamics analysis, the cost for obtaining these tools and datasets might be an obstacle, especially in developing countries. Therefore, in this study, we proposed a methodology that utilizes open-source software and free Earth Observation data for analyzing HSG dynamics through time. Moreover, we developed a QGIS plugin tool for extracting HSG types. Assiut Governorate, located south of Cairo in The Nile Valley (NV), Egypt, was chosen for the analysis because NV is expected to have one of the highest HSG rates in Africa until 2030. Understanding HSG dynamics in NV is the first step towards managing future growth.

Methodology

First, Symbolic Machine Learning (SML) was used for extracting the built-up area using MASADA 1.3 software, developed by JRC. SML is a supervised classification method that allows built-up extraction using multispectral satellite images and training sets. Three Landsat images (2005, 2010& 2015) were used, whereas the utilized training sets were the Global Human Settlement Layer (GHSL)and the Land Cover Map for Africa (LCMA). Second, Landscape Expansion Index (LEI) was used for the identification of HSG type in three periods (1999:2005- 2005:2010- 2010:2015). LEI is a set of spatial metrics that utilizes buffer analysis for identifying three HSG types: infill growth, edge-expansion, and outlying growth. Infill is development in the area between existing patches or when open spaces inside an existing patch are filled. Edge-expansion occurs at the edge of an old patch (i.e., the size of an existing patch increases). Outlying happens when new growth occurs in a distance from old patches. Outlying growth was further divided into three types: leapfrogged ribbon which is any outlying growth that happens in a linear shape where the patch's width is <100m and length is > 150m; clustered growth which is any outlying growth that has an area ≥ 2700 m²; scattered which is any outlying growth that is not ribbon nor clustered. We also proposed another type, edge-ribbon, which is similar to the leapfrogged ribbon but it is connected to an existing patch.

Results

As the built-up area for 1999 was available, a set of 500 random points was used for assessing the accuracy of the classified data. The assessment results for 2005, 2010, and 2015 classifications were 89.2%, 92.2% and 91.6% respectively. The total built-up area in 1999 was 85.46 km². In 2005, the area expanded to be 110.48 km². The classification result also showed that the area in 2010 was 119.45 km². Finally, the built-up in 2015 was 149.74 km². Between 1999 and 2005, the annual growth rate was 4.87%. Whereas it increased to be 1,64% between 2005 and 2010. Finally, it reached 5.07% between 2010 and 2015. For HSG types, the dominant type within the three periods was the edge-expansion. Followed by clustered in period 1 and period 3, whereas edge ribbon in period 2 was the second. Except for edge ribbon, all other types experienced a slight drop in period 2 and an increase in period 3. In addition, the infill growth was the lowest in period 1 and period 3 such that the leapfrogged ribbon was the lowest in period 2.

Outlook for the future

The results of this study suggest that identifying HSG types is applicable by utilizing available open-source software (MASADA 1.3 and QGIS) and free datasets (Landsat data, GHSL, and LCMA). Further research should be undertaken to assess the usability of this methodology as well as the introduced QGIS tool in other areas (whether it is in Egypt or elsewhere) that need additional studies as well as using other metrics that describe HSG dynamics. Moreover, the results of this study raise the question about the effectiveness of the policy toward HSG starting after 2010 in Assiut. In addition, further research should be conducted to identify the underlying processes that control each type of HSG. If these underlying processes are identified, a policy that can manage edge-expansion and outlying growth to reach effective growth in Egypt can be developed.

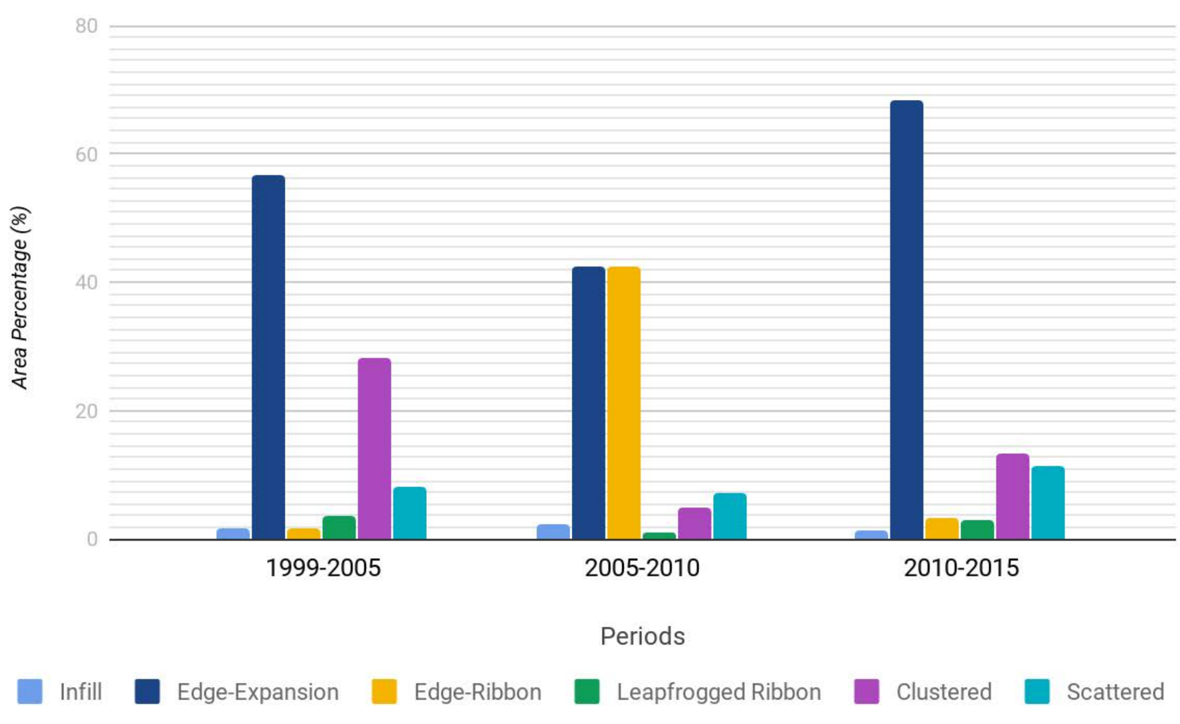

Figure 1:the area percentage of HSG types in Assiut within the three periods

Global Building Map from Sentinel-1 satellite mission

Corresponding Author: marco.chini@list.lu

Marco Chini[1], Ramona Pelich[1], Renaud hostache[1], Patrick Matgen[1], Carlos López-Martínez[2],

[1] Luxembourg Institute of Science and Technology (LIST), Luxembourg
[2]Univeristat Politecnica de Catalunya (UPC), Spain

Keywords: SAR, InSAR coherence, Urban, multi-temporal, Copernicus.

The challenge

Urban areas have a high impact on region's climate and represent therefore an important land cover class. Although urban areas represent a small fraction of the worldwide land cover, the detection and analysis of their extent is an extremely important information for assessing the impact of human activities on the environment. Observations from space are unique information enabling a better understanding of the evolution of built-up areas. The Global Observing System for Climate report highlighted the need for year-to-year change analysis in urban areas at high spatial resolution (10–30 m). So, the development of algorithms for providing reliable urban maps at global scale and with a high spatial and temporal resolutions becomes central. Here we propose an automatic algorithm that exploits several features offered by Sentinel-1 such as high revisit time, dual-polarization data and Interferometric SAR coherence to provide building map at large scale and with a spatial resolution of 20m.

Methodology

The proposed automatic algorithm exploits the multi-temporal interferometric coherence and the temporal information content of both the co- and cross-polarization channels of the Sentinel-1 SAR data in order to generate building maps at a 20 m resolution. The core assumption is that, in SAR images, urban areas exhibit very high backscattering values in both VV and VH channels that are coherent in time. Peculiar characteristics of the Sentinel-1 satellite mission, namely the high revisit time, the availability of dual-polarized data, and a very small orbital tube, are taken into account on the definition of the algorithm. For identifying pixels with high backscattering values in both VV and VH polarimetric channels, an adaptive parametric thresholding approach is adopted. It makes use of a hierarchical split-based approach (HSBA) method to parameterize the PDFs of the classes of interest. Then, based on the PDFs extracted beforehand, a building map is generated using a hybrid SAR-based methodology that consists of a sequence of histogram thresholding andregion growing processes. The interferometric SAR coherence is next used to reduce false alarms caused by land cover classes (other than buildings) that are characterized by high backscattering values but that are not coherent in time such as certain types of vegetated areas.

Results

The algorithm has been tested on areas located in semiarid and arid regions in the Mediterranean region and Northern Africa. The dataset is composed of five sites located in Portugal, Turkey, Israel, Egypt, and Tunisia. These cover areas between 60.000 and 122.000 km². The dataset and test sites were selected by the European Space Agency (ESA) in the framework of an Urban Round-Robin exercise. For each test area, multi-temporal series of Sentinel-1 IW images acquired on both VV- and VH-polarizations and on a monthly basis are available over the whole of 2016. Time series comprise ascending and descending orbits. The performances of the proposed methodology are assessed through a comparison with the Global Urban Footprint (GUF) provided by DLR, which is a binary settlement map with high spatial resolution of 12 m and derived from X-band SAR data provided by TerraSAR-X mission. The overall agreement between the two products is between 92% and 97% over the five different test sites. The proposed algorithm is scalable in terms of test cases since the assumed hypotheses are rather simple but valid for almost all buildings all around world. This is confirmed by the fact that the five test cases are quite different in terms of typology of urban areas, but still the results are quite similar.

Outlook for the future

A future field of application foreseen for this algorithm is the estimation of people impacted by a natural disaster such as a flood event. For example, the detection of flood extents in urban areas is a very challenging topic and the availability of building maps helps the detection of floodwater in such a complex environment. Moreover, to estimate the number of people affected by floods, SAR-based flood extent maps are often intersected with population density maps. In order to provide accurate estimates of the number of affected people, the population density map should ideally indicate the number of people within a grid cell. To this aim, the resident population maps based on census data, which are usually defined at districts scale, could be downscaled based on accurate and up-to-date high-resolution building maps provided by the proposed algorithm.

Automated Urban Footprint Mapping Over Large Areas: a Method Implemented for Massive Streams of Sentinel Data

EARSeL Liege 2020
Abstract
Corresponding Author: anne.puissant@live-cnrs.unistra.fr

Romain Wenger[1], David Michea[2], Anne Puissant[1]

[1] Laboratoire Image Ville Environnement, LIVE/CNRS UMR 7362, University of Strasbourg, France
[2] Laboratoire des Sciences de l'Ingénieur, de l'Informatique et de l'Imagerie, ICube/CNRS UMR 7357, University of Strasbourg, France

Keywords: urban footprint, massive data, machine learning, object-based analysis,

The challenge

The size of urban settlements is increasing worldwide at a rapid expansion rate. This urban sprawl triggers changes in landcover with the consumption of natural areas, and has impacts on the ecosystems with important ecological, climate and social transformations. Detecting, mapping and monitoring the growth and spread of urban areas is therefore important for urban planning and management, risk analysis, human health or biodiversity.

Satellite images have long been used to document human settlements. The availability of the Sentinel constellation (S2) allows monitoring urban sprawl over large areas (e.g. countries) and at high time frequency (with possible monthly updates). This massive stream of data allows proposing new types of urban products at spatial resolution of 10 meters.

In this context, a fully automated and supervised processing chained (URBA-OPT), using open source libraries, and optimized for rapid calculation on High Performance Computing clusters has been developed.

Methodology

URBA-OPT uses both on object-based and machine learning methods to produce urban footprint classification for on-demand acquisition period. For a study site, S2-tiles are firstly selected automatically based on two pre-defined parameters (percentage of clouds and no-data area). The processing chain calculates a series of thematic masks (sea and ocean, cloud, ice or snow, no-data), computes spectral and textural indexes and segments the image into regions. For each of them, a reference product (High-Resolution Layer Imperviousness for Europe or Global Human Settlements Layer for the world) is used to assign a class (urban/non-urban) to make training and validation sets. An object-based classification algorithm is applied on the training set to construct the classification model. With an iterative procedure to examine the class-imbalance within the training set, compensation of the effects of class-imbalance and class-overlap on the error rates is possible. Experiments linked to the choice of the initial training set and the machine learning classifiers has also been made. The outputs for each mono-date tile are a probability map of class certainty, a binary map (urban/non-urban) with an automatic thresholding based on evaluation metrics. Several metrics for a quantitative assessment are also calculated. The final product for on-demand period (by tile) is obtained by stacking all mono-date classifications. Several decision rules of fusion at decision level have been tested.

Results (STYLE: Heading Abstract, max. 1500 characters space incl.)

The method is implemented for the processing of massive streams of Sentinel 2 images on HPC clusters. Use cases over several metropolitan areas, regions or countries will be presented (France, Belgium, etc).

Several experiments tests were made to define inherent parameters of the processing chain, such as HRL threshold, which represents percentage of HRL in a segment. This parameter is used to create training and validation set and it is established at 40%. Single-date results were produced for France and Belgium and provided overall results with accuracy greater than 85% for tiles with large urban areas and approximately balanced commission and omission errors close of 0.4 using 20% of the data for training. The omission errors rate is higher on tile characterised by sparse human settlement and taking into account the temporal dimension by applying fusion technique at a decision level allows reducing this error rate and the commission error. Several decision rules (at decision level) were tested on two regions in France with different morphological urban forms (Grand Est and Occitanie). The best way is then applied to produce a final map with the urban footprint for different time-step (monthly, semi-annually or annually). Results are then compared with others products such as OSO in France (annually) or as Global Urban Footprint over the world (resampled product at 10m). Difference maps or confusion matrix allows identifying the under or over-estimation of each product.

Outlook for the future

The URBA-OPT processing chain is applying on a series of dynamic urban areas over the world (in Africa, China, South America, etc). For these tests, the Global Human Settlement Layer (GHSL) is used as reference data. Mono-date and multi-temporal results are analysed in order to assess if the dynamic of urbanisation can be monitor and useful for end-users. Actually, deep learning methods are compared to traditional machine learning algorithm (Random Forest) to map urban footprint and to map several urban fabrics but at pixel-level.

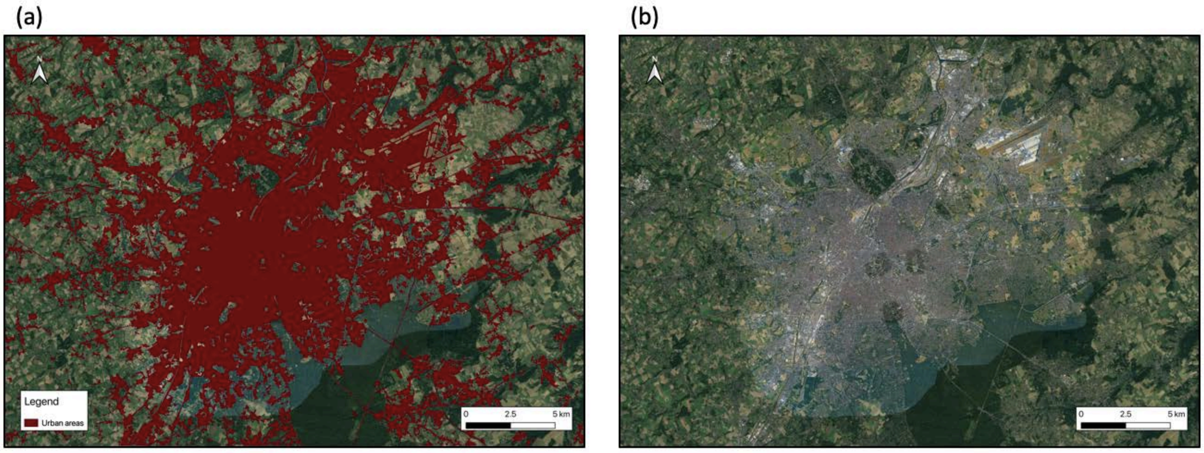

Figure 1 (a) Urban areas classification over Brussels, Belgium (b) True colors Sentinel-2 image (Tile 31UES).

Beyond built-up land: towards a more nuanced analysis of settlement system changes

EARSeL Liege 2020
Abstract
Corresponding Author: Jasper.van.vliet@vu.nl

Jasper van Vliet[1], Mengmeng li[1], Yuan Wang[1] , Peter Verburg[1,2]

[1] VU University Amsterdam, Institute for Environmental Studies, the Netherlands

[2] Swiss Federal Research Institute WSL, Switzerland

Keywords: Land Use, Urbanization, Land Take, Land Use Modelling, Urban Change Impacts

The challenge

Built-up land occupies less than 1% of the terrestrial biosphere, but this share is increasing rapidly. The expansion of built-up land, mostly related to urbanization, comes at a cost of other land cover types, such as cropland and pastures, thus adding to the global competition for land. As a result, there is a need to analyse urban development at large spatial scales. Several studies have done this, mostly by mapping and analysing changes in built-up land at a pixel level. However, this reduces urban land to one homogenous class, while there is a large variation both within and across different settlements. This study combines data on built-up area, derived from remote sensing imagery, with population densities as a proxy for urban intensity, to provide a more nuanced characterization of settlement systems. Subsequently, we use this characterization to analyse changes in settlement systems over time, as well as to project future changes.

Methodology

We characterize land systems along a gradient from rural to urban land using land cover data at a 30-meter resolution and population density data. Land cover data is further processed to represent both the share of built-up land, the number of settlements (clusters of built-up land), and the distance to large clusters. Subsequently, we analyse the changes in land systems between 1990 and 2010 for all of China. In addition, we also analyse the distribution of built-up land over these systems in different time periods. Subsequently, we use the land systems map as a starting point to project potential future changes. These projections are simulated using the CLUMondo model. Changes in CLUMondo are driven by an exogenous demand, in this case a demand for housing population [in persons], producing crops [in tons] and conserving cropland area [in km^2]. Each time step, the model iteratively changes land systems until all demands are fulfilled, where the allocation of changes is based on the empirical relation between existing land systems and a range of biophysical and socioeconomic drivers as well as a number of properties characterizing land systems. The calibrated land system model is used to generate a series of projections under different population and cropland protection scenarios, in order to find solutions for maintaining food production levels in China to ensure food security, while also accommodating urban development.

Results

The land system maps for China for the years 1990, 2000, and 2010 show that for all years a small portion of the country is covered by *Large cities*, *Urban landscapes*, and *Suburban landscapes*, while a much larger area is covered by *Towns* and different types of *Village landscapes* (Figure 1). More surprisingly, the results also show that the vast majority of the built-up land in all three years is included in these *Town* and

Village landscapes, emphasizing their importance for understanding urban development. Simulation results show multiple different urban development trajectories for China, as a result of different scenario assumptions. When we assume that current trends of decreasing population density continue, we find an increase in built-up land despite the expected decrease in population until 2050. Conversely, when we continue with current population densities, we find that China can reduce its land take considerably. The different trajectories simulated here show that sustainable urban development can considerably reduce the competition for land, and at the same time increase food production without further compromising the conservation of natural areas.

Outlook for the future

The results presented here show that settlement systems exist in a range from strictly rural to strictly urban, thus suggesting that a strict urban / non-urban dichotomy employed in many land cover classifications does not suffice. Different land systems can vary in the share of built-up land, but also in the spatial pattern of built-up land, and the urban land use intensity. Yet, land systems can differ in other ways, such as in their spatial structure (for example, peri-urban areas are typically characterized by a mosaic of urban and non-urban land use types), building structure (building footprint, height, and volume), and use (such as industrial, commercial, residential). Including these properties in a land system classification for analysis will further improve our understanding of urban development, as well as identify opportunities to adjust development trajectories towards more sustainable pathways.

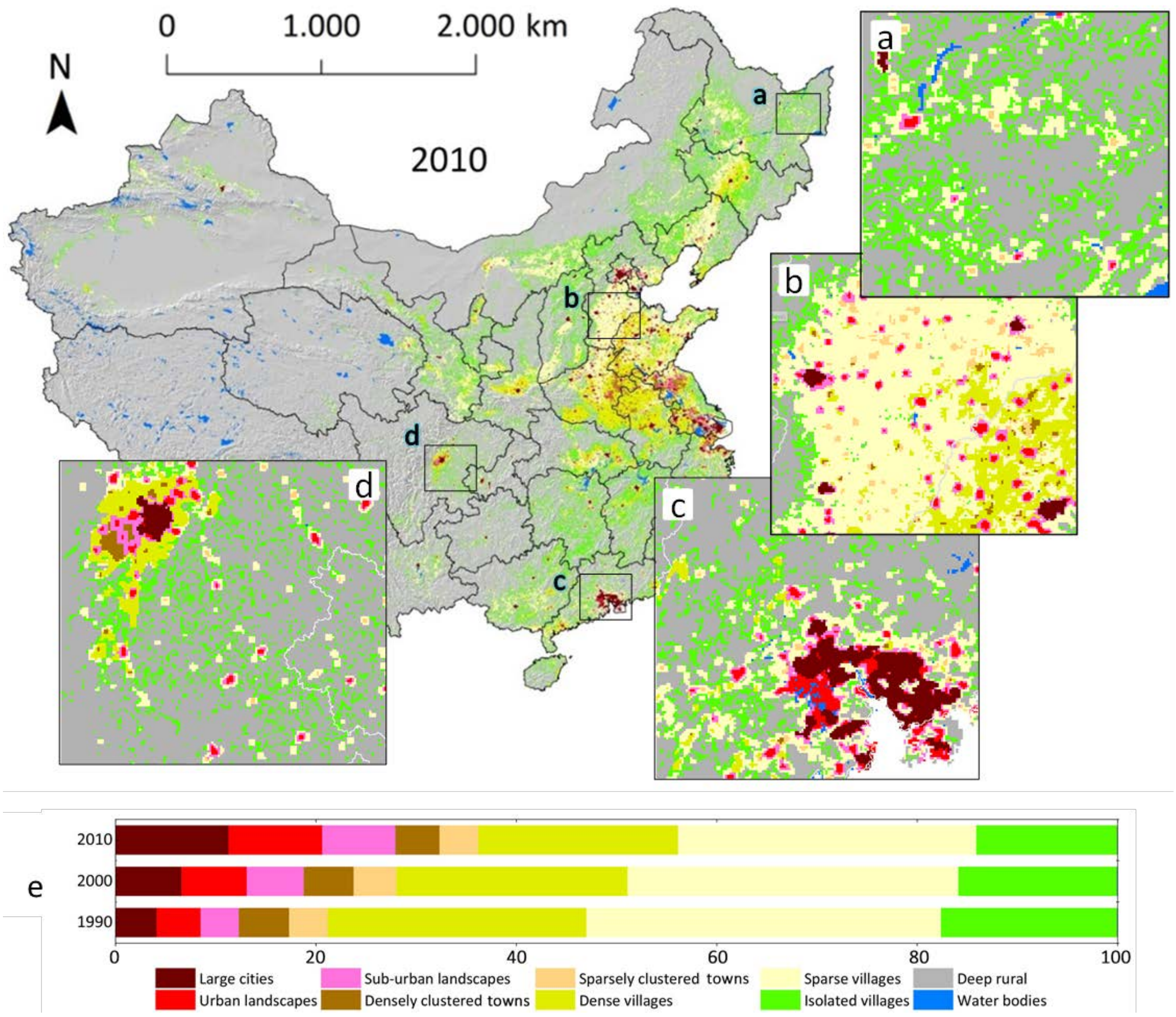

Figure 1: Map of settlement systems in China in 2010 including snapshots of typical landscapes (a-d) and the distribution built-up land over these systems in China for three different years (e)

Spatial analysis of Slum Characteristics based on the Generic Slum Ontology – Case of two Brazilian cities

EARSeL Liege 2021
Abstract
Corresponding Author: d.kohli@utwente.nl

Divyani Kohli, Monika Kuffer

University of Twente / Faculty ITC, Department of Urban and Regional Planning and Geo-information Management, Enschede, The Netherlands

KEYWORDS: Slums; Informal areas; Ontology; Spatial analysis; Brazil

The challenge

Slums are home to around one quarter of the world's urban population; a large part of the population in the Global South lives in these areas (Habitat, 2016). In support of global slum eradication and transformation programs, consistent information about their amount and spatial distribution is needed. However, most urban datasets do not provide such information. Many Earth Observation approaches have been developed that utilize the increasing amount of imagery for mapping slums (Kuffer, Pfeffer, & Sliuzas, 2016). However, most studies do not start with a systematic conceptualization of differences between slum and non-slum areas (Kohli, Sliuzas, Kerle, & Stein, 2012). Furthermore, insufficient knowledge exists about robust indicators that allow monitoring slum developments and the effects of improvement policies. This research builds on the generic slum ontology (GSO) to assess and compare indicators using the example of two Brazilian cities, Rio de Janeiro and Sao Paulo.

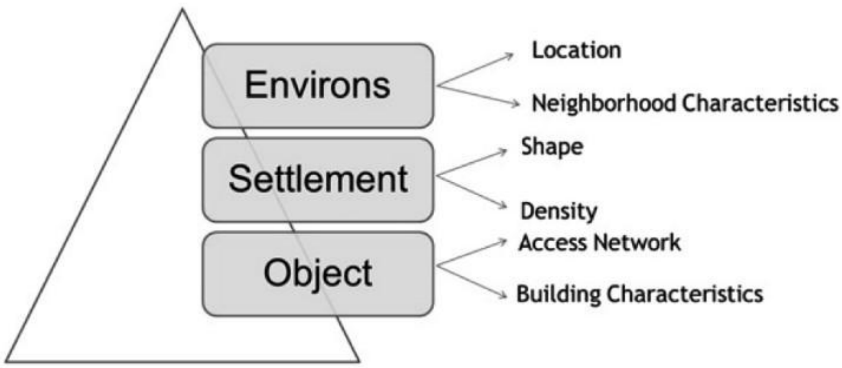

Figure 1 The generic slum ontology (Source: Kohli et al.,(2012))

Methodology

The GSO consists of three spatial levels with indicators and related metrics (Figure 1). Environs comprise the location of slums with respect to socio-economic status, neighborhood characteristics and hazard-prone areas. Settlement level consists of the development characteristics of the settlement referring to the overall shape and density. The object level comprises of building characteristics and access network characteristics. For this study, we quantify differences in the selected indicators over the two cities using the GSO as a conceptual basis. For each indicator level, metrics such as built-up densities, slope, land use etc. are used to quantify the difference in slum and slum areas within the two cities and compared across the cities. Data were downloaded from Open Street Map (OSM) and other freely available EO data (e.g., Sentinel images). Official slum boundaries for both cities were procured from the Brazilian municipal data website and VGI data (e.g., Mapillary) are used for ground reference.

Results

Initial results include the calculated metrics for selected indicators for Rio de Janeiro. At environs level, in Rio, a high percentage of slums exist close to green/recreation and formal, residential areas. These are commonly (locally) known as favelas, and often exist at the outskirt of the city with poor accessibility. A relatively low percentage of slums are close to industrial, transport and commercial areas. In terms of centrality, it exhibits variable percentages of slums spread out up to approximately 58 km from the center of the city with a mean distance from the center being approx. 21 km. With a city with an undulating terrain, slums are situated on slopes with the mean value of approx. 14% and maximum being approx. 57%. At settlement level, indicators are quantified using built-up density and fractal dimension. For built-up densities, 10 sample areas for each city were considered. Rio had a range of densities with the minimum, maximum and average of approximately were 47, 88 and 70 percent respectively. The NDVI values were derived from Sentinel-2 images. The values of NDVI varied for slum and formal settlements within and across the cities. In Rio, the mean NDVI is substantially different for slum and non-slum areas with the values of 0.3 and 0.6 respectively signifying greener formal areas. At Object level, the average building size in slums is less than 100 sq. meters.

Outlook for the future

Future research will focus on calculating the metrics for selected indicators for Sao Paulo and further, compare and assess the similarities and differences in slums among the two cities. The ultimate goal is a consistent assessment of the most robust EO based indicators for the development of a global slum repository towards the provision of spatial data for monitoring the progress on the Sustainable Development Goals (SDGs) in particular of indicator 11.1.1.

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The Morphology Of The Arrival City

EARSeL Liege 2021
Abstract
Corresponding Author:
Hannes.Taubenboeck@dlr.de

Hannes Taubenboeck[1], Michael Wurm[2], Nicolas Kraff[2], Maria Hochleitner[3]

[1]German Aerospace Center (DLR),; [2]German Remote Sensing Data Center (DFD); [3]European Space Imaging, Germany

KEYWORDS: Slums; Informal areas; Ontology; Spatial analysis; Brazil

The challenge

Quite often slums are the most collective term used when describing the living conditions in urban poor areas. These informal settlements conjures a common stereotypical impression of built environments: complex, compact placements of small makeshift or run-down shelters. However, this perceived distinctive morphology is neither globally homogeneous nor does this perception cover morphologic appearances of urban poverty in its entirety. This research provides an empirical baseline study of existing morphologies, their similarities and differences across the globe. To achieve this, a conceptual approach to urban poverty was implemented. This approach took into account places which provide relatively cheap living spaces serving as possible access to the city, to its society and to its functions – so called Arrival Cities.

Methodology

Based on a systematic literature survey, we selected a sample of 44 Arrival Cities evidenced as being "poor areas" across the globe. Using Very High Resolution optical satellite data provided by European Space Imaging in combination with street view images and field work, we derived level of detail-1 3D-building models for all study areas. We measured the spatial structure of these settlements by the spatial pattern (specifically three features – building density, building orientation and heterogeneity of the pattern) and the morphology of individual buildings (by two features – building size and height). From this analysis, we developed a morphologic settlement type index based on all five features allowing categorization of Arrival Cities.
For the categorisation of the measured settlement morphologies we quantified deviations from the measured five spatial features against an expected (model) value. The expected (model) value represents the measured maxima per feature across all Arrival Cities. For every one of the five spatial features we stated a hypothesis such as we expect complex patterns or small building ground floors. The virtual combination of measured maxima per feature generated a theoretical ideal type morphologic slum. We categorized a morphologic settlement type index value as deviation from the theoretical ideal type morphologic slum. With it, the measured physical appearances of Arrival Cities can be classified along a continuous scale for categorization.

Results

We found a large morphologic variety for built environments of the urban poor, from slum and slum-like structures to formal and planned structures. This variability can be found on all continents, within countries and even within a single city. Simultaneously, detected categories (such as slums) are found to have very similar physical features across the globe.

This further proved the need for a consistent method for empirically classifying the types of urban slums. A total of three main categories of Arrival Cities were identified with transitional subcategories between them.

Outlook for the future

This study highlights that it is not possible to derive a global morphologic settlement type solely characteristic for Arrival Cities. Remote sensing is a crucial data source for detecting and characterizing built environments of the urban poor as they are still widely neglected in official maps. This empirical baseline study can be used as an initial point of reference to develop EO-based classification algorithms beyond proof of concept for morphologic slum and slum-like areas. Furthermore, matching the spatial knowledge for morphologically insignificant areas with location-based information of urban geography may allow a more systematic, consistent approach of localizing patterns, quantities and forms of poor urban living on global scale.

Therefore, with this classification methodology, future researchers can establish algorithms to better measure and understand the countless other Arrival Cities scattered across the planet.

Figure 1

Urban Growth Analysis Using Satellite Data and Socioeconomic Variables in Uyo (Nigeria)

EARSeL Liege 2021
Abstract
Corresponding Author: Etido.Essien@uni-bayreuth.de

Etido Essien[1], and Cyrus Samimi [1,3,4]

[1]Climatology Research Group, University of Bayreuth, Germany

[3]Institute of African Studies, University Bayreuth, Germany

[4]Bayreuth Centre of Ecology and Environmental Research, University Bayreuth, Germany

Keywords: Remote sensing, land-use change, Urban growth, Socio-economic variables, federal allocation

The challenge

Urban areas are very dynamic places, and their sizes have continuously increased (Angel et al., 2011; Taubenböck et al., 2012). These changes differ through time and space (Xiangzheng et al., 2010., Henderson 2005). At global scale increase in urban population is triggered by natural population growth and migration towards the urban areas for a better standard of living, education, and income (Kalnay & Cai, 2003., Yu & Qingyum, 2011., Vanum, 2012., Wei & Ye, 2014., Shi et al., 2018). Urbanization processes such as population growth or migration have caused profound changes in the built and socio-economic structures of urban areas as well as significant environmental changes, such as the loss of agricultural land and biodiversity (Champion, 2001., Chase et al., 1999., Grimm et al., 2000., Lambin et al., 2001., Li et al., 2015., Gao et al., 2014., Wei, 2012., Chen et al., 2016). As a critical driver of urban growth, it triggers unsustainable urban development, which means disproportionately high land consumption and agricultural land loss, among many other indicators (Chengri & Lichtenberg, 2011). Although there are several studies on urbanization at different spatial scales, few have addressed the relationship between urban growth and its drivers, such as local government investments and infrastructural developments (Xiangzheng et al. 2010., Tie-Ying et al., 2015., Canfei et al., 2014).
Remote sensing has been used extensively for identifying and analyzing urban growth. It is cost-effective and has been used widely in understanding physical patterns of change (Taubenböck et al., 2012), the relationship with demographic data (Sapena et al., 2019) as well as socio-economic parameters (Tie-Ying et al., 2015) for supporting urban planning and environmental management (Monica et al., 2017., Sivakumar, 2014., Ashraf & Dewan, 2009., Taubenböck et al., 2009). In the above studies, none linked multi-temporal data with urban development based on resource economics. Prior to this study, no similar research exist in Africa. Against this background, this study aims to link socio-economic variables with the changing physical pattern of a growing resource economy in a med-sized city of Uyo, Nigeria. Our data sets are based on satellite data to capture the multitemporal evolvement of patterns, federal government allocation (based on oil-rent revenue), and tax data on the socio-economic growth. We aim to analyze relationships for the period from 2010 to 2018 since major development and urban regeneration started in this period (Essien & Samimi, 2019).

Methodology

Study area

Uyo is situated in the southwestern part of Nigeria with longitudes 37◦50'E to 37◦51'E and latitudes 55◦40'N to 54◦59'N (Essien & Samimi, 2019., Figure 1). It is the capital city of Akwa-Ibom State and located in the center of the state. It has a total area of 362km2 and a low elevation plain with no hill. Uyo is one of the largest commercial cities in southwestern Nigeria after Port Harcourt and Calabar, having an estimated population of 305,961 in 2006 and 429,900 in 2016 (AKGS, 2019). Since the colonial era, the city has been the head of administration and became the state capital in 1987. Development always starts in the city before reaching other local governments. This prompt the governmental authority to design a master plan for the city to cope with unplanned urban regeneration.

Satellite Data

Rapid Eye images were used to monitor urban land cover change from 2010 to 2018 in Uyo. Rapid Eye ortho tiles have 5m resolution and five identical satellites positioned in a single orbit (Tewes et al., 2015). The satellite has five multispectral bands (blue, red, green, red edge, and near-infrared (NIR)) (Tewes et al., 2015). These were geometrically and radiometrically corrected. Thus, sensor-related effects were corrected using sensor telemetry and a sensor model. Spacecraft-related and co-registered effects were corrected using high telemetry and useful ephemeris data (Planet, 2017). We used Rapid eye orthoimages with a cloud cover of less than 10% and downloaded eleven images for our study area. The images were captured during the rainy season (June and July), the core period of vegetation growth.

Object-Based Image Analysis

Object-Based Image Analysis (OBIA) is a technique that split up satellite data into significant objects (Blaschke et al., 2016). One of the OBIA numerous advantages in image classification is its ability to analyze an object in space rather than pixel in space (Vieira et al., 2012., Navulur, 2007). One of the common techniques used to generate the object is image segmentation (Vieira et al., 2012). Segmentation is a method of separating a satellite image into homogenous objects by merging pixels with similar spectral signatures (Gao, 2018., Bhaskaran et al., 2010). Segmentation is an essential aspect of OBIA because it can group pixels with similar features and ensure good image classification results with better accuracy (Wang et al., 2018., Xie et al., 2005). However, the segmentation algorithm parameters need to be adjusted to get the shape, size, and scale of the resulting object (Myint et al., 2011). And the is no generally recognized method that is widely used to determine the scale for different environmental applications of OBIA in remotely sensed images (Vieira et al., 2012). We used K-Nearest neighbor (KNN) classifiers to select samples of training data representing different classes to reassign a class name to the segmented objects (Vieira et al., 2012., Myint et al., 2011).

Regression Analysis

Based on time series, regression and econometric models have been useful tools to determine the correlation between urban growth and socio-economic data (Ciommi et al., 2018., Salvati et al., 2013., Xie et al., 2005). A regression model was used to examine the relationship between different urban land cover types (low-density built-up area, medium-density built-up area, high-density built-up area, and government built-up area) and socio-economic variable (federal allocation, investment tax, direct and indirect tax) (Ciommi et al., 2018., Salvati et al., 2013., Muñiz et al., 2003,). We used a linear regression model because it was less complex in showing the correlation between dependent and independent variables (Ciommi et al., 2018).
Linear Regression Equation:

$$\log(Y) = \alpha + \beta \log(X) + e$$

where Y is urban land cover types (km2), X is socio-economic variable (Naira in local currency), α and β are the regression coefficients, and e is the residual error (Salvati et al., 2013).

Results

Land-cover variation for over eight years in the study area showed around 5.6% of the total Uyo land cover experienced tremendous transformation. Medium-density Built-up areas experienced the highest increase of 11.9km2 by 2018 compared to its amount in 2010, growing primarily into previous vegetative land (Table 1). Equally, vegetative regions have the highest loss in area of -16.8km2 from 2010 to 2018. High-density built-up as well increases in size over the period to 2.2km2, with most of these areas being converted from the vegetative area. Low-density built-up and government area were the most increased urban land-cover classes, with expansions of 13.0km2, 14.3km2 respectively from 2010 to 2018 (Figure 1). From the interval-based analysis, variation occurred at diverse rates depending on the land-cover type. In general, most of the urban land changes were from 2010 to 2018 due to it being the peak period for urban development in the area (Essien & Samimi 2019).
Urban Land change has occurred arbitrarily across Uyo at different land-cover types (Figure 1). For example, vegetation continuously decreased in size until 2018 when the high-density built-up area changed to medium-density built-up and government area, increasing the low-density built-up area outside the city center. This has been the hotspots of land business for buying and reselling for profit-making purposes. Increases in population density and infrastructural development, such as access road network, and electricity installation, are likely to have triggered this vegetation loss (Essien & Samimi 2019). Similarly, low-density built-up increases were experienced beyond primarily changing to medium-density built-up areas and government areas. Industrialization driven by economic growth, new investors, and urbanization has been attributed as the key drivers of increased in the low-density built-up area over the past eight years.

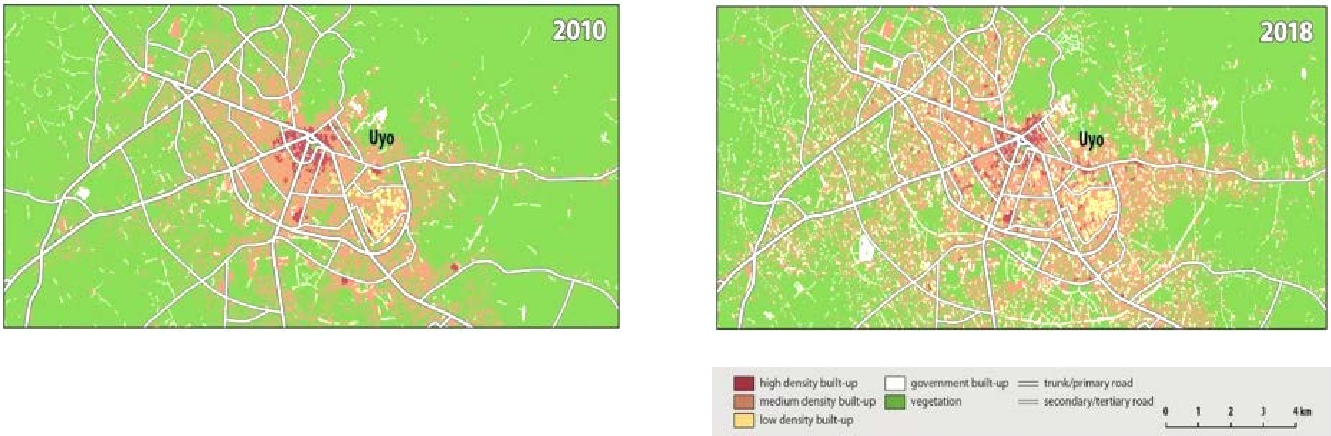

Figure 1. Urban land-use land cover changes in Uyo .

Table 1. Land-use change statistics in Uyo from 2010 to 2018.

Land-use class	Area(km^2) 2010	Area(km^2) 2018	Land-use %	Land-use change (%) 2010 - 2018	Annual change (km^2/yr.)
Low-density built-up	8.6	13.0	6.0	4.4	0.5
Medium-density built-up	28.4	40.3	19	11.9	1.5
High-density built-up	1.6	2.2	3.0	0.6	0.7
Government built-up	4.9	14.3	8.8	9.3	1.2
Vegetation	43.5	26.7	63.8	-16.8	-2.1

Economic growth in Uyo

Economic growth can be traced to an increase in revenue collected by the State government. Our findings show that an increase in socio-economic variables such as indirect tax from 2.3 billion to 6 billion naira (NGN) correlates with changes in urban land cover types and affects the medium built-up and high built-up areas (Figure 2). The correlation coefficient (R2) is used to determine how each socio-economic variable is related to different urban land use classes. Four socio-economic variables have a high correlation with urban land cover classes. For instance, investment tax has the highest correlation coefficient with high-density built-up area, followed by direct and indirect tax on medium built-up area. This could be attributed to several ongoing infrastructural development projects in these areas. Thus, most of these areas have a lot of aged infrastructural facilities and slum areas. Furthermore, business owners took advantage of the government investment in the medium and high built-up areas (slow-developing areas) by increasing their production and having their subsidiaries within the city. This inversely generates more tax revenue for the city. As well attracts rural-urban migration in the city for a better standard of living. Our results affirm with other studies that economic growth in developing countries shows a positive correlation with changes in the urban ecosystem (Shi et al., 2018., Canfei et al., 2014., Kai-y & Hao, 2012).

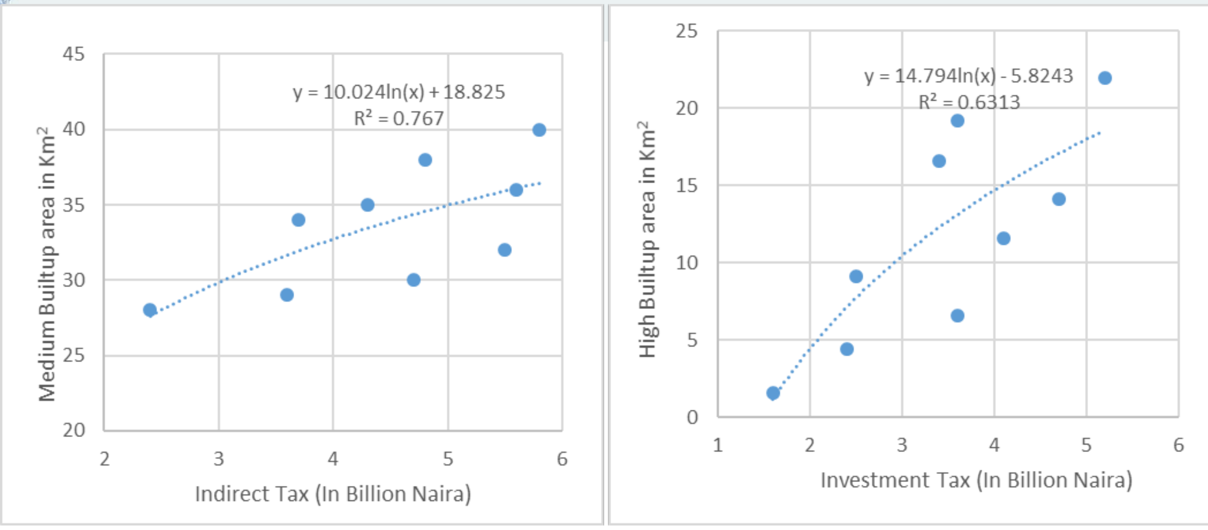

Figure 2. Relationship between socioeconomic variables with medium-density built-up area in Uyo from 2010 to 2018 **p > 0.004

Outlook for the future

This study and other research's on socio-economic growth have shown the vital role resource-driven growth has played on urban growth, such as politically motivated development, divers' infrastructural structure, human capital investment, and industrial development in urban centers (Zheng et al., 2020., Ying et al., 2018., Morten, 2017., Kai-y & Hao, 2012., Ivan, 2013., Hualou et al., 2007). But our land cover classification gives comprehensive urban land cover change data for Uyo southeastern Nigeria. Previously, urban land cover data for Uyo were only at 30m spatial resolution (Nse et al., 2020., Essien & Samimi, 2019., Akpan-Ebe et al., 2016), and this didn't give new insightful information at a multi-temporal level. While they are numerous studies on urban growth in Nigeria, for Uyo, their methodological approach were similar (Nse et al., 2020., Akpan-Ebe et al., 2016). Studies using high-resolution data (5m) have been limited even at the national level. Constraining urban drivers' understanding of change at various urban land cover classes triggered an undefined path for urban land cover change projection. Our 89% accuracy for urban land cover change map linked with socio-economic data makes it appropriate as a high multi-temporal resolution map that shows the key drivers of urban land cover change. This broad analysis can help urban planners understand urban growth patterns and the necessary management strategy to adopt. Our analytical approach to urban land cover mapping linked with socio-economic variables has been transparent. It can be replicated as well adopted and modified to guide researchers looking for apprised data on urban land cover change in mid-sized cities.

A Random Forest Dasymetric Approach For Mapping The Population Distribution At High Spatial Resolution

EARSeL Liege 2021
Abstract
Corresponding Author : e.hallot@issep.be

Eric Hallot[1], Armand Okende [1,2], Tais Grippa[2], Benjamin Beaumont[1]

[1] Remote Sensing and Geodata Unit, Institut Scientifique de Service Public, Belgium
[2] ANAGEO-DGES, Université Libre de Bruxelles, Belgium

Keywords: Population Distribution, Random Forest, Dasymetry, Land Use/Land Cover, Sealing

The challenge

Precisely locating the population is a sustainable development challenge for both regional and local public authorities. In Wallonia, Belgium, the population density of the Walloon municipalities shows significant variability. Like all territories, Wallonia is changing, transformed by a set of spatial planning decisions and regional policies. Knowledge of these aspects is essential to understand and solve problems in many areas. A fine-scale and precise population distribution map, combined with high- resolution thematic data such as land use and land cover, is essential for analysing urban development, monitoring human-environment interactions and spatial planning. Very high-resolution maps are produced from National Register (RNPP) data but they are not freely accessible due to privacy or only in a degraded format. In this paper, we propose a Random Forest algorithm based dasymetric method for the development of an up-to-date and open data population density map at 100m resolution over Wallonia.

Methodology

The dasymetric Random Forest approach disaggregates publicly available population census at the municipality level using thematic ancillary data. The methodological approach is carried out within the open source GRASS GIS geographic information system, via a Python script using the Scikit-learn and Pandas scientific libraries.

The approach uses - four different inputs: the population data of 2018 provided at the statistical sectors level by the Federal Institution (StatBel) and three inputs based on Earth Observation. Walous project produced the new land cover map of Wallonia for the year 2018 using very-high-resolution aerial orthophotos with height information and ancillary GIS data. The European Corine Land Cover (CLC) data from 2018 and the European High Resolution Layer Sealing from 2015 served as land use and ancillary thematic information.

Before running the Random Forest algorithm, the land cover classes are reclassified as inhabited and uninhabited areas and a population density weight is attributed to each of the CLC land use classes. The validation of the predicted population density at 100x100m is carried out by comparing these results to the 2018 statistical sectors data. Then, the accuracy of the results is quantified using the average error based on the rated total absolute error (RTAE) index.

Results

The predicted population density per hectare map using the Walous LC 2018, CLC2018 and Sealing 2015 thematic data is shown on the map below. The most densely populated areas are found in the industrial areas south of the Sambre and Meuse rivers axe, with a peak over the city of Liège. Validation was carried out by reintegrating the results to another finer census level. The accuracy assessment (RTAE of 0.47) indicates a very good prediction of the population distribution with very little prediction error bias in the range of observed census values between the statistical sector and population prediction. It is also observed that the use of Random Forest approach gives better results than dasymetric methods based on a weighted geometric disaggregation of census using a single LC layer, even with continuous ponderation such as the sealing.

Outlook for the future

This research proposed a new open source approach using Random Forest algorithm for precisely mapping the population distribution in Wallonia for the year 2018. The method requires only recent population statistical data and a land cover map to run. However, including land use and sealing data improves the prediction. It is thus easily replicable given new input data or on other regions. This is a new tool to assist the authorities in territorial planning in order to study and reduce environmental and health risks resulting from population growth and urbanization. The validation of the population map presented in this work is based on 2018 publicly available population figures at the statistical sectors. The data from the National Register are treated for finer validation on the same scale, not requiring re- aggregation of the results and will be presented on the poster.

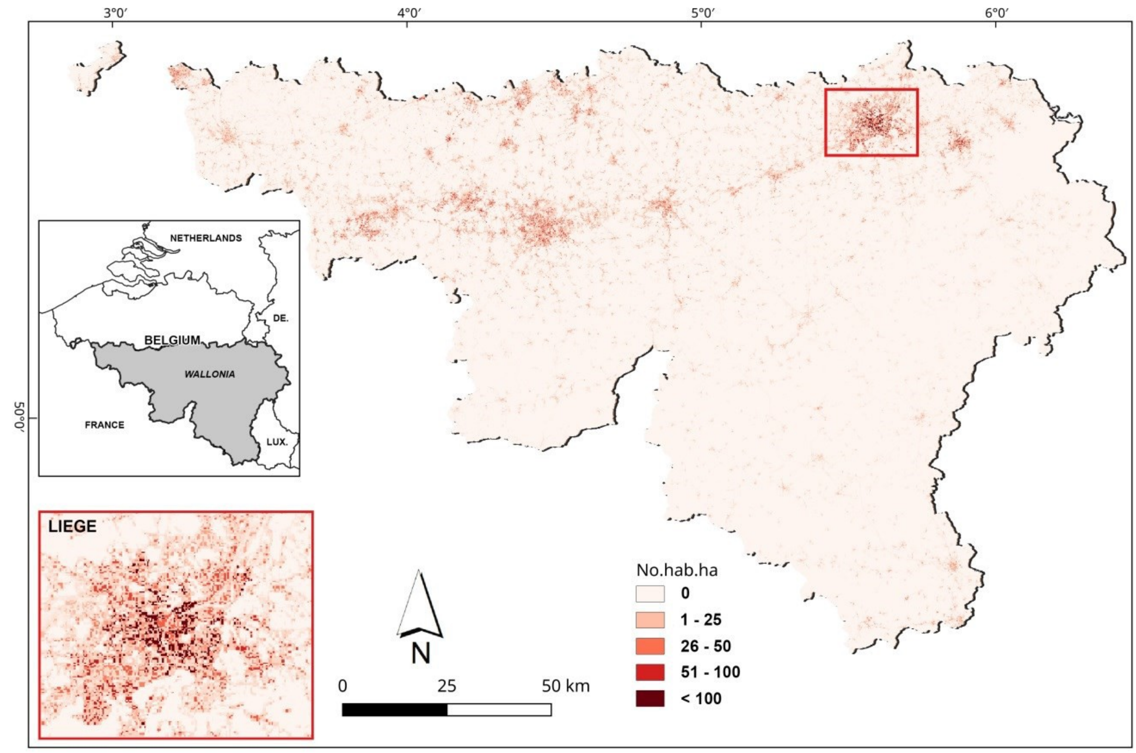

Fig 1: Map of the redistribution of the population in Wallonia

Artificial Intelligence Helps Monitoring Urban Functions

Corresponding Author: devis.tuia@epfl.ch

Devis Tuia[1]

[1] EPFL ENAC, Environmental Computational Science and Earth Observation Laboratory (ECEO), Switzerland

In this talk, I will show recent advances in the characterization of urban spaces achieved with artificial intelligence techniques. I will first talk about the use of deep learning algorithms to characterize urban fabric and about how to inject spatial information explicitly to decrease the data requirements. Then, I will present recent results aiming at describing building usages by multiplying the points of view: by integrating different sources of data (e.g. ground level panoramas vs aerial imagery), deep learning models can start seeing how buildings are being used and scale prediction to the level of entire cities.

The Rise of Artificial Intelligence for Earth Observation (AI4EO)

EARSeL Liege 2021
Abstract
Corresponding Author:
Pierre.Philippe.Mathieu@esa.int

Pierre-Philippe Mathieu[1]

[1] European Space Agency (ESA), Italy

Philab team

The world of Earth Observation (EO) is rapidly changing as a result of exponential advances in sensor and digital technologies. The speed of change has no historical precedent. Recent decades have witnessed extraordinary developments in ICT, including the Internet, cloud computing and storage, which have all led to radically new ways to collect, distribute and analyse data about our planet. This digital revolution is also accompanied by a sensing revolution that provides an unprecedented amount of data on the state of our planet and its changes.

Europe leads this sensing revolution in space through the Copernicus initiative and the corresponding development of a family of Sentinel missions. This has enabled the global monitoring of our planet across the whole electromagnetic spectrum on an operational and sustained basis. In addition, a new trend, referred to as “New Space”, is now rapidly emerging through the increasing commoditization and commercialization of space.

These new global data sets from space lead to a far more comprehensive picture of our planet. This picture is now even more refined via data from billions of smart and inter-connected sensors referred to as the Internet of Things. Such streams of dynamic data on our planet offer new possibilities for scientists to advance our understanding of how the ocean, atmosphere, land and cryosphere operate and interact as part on an integrated Earth System. It also represents new opportunities for entrepreneurs to turn big data into new types of information services.

However, the emergence of big data creates new opportunities but also new challenges for scientists, business, data and software providers to make sense of the vast and diverse amount of data by capitalizing on powerful techniques such as Artificial Intelligence (AI). Until recently AI was mainly a restricted field occupied by experts and scientists, but today it is routinely used in everyday life without us even noticing it, in applications ranging from recommendation engines, language services, face recognition and autonomous vehicles.

The application of AI to EO data is just at its infancy, remaining mainly concentrated on computer vision applications with Very High-Resolution satellite imagery, while there are certainly many areas of Earth Science and big data mining / fusion, which could increasingly benefit from AI, leading to entire new types of value chain, scientific knowledge and innovative EO services.

This talk will present some of the ESA research / application activities and partnerships in the AI4EO field, inviting you to stimulate new ideas and collaboration to make the most of the big data and AI revolutions.

An Open Source Mapping Scheme For Developing Wallonia's INSPIRE Compliant Land Cover And Land Use Datasets.

EARSeL Liege 2021
Abstract
Corresponding Author: b.beaumont@issep.be

Benjamin Beaumont[1], Tais Grippa[2], Moritz Lennert[2], Julien Radoux[3], Céline Bassine[3], Pierre Defourny[3], Eleonore Wolff[2]

[1] Remote Sensing and Geodata Unit, Institut Scientifique de Service Public, Belgium
[2] ANAGEO-DGES, Université Libre de Bruxelles, Belgium
[3] Earth and Life Institute, Université catholique de Louvain, Belgium

Keywords: Land Cover, Land Use, Data Fusion, Very High Resolution, User-Driven

The challenge

Wallonia wishes to acquire reproducible methodologies for mapping Land Cover (LC) and Land Use (LU) in order to meet, by 2020, the requirements of the European INSPIRE Directive. To this end, the regional authorities are financing the development of automatized, scalable and high quality open-source methodologies, making the most of the rich catalogue of geodata available over the Region.

LC and LU play both important roles in territorial planning and environmental assessments relative to a large number of themes and issues, and thus stakeholders. Consequently, the first challenge is that the new developments must take into account a broader vision of needs, from regional to city representatives, research labs and data producers, and should not simply follow the specifications provided by INSPIRE to the letter.

The technical objectives also raise several challenges related to the management of mixed-kinds of big data, automation and quality goals.

Methodology

Despite being oriented (Pure Land Cover Legend) or locked (HILUCS legend) by the INSPIRE data specifications, it is crucial to specify the new maps according to a broad review of Walloon users' needs. More than 50 experts from different backgrounds, professions and responsibilities took part to a continuous consultation process. During interviews and plenary meetings, they expressed their current/potential needs and provided feedbacks on the preliminary outputs. This analysis aimed to quickly prioritize and guide the methodological choices for the production of the new maps.

LC mapping scheme principally relies on a VISNIR orthophotos coverage at 0.25m resolution with height information derived through photogrammetry. To improve the classification (e.g. classification of arable lands), Sentinel-1/-2 data are included given their higher spectral/temporal resolution. Walloon thematic ancillary databases are used for training object-oriented (OBIA) and pixel-based classifications as well as for postprocessing and validation steps. Results from the two classifications are integrated through a machine learning fusion approach, further consolidated by semi-automatic works. The entire toolchain is based on free and open source software such as GRASS GIS and OTB.

LU rule-based approach combines LC with multiple reference alpha-numeric, geocoded databases (localization of industries, commercial activities, population...) to provide a HILUCS compliant map for any given mapping unit.

Results

The continuous consultation process allows for consensus to be reached on LC and LU nomenclatures, minimum mapping units, formats and accuracy goals. Exchanges with the user group are dynamic. They allow making decisions, objectifying certain technical choices and informing the end users efficiently.

Qualitative and quantitative analysis of LC results indicate the importance of the quality of the individual classifications for the fusion results and justify the choice of combining OBIA and pixel-based approaches in order to avoid the pitfalls of each. Manual postprocessing helps creating one extremely high quality LC base map (>90% OA) serving as a basis for subsequent and more frequent updating.

What was already true for the LC classification is all the more so for the LU component, i.e. the importance of the reliability and up-to-date nature of the ancillary input data on the quality of the classification. The LU results show numerous confusions between databases requiring the development of complex classification rules. However, it is important to ensure a compromise between quality, complexity and repeatability of the rule set.

The final LC and LU results, published on the WalOnMap web platform, are on par with the precision levels expected by the users, and the entire processing chain can potentially be in-housed by the regional authorities as it relies entirely on free and open source software and is fully automated.

Outlook for the future

One of the main objectives of the research is to drastically accelerate the production cycle of the Walloon LC and LU maps (the previous reference map of Wallonia dates back from 2007). This is guaranteed by providing an open source processing chain relying entirely on yearly acquisition of Earth observation and on reference ancillary data. Still, future research will have to confront the current methods to new ones, notably the new opportunities offered by deep learning for change detection. Given the very high quality of the 2018 maps, they could prove ideal for training new deep learning networks.

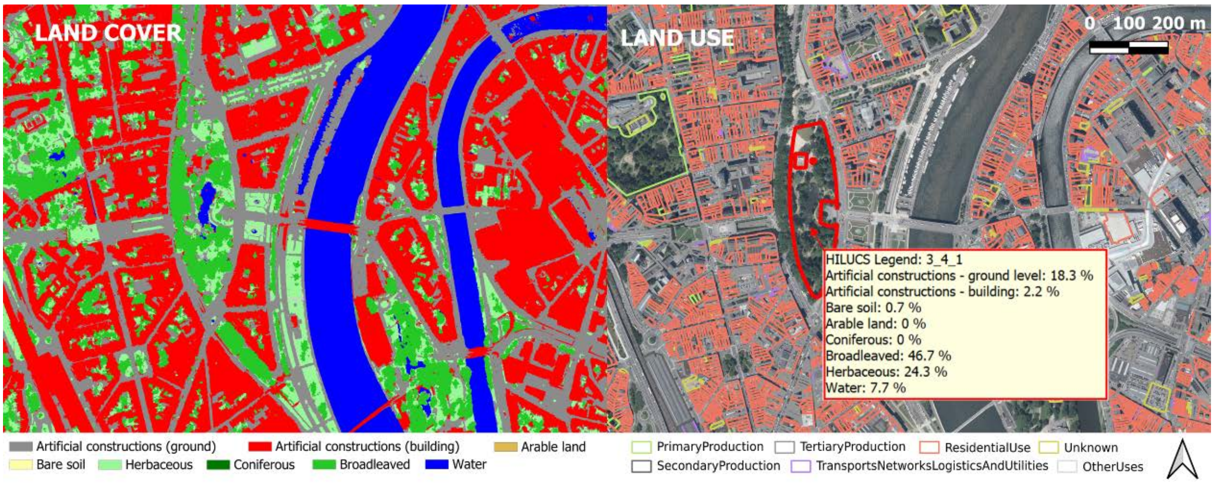

Figure: 2018 Land Cover (left) and Land Use, with Land Cover statistics at the scale of cadastral parcels (right) maps over the centre of Liège, Belgium.

Towards automated urban map revision using deep neural networks on airborne lidar and hyperspectral data

EARSeL Liege 2020
Abstract
Corresponding Author: trier@nr.no

Øivind Due Trier[1]

[1] Norwegian Computing Center, Section for Earth Observation, Norway

Keywords: Building detection, hyperspectral dimensionality reduction, Mask R-CNN, U-Net, airborne laser scanning

The challenge

Urban maps in Norway are currently updated using manual photo interpretation on stereo aerial imagery. However, there is often a substantial delay after completion of construction work until new buildings, roads, etc. appear in updated versions of the urban maps.

Automated pixel-based urban land cover classification from multispectral aerial images of very high resolution has proven difficult since the same spectral values may occur within several land cover types. Airborne hyperspectral data may provide better discriminative power. However, there is still the problem that the same types of material may exist within different land cover types, such as buildings, roads, parks, gardens, etc.

With the rapid development in deep neural network methods and computer processing resources, it should be possible to develop methods that could automate at least some of the urban map revision tasks. Detection and mapping of new and/or changed buildings is one such task that is important in Norway.

Methodology

Airborne hyperspectral and lidar data were acquired simultaneously for an urban/suburban area in Bærum municipality near Oslo, Norway, on 24 August 2019. The hyperspectral data had 30 cm pixel spacing and 186 channels in the visible and near-infrared spectrum. The lidar data had five emitted pulses per m^2. Each lidar (x, y, z) point was classified as either 'ground' or 'other'.

To use an image recognition deep neural network, such as Mask R-CNN or U-Net, the number of hyperspectral channels was reduced. Initial experiments suggested that using six hyperspectral channels was suitable, but that the exact number was not critical. However, it was important to include the object height, retrieved from the lidar data as the difference between the digital surface model (DSM) and the digital terrain model (DTM). In addition. The lidar intensity of the first return points was used as an additional layer. This resulted in input images with 30 cm pixel spacing and eight channels: six hyperspectral channels and two lidar channels (Figure 1, upper half). The hyperspectral channels were 3 nm wide with central wavelengths: 666 nm (red), 539 nm (green), 468 nm (blue), 704 nm (red edge), 858 nm (near infrared) and 405 nm (coastal blue).

Existing vector maps with building outlines were used as ground truth. The image data was split in three parts: training, validation (also part of training) and test (not seen during training). Mask R-CNN and U-Net were both trained on the same image data.

Results

Both methods were able to detect almost all medium and large buildings visible in the image data. However, some small buildings were missing. The few false positives included some small objects and some temporary objects at construction sites. Buildings completely covered by vegetation, e.g., tree canopies or roofs with grass vegetation, were not detected. Also, buildings below the road surface were not detected. A quantitative evaluation in terms of consumer's accuracy (precision) and producer's accuracy (recall) remains to be done, as the ground truth data is slightly outdated and needs to be corrected for newly erected buildings and removed buildings.

The main issue with the detection results was that the object outlines had rounded corners and did not match exactly the actual building outlines. Thus, the detected object outlines could not be used directly in automated map revision. However, the detection performance seemed to be sufficiently good, so that automatic detection of buildings may be used to guide a human operator in doing map revision, or as a quality control function to check the completeness of the updated map.

In order to explore the potential of the methods on other automated mapping task, U-Net was trained in a rural area with four land use classes: agricultural fields, cattle grazing fields, forests and gardens. The method was able to detect the general land use patterns, but with misclassification rates per class ranging from 10% to 50%.

Outlook for the future

In order to explore if increased spatial resolution of the image data may help in improving the accuracy of the detected building outlines, a new dataset has recently been acquired. In addition to lidar data and 30 cm resolution hyperspectral data, 10 cm resolution RGB images were acquired. All three sensors were mounted on the same aircraft for simultaneous data acquisition. We may then reprocess the lidar data to 10 cm resolution and train the deep neural networks on image data with five layers: three optical and two lidar channels. If more optical channels are needed, we may resample a few hyperspectral channels to 10 cm resolution.

For rural vegetation mapping, the main problem seemed to be a mismatch between land cover and land use, e.g., there might be single trees along field boundaries, and forests may have clear cuts. Thus, further work is needed to improve the method for vegetation mapping.

Next, the plan is to develop automated detection methods for other object types.

Acknowledgments

This research is part of a project on machine learning in map revision, financed by: Regional Research Fund Viken, Bærum municipality, TerraTec AS and Geovekst.

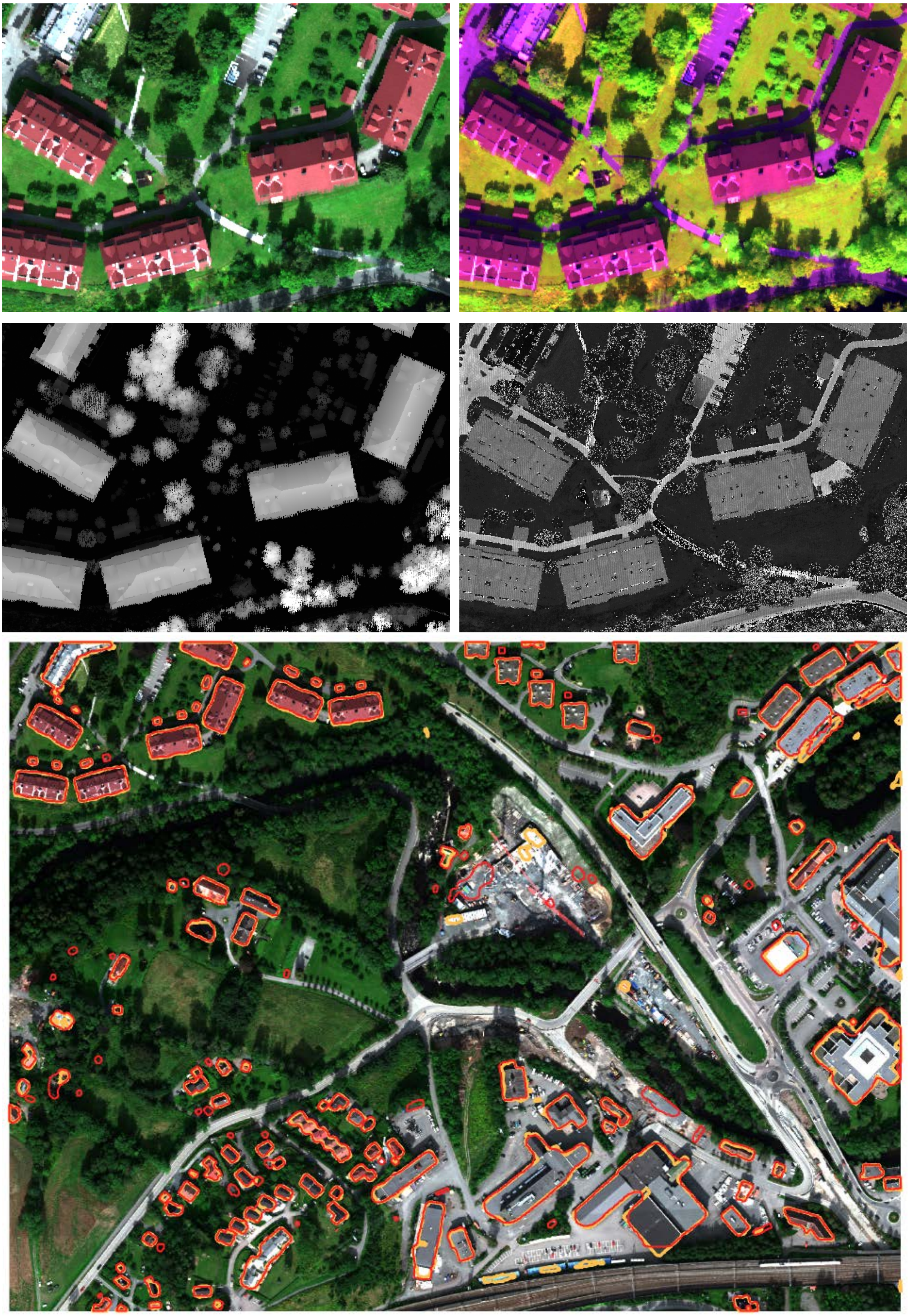

Figure 1 Upper left: Natural colours. Upper right: false colours, displaying red edge (704 nm), near infrared (858 nm) and coastal blue (405 nm) as red, green, and blue, respectively. Middle left: object height. Middle right: lidar intensity. Bottom: Detection results using Mask R-CNN (red thin outlines) and U-Net (yellow outlines).

Fully Convolutional Networks For Landcover Classification From Historical Black And White Aerial Photographs Of Central Africa

EARSeL Liege 2021
Abstract
Corresponding Author: nmboga@ulb.ac.be

Nicholus Mboga[1], Taïs Grippa[1], Stefanos Georganos[1], Sabine Vanhuysse[1], Benoit Smets[2,3], Olivier Dewitte[2], Eléonore Wolff[1], Moritz Lennert[1].

[1] Université libre de Bruxelles, Department of Geosciences, Environment & Society, Av Franklin Roosevelt 50-1050 , Brussels, Belgium

[2]Department of Earth Sciences, royal Museum for Central Africa, Leuvensesteenweg 13, 3080 Tervuren, Belgium

[3]Cartography and GIS Research Group, department of Geography, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium

Keywords: Deep learning, historical aerial black and white photographs, very high resolution, land-cover classification, fully convolutional networks

The challenge

Historical panchromatic aerial photographs provide an invaluable source of historical baseline data, useful for conducting multitemporal environmental studies. However, these images pose significant challenges to existing algorithms due to characteristics like limited spectral information, radiometric differences due to aging or overexposure during scanning, artefacts such as clouds, blur, and shadows, and difficulty in the preparation of reference data is often faced. This work is conducted as part of the Historical Aerial Photographs and Archives to Assess Environmental Changes in Central Africa (PASTECA) project aiming to valorise historical archives at the Royal Museum of Central Africa to support various environmental studies in target regions of Central Africa. We implement a deep learning algorithm in the form of fully convolutional networks and carry out automatic landcover classification on the 1947 images of the city of Goma, the Democratic Republic of Congo.

Methodology

In our methodology, a deep learning approach is adopted. A fully convolutional network that has two key main components i) a series of atrous convolutional layers allow for increased field of view without increasing the number of the network parameters ii) skip connections that allow for the re-introduction of high spatial details from the lower depths of the network to the higher network layers, that are otherwise degraded through a series of repeated convolution operations. The network does not have downsampling layers to maintain the same spatial resolution in the feature maps and the input data. It is trained using fully labelled patches of (128 x 128) pixels generated from the 1947 black and white aerial photographs of Goma, the Democratic Republic of Congo (DRC), with a spatial resolution of 1 m. Three major classes are identified through visual image interpretation namely Buildings, High vegetation, and Mixed low vegetation and bare. Unsupervised K-means clustering in the GRASS GIS software is used to further generate four sub-classes in the mixed low vegetation and bare because it is difficult to visually do so. During testing, the image is split into patches of (256 x 256) pixels and with an overlap of 28 pixels to overcome GPU memory constraints and minimize border effects respectively. Keras and TensorFlow deep learning frameworks are used in the deep learning workflow.

Results

Preliminary results demonstrate the utility of deep learning in a landcover application. Deep learning presents the capability to extract the underlying feature representations in an image directly as opposed to other machine learning approaches for landcover classification. In this work, we demonstrate the utility of using fully convolutional networks for semantic landcover classification from historical black and white aerial photographs, using the city of Goma in DRC as a case study. We observe that the use of k-means clustering to generate sub-classes in the Mixed low vegetation and bare improves the quality and accuracy of the map. The four sub-classes are combined when computing the classification accuracy of the deep learning network. High overall classification accuracy of 95 % is obtained on an independent set. The Buildings, High vegetation, and combined Mixed Low vegetation and bare classes have F1 scores of 71 %, 96 %, and 95 %. A sample scene from the generated classified map is presented in Figure 1 and shows an impressive detection of the three classes. We observe that it takes about 10 hours to train the network and less than one minute to predict a tile of 1 x 1 km on an NVIDIA 1080GTX GPU. Our work presents a novel contribution to the generation of landcover maps from historical aerial black and white photographs, especially since most applications apply deep learning methodology to recent multispectral remote sensing imagery.

Outlook for the future

In this work, the 1947 black and white aerial photographs from the city of Goma in the Democratic Republic of Congo (DRC) have been used for the experiments. The city was predominantly rural in the 1940s. Post-processing of the maps will be conducted to refine the generated landcover products. Future works will involve directly extracting land use maps from historical black and white orthomosaics.

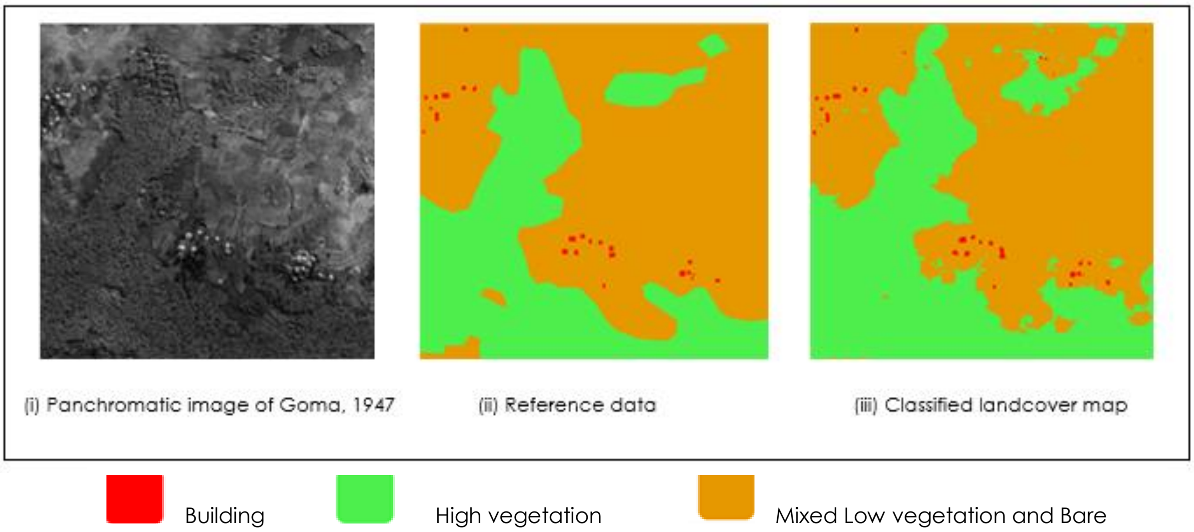

Figure 1 (i)An illustration showing a scene in the historical black and white photographs of Goma acquired in 1947, ii) a ground reference map that was prepared through visual image interpretation, and iii) the classified map obtained from classification using a fully convolutional network. The city of Goma in the 1940s was predominantly rural with buildings appearing in small clusters.

Assessment of texture features' contribution in discriminating natural bare areas vs. artificially covered ones: Chania case study

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Abstract
Corresponding Author: imanakos@iti.gr

Ioannis Manakos,[1], Adel Ledawi[2], Argyrios Stergioudis[1] Chariton Kalaitzidis[2]

[1] Centre for Research and Development Hellas, Information Technologies Institute, Greece
[2] International Centre for Advanced Mediterranean Agronomic Studies, Mediterranean Agronomic Institute of Chania, Greece

Keywords: urban areas, texture features, spectral confusion, Grey Level Co-occurrence Matrix, dimensionality reduction, Google Earth

THE CHALLENGE (1000 CHARACTERS)

Urban areas across the Mediterranean region consist of a mixture of bare land, vegetation and human-made constructions. This rich pattern of irregular shapes and shadows challenges the successful unique land cover (LC) classification, when based solely on spectral responses. Focus is on the ability to discriminate natural bare land areas from those covered with artificial constructions, and not necessarily among their components. Spatial neighbourhood (spatially contextual) information can be introduced in the discrimination process. This study shows that the incorporation of textural information using Haralick's textural features could be used to produce accurate LC maps in urban and suburban areas of Chania. Moreover, findings on the IKONOS image were successfully transferred to the limited spectral resolution google earth ones (i.e. R,G,B); hence, offering a significant high to very high spatial resolution alternative for the specific land cover discrimination.

Methodology (1500 characters)

Two subset areas of an IKONOS image of Chania were used. One was an urban and the other a suburban one. Available LC classes were identified (i.e., roads, red tile roofs, white roofs, light grey roofs, dark grey roofs, vegetation, bare rocks, bare soil). Shadows were considered as a source of information about the shape and surface properties of the objects. The Jeffries–Matusita distance was applied to identify the least separable classes. A semi-variogram was used to derive suggested window sizes for texture extraction, using the Grey Level Co-occurrence Matrix (GLCM). Dimensionality reduction was applied, selecting features that maximize LC classes separability. Angles of 0°, 45°, 90° and 135°, available spectral bands, textural descriptors, and various windows sizes were considered. Texture features have distributions that cannot always be considered Gaussian; thus, non-parametric classification methods are preferred (i.e., here the SVM classifier). Finally, validation was performed against all pixels, as reference digitization was performed on screen for the whole subsets. Results are presented for all classes and the two most commonly used ones in LC analyses, namely bare land vs. human made constructions' cover. The finally selected workflow was further applied on the same areas on a Google earth derived image (resampled at 1m resolution for the three spectral bands: R,G,B).

Results (1500 characters)

For the IKONOS subsets, the separability analysis concerned the direction angle, spectral band and texture descriptors. It indicated best performance at 90°, for most of the window sizes between 3x3 and 15x15 pixels. Similarly, the separability analysis resulted with the Blue and Green bands having the highest JM distances and Variance, Second Moment and Dissimilarity. The overall classification accuracy (OA) of the urban subset, using only the four spectral bands of IKONOS was 63.6% with a kappa coefficient (*k*) of 0.53. For the suburban subset the OA was 66.16% with a *k* of 0.56. Adding the six texture layers resulting from the separability analysis, and for the optimally performing window sizes of 5x5 and 13x13 for the urban and suburban subsets, the OA increased to 66.15% and to 67.32%, respectively. Especially, the two major classes, namely bare land and human constructions' cover (roads and roofs), revealed for the urban subset an OA of 80.5% and 81.2% for spectral vs. combined spectral and textural features input, respectively. For the suburban area this increase was higher, from 66.4% to 72,1%. In relation with the Google Earth images, for the urban subset, the OA was 86.06% with a *k* of 0.58. Adding the six texture layers resulting from the separability analysis, and for the optimally performing window size of 3x3 the OA increased to 89.40% with a *k* of 0.69. For the suburban subset the OA increased from 74.10% with a k of 0.53 to 79.6% with a k of 0.65.

Outlook for the future (1000 characters)

For the urban subset, using textural layers slightly increased overall accuracy, while also improved the mapping accuracy of urban targets. A small texture window size was recommended. For the suburban subset, integration of texture reduced the confusion between urban and bare land targets; especially, between grey roofs vs. rocks and red tile roofs vs. bare soil. The use of the higher resolution Google Earth image (1m instead of 4m with IKONOS) resulted to an increment of accuracy of more than 7.5 %. This has to be verified at further areas. Deep learning, object-based analysis, hierarchical multiresolution analysis methods, use of time series, and/ or ancillary data, may result to further accuracy improvement. Google earth image results indicate that it can be used for classifying urban and suburban areas as an alternative inexpensive source of very high/ high spatial resolution spaceborne images.

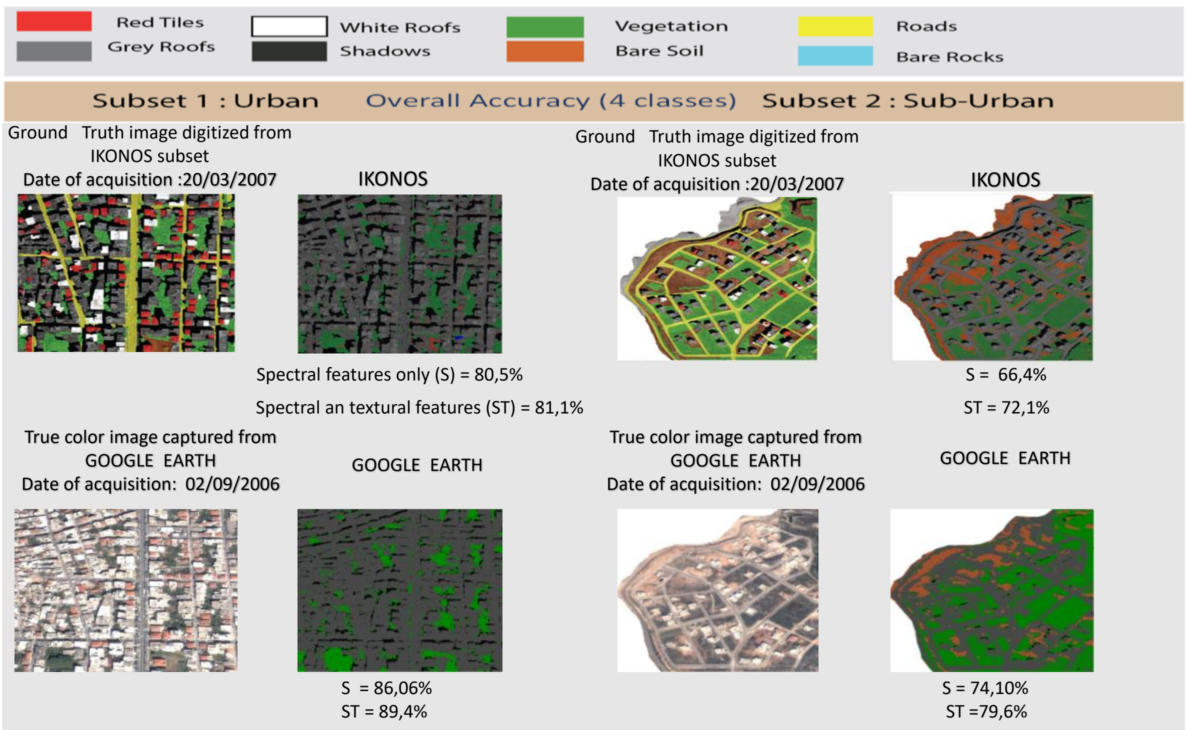

Figure 1 Ground truth (full legend applicable) and Classification maps (classes: Bare land/ indicated as bare soil in the legend, human-made constructions/ indicated as grey roofs in the legend, shadows, vegetation) with the achieved overall accuracies using the spectral features and the combined spectral and textural features as inputs for the a) urban subset area, and (b) suburban subset area. The images form the first row are from the IKONOS subsets and the images form the second row are from the Google earth subsets.

Mapping settlement and vegetation continuous fields at national scale in a temperate environment using Sentinel-2

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Abstract
Corresponding Author: franz.schug@geo.hu-berlin.de

Franz Schug[1], David Frantz[1], Akpona Okujeni[1], Sebastian van der Linden[1,2], Patrick Hostert[1,3]

[1] Earth Observation Lab, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany
[2] Institute of Geography and Geology, Universität Greifswald, Friedrich-Ludwig-Jahn-Str. 16, 17489 Greifswald, Germany
[3] Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys), Humboldt-Universitat zu Berlin, Unter den Linden 6, 10099 Berlin, Germany

Keywords: Urban, Sentinel-2, Unmixing, Land Cover Fractions, Spectral-Temporal Metrics

The challenge

The impact of human activity on the Earth's surface has rapidly increased over the last decades. Human activity includes agriculture and forestry, but is mainly driven by the presence of settlements. Knowing that future population growth will be important (from 7.4 billion in 2015 to 9.2 billion in 2040), there is an urgent need to understand spatial-temporal patterns of settlements and related processes on broad scales and along a rural-urban gradient. In contrast to classification approaches, subpixel mapping has been introduced to meet the requirements of heterogeneous areas with small object sizes. Here, we examine the robustness of spectral-temporal metrics (STM) from optical time series imagery as an input to machine-learning regression-based unmixing with synthetically mixed training data. While STM are robust with regard to phenology and data gaps, synthetically mixed training data requires few pure spectra and minimizes the need for training data collection.

Methodology

We map subpixel fractions of four land cover classes (*built-up/infrastructure*, *woody vegetation*, *non-woody vegetation* and *soil*) from Sentinel-2A/B for Germany and Austria on a 10m resolution. We use all cloud-free image acquisitions from 2017 and 2018 and use STM for regression-based unmixing. We study the performance of different feature set inputs for large area mapping and if specific feature sets stand out. The study area comprises 440,000km² and a population of 91.1 M. We used 15,398 acquisitions from 86 Sentinel-2 scenes.

We compute 18 different STM and NDVI metrics and train 1,275 Kernel Ridge Regression models per class with randomly different input metrics sets. Training data is drawn from input features at 534 reference locations, selected based on a hierarchical classification scheme. For synthetic mixing, we adapt a parameter setup used in regional studies before and create 1200 inter- and intra-class artificial mixtures of pure spectra at different randomized binary and ternary mixtures as regression input.

Validation used stratified random sampling with four population density classes (from GPW4) and four imperviousness classes (from Copernicus Imperviousness) in order to cover the range of the rural-urban gradient. We labelled 36,000 validation points and calculated reference fractions for 640 pixels at 160 sample locations. Model performance was evaluated based on a weighted score accounting for different regression qualities across all classes.

Results

We find that the use of STM for synthetic training data generation leads to robust regression models for large area fraction mapping. Model qualities at 20m resolution showed a compact range of MAE values from 0.11 to 0.20 (*built-up/infrastructure*), 0.15 to 0.23 (*woody veg.*), 0.13 to 0.22 (*non-woody veg.*) and 0.02 to 0.24 (*soil*). Model slope and intercept showed a similarly compact distribution with larger between-class differences. Median slope/intercept for built-up/infrastructure is 0.73/0.14. The overall performance of soil predictions was rather poor. Regarding model selection, we showed that maximum model quality was reached with three to four input STM. 660 models with less than five input STM were systematically compared using a weighted quality score. Three quality metrics (MAE, Slope, R^2) for each class and each model were transformed using a logarithmic transform function that disproportionally penalizes values that are not among the high-performance models. This score was computed for all class qualities except soil and summed. The new ranking rewards models with good and balanced quality across the classes.

We select a model using the first, second and third reflectance quartile and a maximum NDVI to map fractions across Germany and Austria (c.f. Figure 1). Its performance (MAE 0.13 / Slope 0.73 / R^2 0.74) is comparable to that reached in similar studies at lower resolutions. Little difference in quality can be observed in different areas of the study region.

Outlook for the future

This study uses machine learning regression with synthetically mixed training data for land cover fraction mapping on a national scale in a temperate environment. We showed that Sentinel-2 STM are robust input features for large area multi-class land cover subpixel mapping at a spatial resolution of 20m. A good overall quality of many different models implies a high model robustness, being less susceptible to varying feature quality and availability. Historic and spatial transferability of the models might benefit from this robustness. The approach is likely to yield good results for nations with similar environmental and architectural settings in Europe. Future research will particularly look into the transferability of the applied method to other regions and in a historic context. The integration of the results into large area products of land cover mapping or the benefit of additional data sources (e.g. Sentinel-1) is a further topic to be examined.

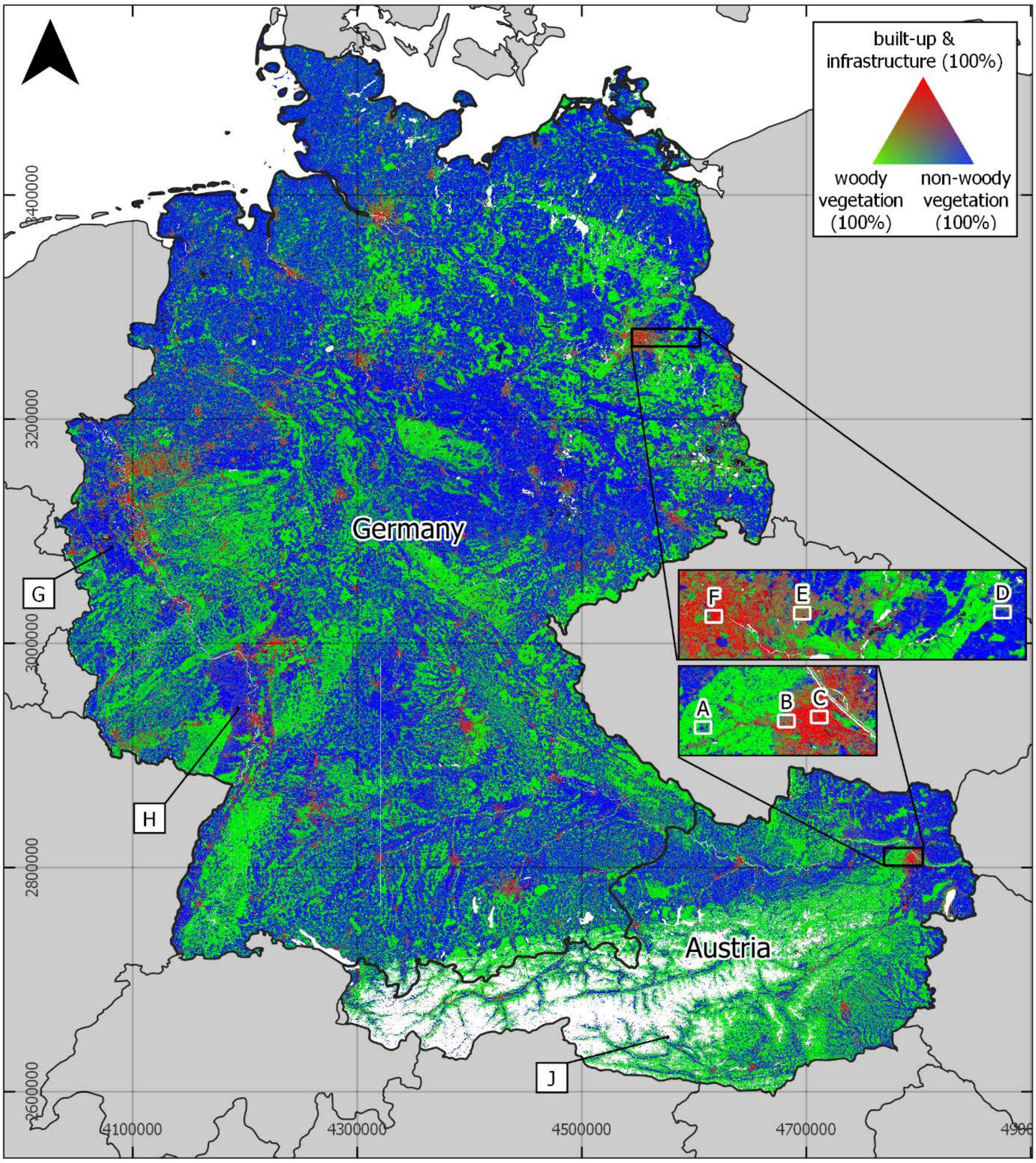

Figure Land cover fractions of built-up and infrastructure, woody vegetation and non-woody vegetation in Germany and Austria. Whit pixels: Masked due to the occurrence of water, permanent snow or steep slope.

Land cover semantic segmentation of SPOT-6/7 and Sentinel-2 data using CNN

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Abstract
Corresponding Author: arnaud.le-bris@ign.fr

Arnaud Le Bris[1], Olivier Stocker[1]
[1] LASTIG, Univ. Gustave Eiffel, ENSG, IGN, France

Keywords: VHR satellite, Land cover, Deep learning, Semantic segmentation

Challenge

Some applications, as the ones involving physical simulation (e.g. climat services), require the most up-to-date as possible land cover (LC) information. Automatic LC analysis out of Earth observation satellite imagery is the only possible answer to such need. Automatic LC products already exist, but their description of urban environment is not necessarily sufficient. Indeed, it is often limited to an urban area or a difficult distinction between different densities, while enhanced information about fine grained objects can be required.

Answering such need has become realistic during the last years. Indeed, on one hand, the availability of very high spatial resolution (VHR) satellite images over large territories has increased. For instance, in France, SPOT-6/7 images are captured each year over the whole territory. On the other hand, the development of deep learning approaches has provided a real gain in semantic segmentation, with an enhanced use of texture and context information.

Methodology

A fully convolutional neural network (CNN) "single source" architecture has been set up to perform land cover semantic segmentation out of SPOT-6/7 VHR satellite data (1,5m GSD after fusion, red-green-blue-near infrared bands). The proposed architecture is inspired by U-NET and DECONV-NET, using respectively their skip connections between equivalent encoder and decoder layers as well as the transfer of pooling indices to better cope preserve spatial information. Compared to the original U-NET, the depth of the network was also reduces (only 2 pooling layers) in order to have a receptive field compatible with the identification of "small" objects in these 1.5m GSD images. At the end, this architecture remains quite light with almost 1 300 000 training parameters.

Then this architecture has been modified to enable the fusion between two input data sources. This second "two sources" CNN is inspired by FUSE-NET. It consists of two encoder branches (one per information source) that are concatenated just after the last pooling layer. Skip connections between equivalent encode-decoder layers exist only from the encoder branch corresponding to the finer spatial resolution input source. This network can be used to perform data fusion at different levels, depending whether the input data are raw images or classification results (maps or class probabilities).

Results

Experiments were performed over 4 important French agglomerations. For each of them, the CNN was trained out of reference maps generated out of existing national LC or topographic databases (DBs) considering they are available everywhere in France. Different LC legends have been considered. Besides, aiming at better describing some classes missing from existing DBs (e.g. urban vegetation), experiments have also been done for training data mixing references from existing DBs and classification maps obtained out of aerial data (for more classic methods but using both 3D and radiometric data).

Good results have generally been reached using only monodate monoscopic SPOT-6/7 images. Basic urban objects (buildings, roads) are generally well retrieved, without over-detection over natural areas (crops, trees), while the discrimination between finer classes (e.g. different forest types) can be more difficult.

Using Sentinel-2 (S2) data has also been considered. To assess VHR imagery wrt enhanced spectral configuration, a 10 band Sentinel-2 image (acquired at the same period than SPOT data) resampled at 1.5m has first been classified by the single source CNN, before SPOT and S2 data were classified together by the "two sources" CNN, improving results especially for the classification of industrial buildings. The "two sources" CNN was also applied to improve the level of details of an already existing S2 time series based land cover map, taking SPOT imagery and the LC map as inputs.

Outlook for the future

The proposed architectures were not too deep in order to enable a good detection of small objects (buildings, road) out of 1.5m GSD imagery, and good results were obtained for them. However, this depth is not sufficient to cope with classes requiring to consider a wider context (e.g. urban densities). The preliminary proposed fusion architecture was applied only to data resampled at the same spatial resolution. Thus, further work will aim at modifying it to better use multi-resolution information. It has also to be modified to enable the use of S2 time series.

However, these simple architectures already make it possible to correctly retrieve basic land cover topographic objects. Thus, another perspective is to use these basic LC maps to derive other lower resolution land use/ land cover classes, as for instance distinguishing different urban morpho-types (densities, residential Vs. industrial or commercial). Classic spatial analysis or deep learning approaches can then be used.

Figure From top to bottom and left to right: crop of a SPOT-6/7 image, associated reference map, classification result out of SPOT-6/7 imagery alone, classification result using both SPOT-6/7 and S2 images (dark green: forest/high vegetation ; light green: crops and low vegetation ; magenta: buildings ; grey: roads ; orange: building neighbourhood ; blue: water areas)

Using Sentinel-2 Data to Detect New Urban Elements in Agricultural Parcels

EARSeL Liege 2020
Abstract
Corresponding Author:
e.beriaux@cra.wallonie.be

Émilie Bériaux[1], Alban Jago[1], Cozmin Lucau-Danila[1] and Viviane Planchon[1]

[1] Walloon Agricultural Research Centre – CRA-W, Belgium

Keywords: Change detection, Agriculture, Urban, Sentinel-1/2

The challenge

As part of the upcoming reform of the Common Agricultural Policy (CAP) in 2020, the satellite Earth Observation for crop monitoring will play an increasing role. In order to implement the next Area Monitoring System (AMS) using Remote Sensing data in near real time, accurate and up-to-date agricultural field boundaries maps is one of the main conditions, helping to identify crop types, agricultural practices, etc. In this context, the detection of new non-eligible areas (buildings, infrastructure, ...) inside agricultural parcels is of great importance. At present, this information is usually derived from Very High Resolution (VHR) images but these data are not frequently updated. The present work proposes a simple, operational and automated method for detecting such changes using Sentinel-2 (S2) images. The high temporal resolution of images from those satellites (2-5 days over Belgium) allows for a more frequent detection of the changes.

Methodology

Study site & data

The study site is located in the Walloon Region (WR), South part of Belgium. Our area of interest is a 20 x 20 km zone which is covered by one Sentinel 2 tile. We use NDVI Sentinel-2 time series from May to July 2020. The selected period corresponds to a high vegetation in most of the Walloon agricultural crops.

The Land Parcel and Identification System is also used. It contains polygons of agricultural blocks that are surrounded by physical non-agricultural elements (road, forest…) and polygons of fields parcels with information about their crop type.

The 2019 & 2020 orthophotos (25 cm resolution) are used to create a validation dataset containing 46 urban elements and about 4000 non-urban polygons.

Methodology

Our method combines pixel and object-based algorithms:

1) Pixels in agricultural fields with a high probability of containing a new construction are selected, based on their S2 NDVI temporal behaviour during the 3 months period. However, the non-perfect alignment of S2 images from different dates requires to use 2 tricks in order to account for the possible jump of a point of interest from a pixel to an adjacent one. An algorithm of co-registration of the Sentinel-2 imagery is first used to improve the pixels alignment for all the time series. Moreover, for each pixel, the retrieved temporal behaviour of the NDVI corresponds to the minimal NDVI of a 3x3 window surrounding the considered pixel. A pixel is flagged if this minimal NDVI is under 0.3 during all the 3 months period.

2) Knowing the NDVI temporal behaviour per crop type and using knowledge about crop practices in our zone of interest, the pixels selected at 1) that are located in fields for which the NDVI can be low during the whole 3 months period are excluded.

3) The method flags the agricultural blocks containing at least one of the selected pixels from steps 1 and 2 after a negative buffer application of –10m.

Results & outlook for the future

78 % of agricultural polygons including urban elements are detected. The 22% of agricultural polygons including urban elements that are not detected concerns small urban elements at the border of the polygon that are not anymore in the polygon after the negative buffer application. 10 % of agricultural polygons with no urban elements are incorrectly detected. The false positives include some polygons where there are machine storages or mud in grasslands. They also include lots of cases with high numbers of pixels selected in spring crops.

We notice that in this experiment, we still have false-positive cases to eliminate.

In arable land, this issue could be addressed by a stronger selection on the fields where it is possible to work considering a specific period and the crop types evolution of the NDVI. Another way would be to look at the percentage of flagged pixels contained in a field.

In grasslands, it could be useful to consider changes over time or to use additional Sentinel 2 indices such as bNDVI to distinguish mud from urban elements.

Conclusion

The present work shows that Sentinel-2 data can be used to study the appearance of new urban elements in agricultural parcels in the specific context of high-quality information about agricultural crop type. Compared to techniques using VHR images, this allows more frequent detections of the changes. This can be valuable in helping countries to maintain an accurate description of their agricultural lands in a more automated way.

Furthermore, depending on the application requirements, the combination of the probabilities coming from the different methods can be adapted.

Figure 1 (left) detection of a new construction zone (right) orthophoto verification

Regional Environment monitoring using Copernicus Sentinel-1 SAR images: Interferometric SAR coherence as an indicator of dynamic land cover changes

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Abstract
Corresponding Author: aorban@uliege.be

Dominique Derauw[1], Ludivine Libert[1], Anne Orban[1], Christian Barbier[1]

[1] Centre Spatial de Liège, University of Liège, Belgium

Keywords: Earth Observation, Regional monitoring, Land cover changes, InSAR Coherence

The challenge

With the climatic change, there is a known risk of increasing drought and heavy precipitation periods. Globally all natural impacting events will increase in magnitude and frequency in the coming decades. Among those events, wildfires and floods are already considered as major threats for numerous European regions. Dynamically monitoring such events is of major importance for correct and efficient emergency response.

With its wide range and recurrent observation modalities, the space component of the Copernicus program offers a possibility to provide such monitoring, helping in giving an adequate response to those dramatic events.

Methodology

The Centre Spatial de Liège has developed a long-standing experience in the frame of radar remote sensing and more particularly in the frame of SAR interferometry (InSAR). In the frame of InSAR processing, a major quality criterion is the so-called coherence which indicates the ability of the two wave fronts used in the interferometric processing to stay in phase. Consequently, coherence loss indicates interferometric phase information loss.

However, since coherence loss is related to changes of scatterers distribution within the pixel, this information loss can itself be used as an information source. As such, coherence is an indicator of land cover changes. Using temporal series of acquisitions, this property can, in turn, be used to perform dynamic observations of floods extends and wildfire propagation.

Results

We present results obtained using our homemade interferometric software (CIS) with Sentinel1 acquisition in different illustrative cases, among these: Australia wildfire in December 2019 and Luxembourg area floods in January 2020.

Advantage of this simple technique is its dynamic aspect since in most cases, Sentinel1 A and B allow updating this land cover change indicator every 6 days and even more if using ascending and descending interferometric pairs. The technique can also be used as an indicator of area recovery after these types of events.

Outlook for the future

In addition to simple monitoring and floods or wildfire zone delineation, it is expected that dynamic coherence monitoring may also be used as an indicator of area recovery after the event.

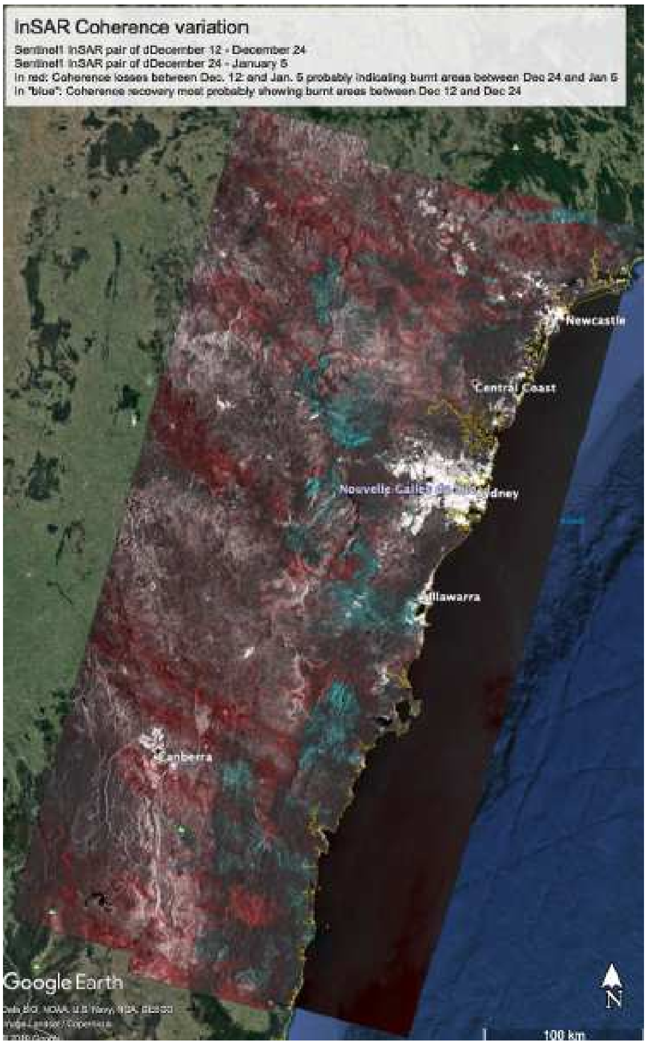

Figure 1 Example of wildfire delineation: New South Wales wildfires, Australia
Figure shows a covered area of about 135000km2 combining three successives S1 frames.
Color combination shows in blue already burnt surfaces before December 24, 2019,
in red additional ones on January 5, 2020

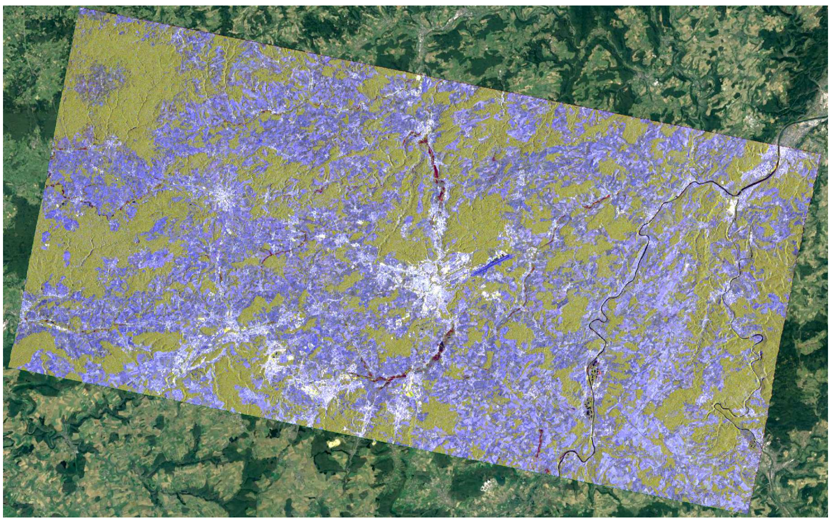

Figure 2 Example of flood monitoring: Luxembourg area and surroundings, S1 acquisition, January 2020.
Amplitude images are used for R and G channels. Coherence is used for B channel.
Already flooded areas or normal water surfaces appear in black. Flooded areas between acquisition dates appear in red. Water level drop appear in green showing the ability of the approach to analyse area recovery.

Climate Change Mitigation and Adaptation: Strategic Directions for Urban Remote Sensing

EARSeL Liege 2021
Abstract
Corresponding Author: karen.seto@yale.edu

Karen Seto[1]

[1] Yale University, School of the Environment, United States of America

With a growing recognition of the importance of urban areas for mitigating and adapting to climate change, both the science and policy communities are calling for more information about urban areas. For example, the IPCC approved a Special Report on Cities and Climate Change in the 7th Assessment Cycle. What type of information is needed to inform policies that can help create a more sustainable urban future and how can urban remote sensing 2.0 contribute? This talk will draw on the 5th and 6th Assessment of the IPCC Reports and recent developments in urban remote sensing to discuss opportunities for filling critical knowledge gaps about cities and climate change.

UrbanTEP – EO data processing, integrative data analysis and monitoring for SDG reporting

EARSeL Liege 2021
Abstract
Corresponding Author: felix.bachofer@dlr.de

Felix Bachofer[1], Thomas Esch[1], Jakub Balhar[2], Martin Boettcher[3], Enguerran Boissier[4], Mattia Marconcini[1], Annekatrin Metz-Marconcini[1], Michal Opletal[2], Fabrizio Pacini[4], Tomas Soukup[2], Václav Svaton[5], Julian Zeidler[1]

[1] German Aerospace Center (DLR), Earth Observation Center (EOC), Germany
[2] GISAT s.r.o., Czech Republic
[3] Brockmann Consult GmbH, Germany
[4] Terradue Srl., Italy
[5] IT4Innovations, VSB-Technical University of Ostrava, Czech Republic

Keywords: SDG Monitoring, Platform services, Cloud processing, Earth Observation, Urban analysis

The challenge

Urbanization is among the most relevant global trends that affects climate, environment, as well as health and socio-economic development of a majority of the global population. Detailed and reliable information on global human settlements can directly contribute to the monitoring and decision-making regarding the 2030 Agenda for Sustainable Development. Here, the provision of relevant data for the Sustainable Development Goals (SDG), specifically SDG 11, as well as for other global and national policy frameworks is of particular interest. Scientists, analysts, planners and decision makers need capabilities to effectively and efficiently access, process, and jointly analyse the constantly increasing, but often heterogeneous and large-volume data collections on the built environment.

Methodology

The U-TEP is developed to provide end-to-end and ready-to-use solutions for a broad spectrum of users (service providers, experts and non-experts) to extract unique information/ indicators required for urban management and sustainability. Key components of the system are an open, web-based portal connected to distributed high-level computing infrastructures and providing key functionalities for

i) high-performance data access and processing,

ii) modular and generic state-of-the art pre-processing, analysis, and visualization,

iii) customized development and sharing of algorithms, products and services, and

iv) networking and communication.

The service and product portfolio provides access to the archives of Copernicus and Landsat missions, DIAS processing environments, as well as premium products like the World Settlement Footprint (WSF). External service providers, as well as researchers can make use of on-demand processing of new data products and the possibility of developing and deploying new processors.

Results

The Visualization and Analysis Tool (VISAT) on U-TEP allows experts and non-experts to conduct geospatial analyses, queries and the visualization of results. In order to allow for the calculation and provision of SDG 11.3.1 ratio of land consumption rate to population growth rate, a dedicated scope was prepared for the research project FloodAdaptVN (German Federal Ministry of Education and Research, funding number 01LE1905A) and demonstrated for the SE-Asian region (Figure 1). The WSF Evolution product, which delineates the development of urban settlements from 1985 to 2015 (derived from advanced Landsat-based analysis), as well as annual population data for four SE-Asian countries were used to track and compare their development path. All countries show an unbalanced development, demonstrated by a higher increase of land up-taken by urban settlement compared to the increase of population. The population of Cambodia doubled in the period of 1985 to 2015, while the settlement area is five times the area of 1985. In Thailand, the settlement area doubled and the population grew only by 32%. Sub-national administrative areas show a more diverse pattern. Further, additional geodata and statistical data can be integrated in-depth analysis in UrbanTEP.

Outlook for the future

The product and service portfolio is being improved constantly. The major developments envisaged in 2021 are:

i. City DataCube services and functionalities will be made available on UrbanTEP

ii. The next version of the VISAT tool will allow developing storylines that enhance the communication with end-users and stakeholders

iii. New EO based products and other geospatial datasets will be made available via the platform

iv. A new business model will support the mid- to long-term sustainability of the platform and ensure availability and reliability of the UrbanTEP services.

Since 2020, the on-boarding of service providers, developers and researchers is supported by the Network of Resources (NoR) program of the European Space Agency (ESA) and the OCRE initiative of the European Commission.

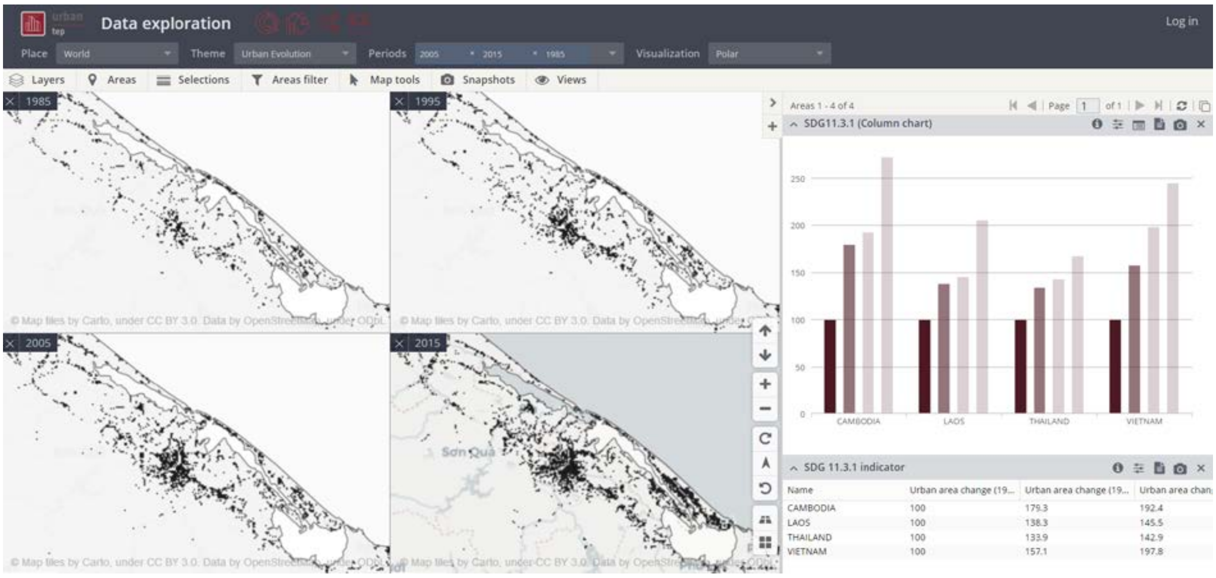

Figure 1 (left) settlement development based on the WSF for Hue, Vietnam 1985, 1995, 2005 and 2015 (right) SDG 11.3.1. Indicator for SE-Asian countries

COPERNICUS Global Land Products and Services and the Sustainable Development Goals

EARSeL Liege 2020
Abstract
Corresponding Author:
pietro.ceccato@spacebel.be

Pietro Ceccato[1], Michael Cherlet[2], Marie Lang[3]

[1] SPACEBEL, Geospatial Information & Systems, Belgium
[2]EC Joint Research Center, Italy
[3] University of Liège, Belgium

Keywords: Earth Observation, COPERNICUS Global Land Products and Services, Sustainable Development Goals

The challenge

COPERNICUS Global Land Products and Services provide an unprecedented amount of products derived from Earth Observation (SPOT-VEGETATION, PROBA-V, Sentinel 1, Sentinel 2 and Sentinel 3). The products and services encompass a large amount of products related to vegetation (such as NDVI, EVI, FAPAR, FCOVER, LAI…), water (quality, level), snow cover, land cover etc... Those products are a great opportunity for using them in the monitoring and evaluation of the Sustainable Development Indicators (SDGs) required by the custodian agencies. However, their integration into monitoring and evaluation of the indicators is not a straightforward process. This proposed oral presentation will discuss the challenges and opportunities that the COPERNICUS Global Land Products and Services provide to the SDGs' communities both to the custodian entities such the UN, and European and national statistical agencies.

Methodology

We have conducted technical user group meetings gathering UN agencies, GEOSS, National statistical agencies, Conservation International, Global Partnership for Sustainable Development Data to evaluate the needs for monitoring and evaluating the SDGs' indicators and came up with a series of recommendations on how to integrate COPERNICUS GL into the SDGs.

Results

This oral presentation will discuss the results obtained from the discussions and recommendations for integrating the COPERNICUS GL into the SDGs indicators as presented in the Table below:

	Goal	CGLS products	Products Requested	Relevant projects/topics
1	No Poverty		- Urban settlements	- EO4poverty
2	Zero Hunger	- Vegetation - Energy - Land Cover	- Soil carbon - Evapotranspiration (at parcel level) - EVI	- Governmental initiatives for small farmers to develop sustainable business

3	Good Health and Well Being	- Water		- Global Partnership for Sustainable Development Data
6	Clean Water and sanitation	- Water - Hot Spots - Land Cover		- Global Partnership for Sustainable Development Data
9	Industry, Innovation and Infrastructure	- Urban Atlas - Land Cover		
11	Sustainable Cities and Communities	- Urban Atlas - Land Cover	- Urban settlements	- Detection of urban VS rural areas, computation of Land Cover and Agricultural statistics (INEGI Mexico) - UN Habitat
15	Life on Land	- Land Cover - Hot Spots - Vegetation, Energy	- Land degradation - Soil carbon - Evapotranspiration (at parcel level) - EVI	- Land cover mapping + forest change (GOFC-GOLD) - Land Degradation (LDN)

Outlook for the future

This presentation will outline the recommendations made for a better integration of COPERNICUS GL within the SDGs' framework in terms of continuity, reliability, consistency, spatial and temporal requirements, validation and access.

Automatic Detection Of Urban Vacant Land: An Open-Source Approach For Sustainable Cities

EARSeL Liege 2020
Abstract
Corresponding Author:
shaojuan.xu@ils-forschung.de

Shaojuan Xu[1, 2], Manfred Ehlers[2]

[1] Research Institute for Regional and Urban Development, Germany
[2] Osnabrück University, Germany

Keywords: Brownfield, Data Fusion, Open Source, Sustainable Cities, Vacant Land

The challenge

Urban vacant land including brownfield has garnered increasingly attention.

The current vacant land inventory or typology mostly classify sites according to the size, land use history, site conditions etc. In other words, the location and character of vacant land have been well-documented. However, quite often, none of this information is known by the government, thus the definitions of vacant land are not suitable for site detection and separation.

Using remote sensing methods to identify brownfield is also challenging. One approach focuses on the implementation of satellite image classification, based on the assumption that there are collapsed buildings or contamination on a brownfield. However, this is not always the case. The morphology of brownfield varies from derelict structures, bare soil, vegetation, or a mix. Consequently, even though commercial high-resolution remote sensing images were applied, it is still difficult to achieve the goal of automatic vacant land detection.

Methodology

This study introduces a new definition of urban vacant land typology. The typological classification considers the cause of vacancy, related land-use type, and required data sources for site detection. It includes four categories: i) *Transportation-associated land*, ii) *Natural sites* with unfavourable conditions such as wetlands, steep slopes, river bands, beaches, and gravel fields, iii) *Unattended areas and reserve parcels* which are the leftover spaces within the urban fabric, and iv) *Brownfield* which has been used before but now abandoned.

Vacant land is influenced by human activities, and therefore referred land use information cannot be extracted by using image classification alone, but needs to be coupled with additional data sources. Due to the increasing number of open source initiatives, abundant geospatial data are available. Copernicus, in particular, provides not only satellite images but also rich GIS layers. OpenStreetMap and some of the social media data are also freely accessible. Here, another advantage of the proposed typology comes into play, as the categories match to Copernicus Urban Atlas classes. Therefore, the Urban Atlas provides a starting point from which additional data are integrated to complete site selection. For each type of vacant land, a separate data processing chain was developed. Moreover, all the data processing was done with the open source software.

Results

The developed method has been tested in 63 urban and rural districts in Germany. Vacant sites are automatically extracted with the location, shape and size, forming a spatial vector layer. The identified sites show different site properties. *Transportation-associated land* is located at the highway junction, enclosed by the roadways, or sparsely distributed near railways. *Natural sites* occur partly near rivers and partly on the urban outskirts or borders of suburban areas. *Unattended areas and reserve parcels* mostly appear as gaps in the dense urban fabric, which have the best-suited condition for further utilization, easily to be filled with new houses. Brownfield feature visible building damage on site, low temperature emissions of buildings in wintertime, and lack of human activity indicated by social media data. The detected sites were validated by Google earth images or aerial photos. The figure below presents some examples for each type of vacant land.

Outlook for the future

Beyond the pilot study sites, using open source software and input data, particularly Urban Atlas, which is available for 800 urban areas in EEA39 countries, presents a cost-effective way to reveal a considerable amount of vacant land for urban development.

Currently, the Environmental Mapping and Analysis Program, aimed at providing hyperspectral data at a global scale, is in the development and production phase (www.enmap.org). In the future, the produced data could be integrated into the detection of brownfields.

The detected vacant land could be further developed or recycled, to provide additional housing spaces or for redevelopment for commerce and industry, in order to reduce urban sprawl to prevent further encroachment into natural areas.

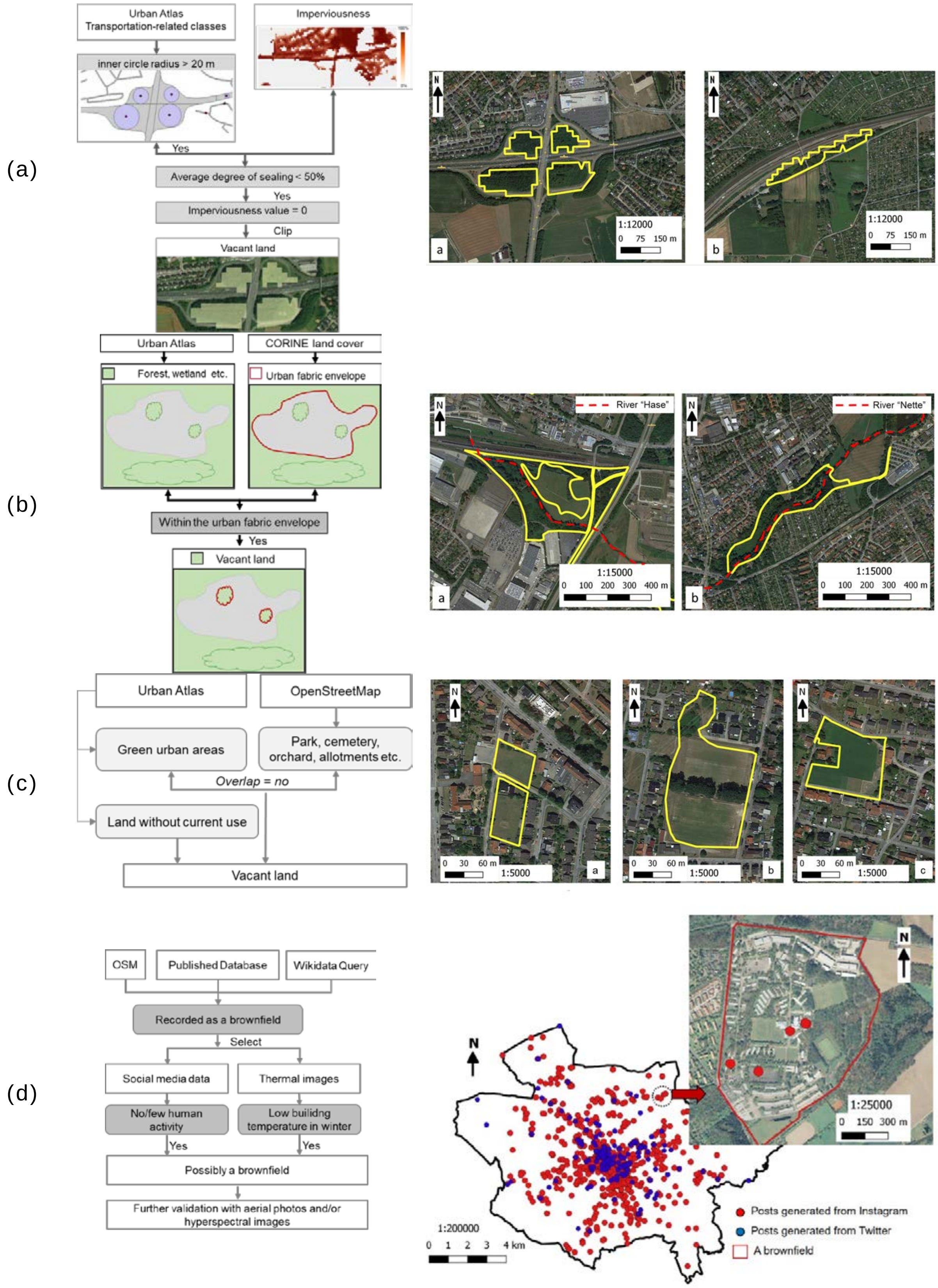

Figure Data processing procedure and examples of automatic detected vacant sites for (a) Transportation-associated land, (b) Natural sites, (c) Unattended areas and reserve parcels and (d) Brownfield

Earth Observation for Sustainable Development in Urban Areas: Results and Achievements from ESA's EO4SD-Urban project

EARSeL Liege 2020
Abstract
Corresponding Author:
manuela.hirschmugl@joanneum.at

Manuela Hirschmugl[1], Jan Kolomaznik[2], Tomas Soukup[2], Amelie Broszeit[3], Carina Sobe[1], Herwig Proske[1]

[1] Joanneum Research Forschungsgesellschaft mbH, Graz, Austria
[2] GISAT, Czech Republic
[3] GAF AG, Germany

Keywords: Earth Observation, Urban, Land Use, SDG11, capacity building

The challenge

EO4SD is a European Space Agency initiative to support the uptake of EO-derived information in sustainable development. There are currently eight projects dealing with various aspects in this frame. One of them is the EO4SD-Urban project, which is dedicated to urban development. The challenge is to increase the uptake of EO-based information in the International Financing Institutes' (IFIs) regional and global programmes by means of a systematic user-driven approach. To achieve this aim, a consortium of Earth Observation providers and research organizations is providing EO-based use case examples in 32 cities worldwide. The cities and urban areas were selected according to the needs of several initiatives from the World Bank, Asian Development Bank, Inter-American Development Bank and the Global Environment Facility. The cities are located in developing and emerging countries in Africa, Latin America and Asia.

Methodology

The methodology to address the challenge above is twofold: first, to produce use case examples in selected cities to show the benefit of EO data and methods for urban applications. The second pillar is awareness raising and proper capacity building in the IFIs and in the selected cities based on the practical use cases.

To produce high-quality use case examples, state-of-the-art EO technology is employed in a stringent and harmonized manner. This is important especially for initiatives involving a set of cities or for repeated assessments. Only a harmonized and clearly documented methodology can allow different indicators to be comparable between cities or to track the development over time. Use case examples involve settlement extent maps over time; land use and -change; building footprints and –heights; land subsidence maps; flood risk maps; maps of transport infrastructure; informal settlement maps and population distribution maps. Based on such basic information, various added value products can be derived, e.g. for the generation of indicators for the SGDs. The indicator 11.3.1: "Ratio of land consumption rate to population growth rate" can for example be calculated based on our mapping results and can be tracked over time using framework developed in the project. Other indicators are e.g. Proportion of urban population living in slums, informal settlements or inadequate housing (11.1.1) or proportion of population that has convenient access to public transport (11.2.1).

Results

In the frame of this work, we have included 32 cities from around the globe with an emphasis on low-capacity environments, selected megacities and their hinterlands, and secondary (emerging) cities with a population between approximately 300,000 and 3 million inhabitants. In total, we produced more than 510 products and 11,000 km² mapped. In order to bring not only the data to the users, but also generate a better understanding, four main communication channels were followed. First, classical data delivery and user utility assessment was performed with the counterparts in the cities and in the IFIs. Second, a series consisting of eleven Webinars were held to showcase the use of EO data in the frame of urban development. These Webinars also included background knowledge on satellite data properties and remote sensing technology. All webinars were recorded and later on also included into the learning platforms of the World Bank (Open Learning Campus – OLC) and the Asian Development Bank (k-learn platform). Third, we performed city-specific training tailored to the need of the users and the specific product for that city. Finally, fourth, we organized regional workshops with face-to-face trainings. The whole capacity building efforts are supplemented by a selection of web stories to specific topics and interactive analysis functions for users to easily understand and obtain data from Earth Observation. One graph out of one of the web story is shown in the Figure below.

Outlook for the future

This project is considered as starting point in order to improve the impact of IFI-projects and for safeguarding un-wanted side effects. Without "the big picture", EO can deliver, these side effects are often overlooked. In terms of methodology, more efforts will be put on the spatial analytics and statistics to derive meaningful information for non-EO people. In technical terms, the inclusion of upcoming sensors in the domain of VHR data (e.g. Pléiades NEO) is the logical next step. In terms of capacity building, more work needs to be done both in the cities, which often lack hard-and software aside from human capacity, and in the IFIs to pave the way to an institutionalized integration of Earth Observation in their day-to-day business.

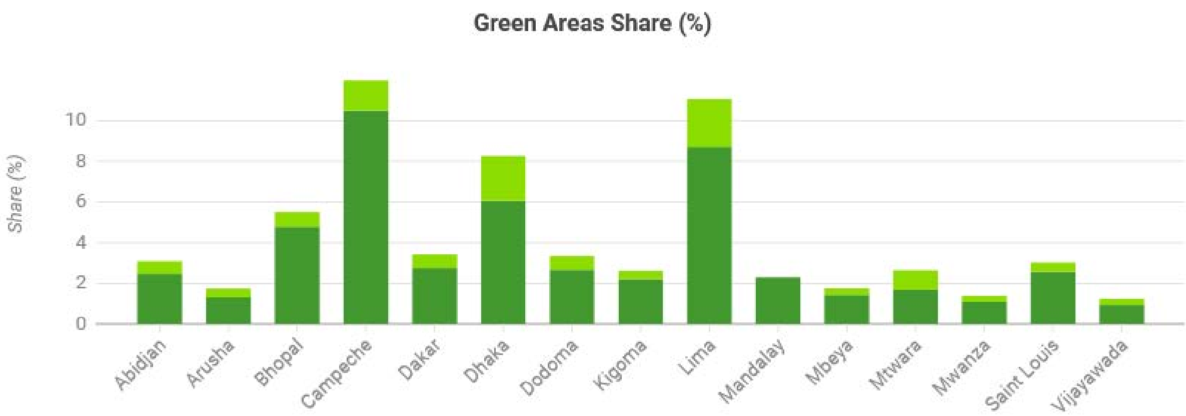

Figure shows part of the web story on urban green areas: the share of urban green areas (dark green) and sport and leisure facilities (light green) on the total area of the city

EARSeL Liege 2020
Abstract
Corresponding Author: m.kuffer@utwente.nl

An Integrated Deprived Area Mapping "System"

Monika Kuffer[1], Dana Thomson[2], Gianluca Boo[2], Ron Mahabir[3], Tais Grippa[4], Sabine Vanhuysse[4], Joao Porto de Albuquerque[5], Ryan Engstrom[6], Robert Ndugwa[7], Jack Makau[8], Caroline Kabaria[9]

[1] University of Twente, ITC, The Netherlands
[2] University of Southampton, Geography and Environmental Science UK
[3] George Mason University, Department of Computational and Data Sciences, USA
[4] Université libre de Bruxelles (ULB), Department of Geosciences, Environment and Society, Belgium
[5] University of Warwick, Institute for Global Sustainable Development, UK
[6] George Washington University, Department of Geography, USA
[7] UN-Habitat, GUO, Kenya
[8] Slum Dwellers International, Kenya
[9] African Population and Health Research Center, Kenya

Keywords: Earth Observation, Deprivation, Slums, Machine Learning

The challenge

Monitoring the growth, persistence, and diversity amongst deprived urban areas remains one of the primary goals of the Sustainable Development Goals (SDGs). This requires spatially explicit and accurate data, which is lacking in many global, national, and local monitoring programs. Several approaches have been used to monitor cities, with no single approach being superior. Typical mapping approaches of deprived areas, e.g., Earth Observation (EO), aggregated census/survey data (common for SDG 11), and community-based are siloed, lack transferability and scalability. EO approaches are mostly top-down, with no or limited local interaction, while survey-based approaches tend to be bottom-up and lack spatial and temporal coverage. To produce policy-relevant maps, top-down and bottom-up approaches need to be combined. We are building an Integrated Deprived Area Mapping System, which provides a flexible mapping system for different users at different spatial scales to support SDG 11.

Methodology

Different mapping approaches have been integrated into a deprivation mapping system (Figure 1). Spatial data at three different levels (i.e., neighbourhood, city and national) are combined, providing detailed physical, social and environmental information to meet the needs of different stakeholders. For example, local data in support of community advocacy are combined with machine learning-based EO methods producing data at city scale, with fewer details but extensive areal coverage. At a city to a national scale, a high-resolution gridded dataset is proposed, where each grid cell provides an estimation of the degree of deprivation, covering multiple domains of deprivations via a large set of covariates (e.g., physical, socio-economic, contextual) (More information: https://ideamapsnetwork.org/domains-of-deprivation-v1/). In general, gridded datasets provide high aggregation flexibility (e.g., to administrative units), with users able to set thresholds and query the data. Furthermore, gridded datasets allow for the protection of privacy and safety of the local communities. A web interface is designed to allow user interaction, e.g., also adding more local data, which will allow for the improvement of statistical models. As such, the platform can be used for SDGs reporting, national and local reporting and allow national statistical agencies to generate deprived area maps in support of local surveys.

Results

To map the degree of "deprivation" for a global database of deprived areas, a 100 m by 100 m gridded system is showcased for several cities. Figure 2 shows an example of an Indian city, Bangalore. The census for this city reports 8% of its population living in around 600 deprived areas while a local survey mapped over 1,500 slums (http://www.dynaslum.com/). The omitted deprived areas are particularly those that are small and temporary (see ground photo lower right). This example is different from many other large cities, e.g., Mumbai (India), where the census of 2011 reports around 42% of the population living in deprived areas, or the city of Dar es Salaam (Tanzania) with around 70% of the population living in deprived areas (http://slumap.ulb.be/). In such cities, relatively large areas across the city are deprived. To effectively map the boundaries of deprived areas in the case of small pockets as well as for cities that are dominated by deprived areas, mapping strategies need to be flexible using the utility of machine learning. To support scalability and reduce acquisition and computational costs of gridded mapping systems, High Resolution (HR) imagery (e.g., Sentinel-2 or Planetscope) having a spatial resolution of 10m and below are of great advantage to display the general patterns of deprived areas across cities. However, there is a risk that such HR grid-based approaches are not able to capture very small deprived settlements (see example of Bangalore).

Outlook for the future

Spatial data on deprived areas are presently insufficient, both at the local and global scale and do not allow for spatially explicit policy support. The proposed Integrated Deprived Area Mapping System (IDEAMAPS) framework (https://ideamapsnetwork.org/) provides a gridded and flexible mapping system that can easily be integrated with other existing global, national and local data layers. Such a system supports cross-disciplinary analysis of deprived areas, e.g., of environmental and health conditions and climate change risks. This will allow an understanding of local conditions, and support local and global policies in the context of SDGs.

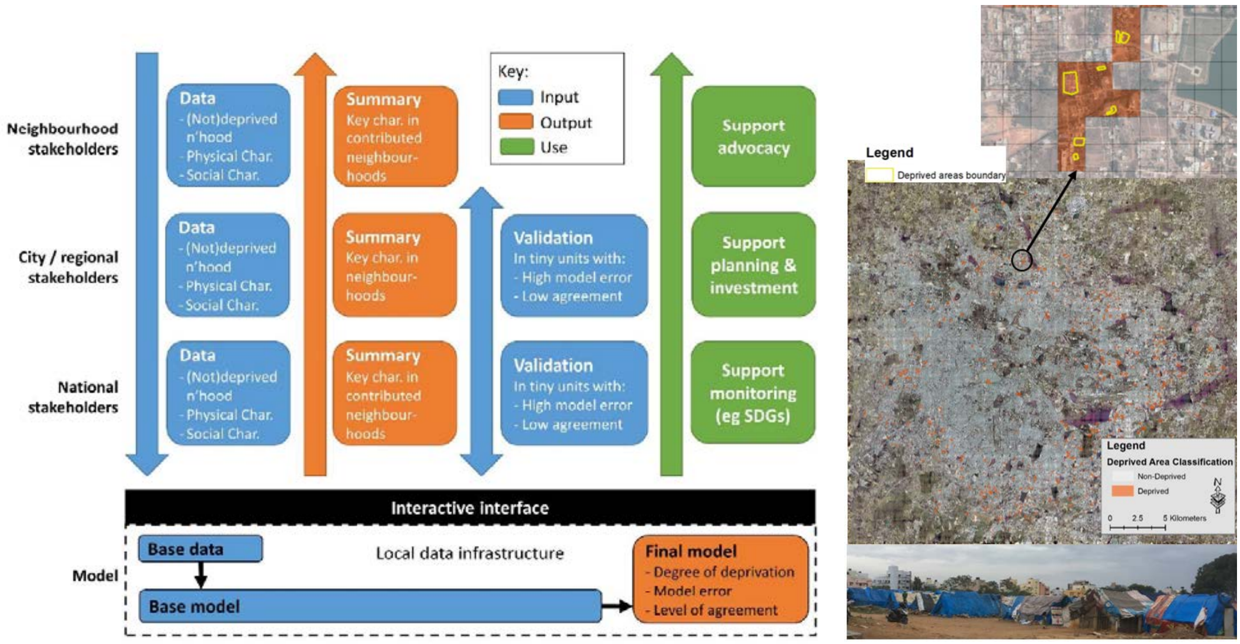

Figure 1 Diagram of an integrated deprived area mapping system (IDEAMAPS) (Source: https://www.mdpi.com/2076-0760/9/5/80) (left), Example of a gridded deprivation area map for the city of Bangalore, India (Source: https://www.mdpi.com/2072-4292/12/6/982) (right).

Urbanisation and ground deformation patterns in Khulna, Bangladesh in the context of a climate change adapted urban planning

EARSeL Liege 2021
Abstract
Corresponding Author:
nicolasjakob.wagener@bgr.de

Nicolas Jakob Wagener[1], Lukas Wimmer[1], Andre Cahyadi Kalia[1]

[1] Federal Institute for Geosciences and Natural Resources (BGR), Germany

Keywords: SAR Interferometry (InSAR), Small Baseline Subset (SBAS), ground deformation, urban planning, urban growth

The challenge

With 1.5 million inhabitants, the city of Khulna is the third largest city of Bangladesh, located in the Ganges-Brahmaputra delta. With an elevation of just 2-4 metres above sea level and located just 90 kilometres from the shore, Khulna is particularly vulnerable to flooding. Land subsidence can further exacerbate this vulnerability and understanding the deformation patterns and identifying the affected communities is therefore vital.

In this work, we examine the relationship between urban growth and urban structure, geology and InSAR-derived ground deformation. Since the year 2000, Khulna experienced strong urban growth. New residential and commercial areas are often established on land that is already at high risk for flooding such as flood plains and swamps that are filled in.

We describe the relationship between the age of built-up areas, the underlying geomorphology and observed ground motion. We identify and characterise affected parts of the city and assess the relevance of this information in the context of a climate change adapted urban planning.

Methodology

A total of 277 Sentinel-1 ascending and descending scenes from October 2014 to September 2020 are processed using the Small Baseline Subset (SBAS) and Persistent Scatter Interferometry (PSI) multi-temporal InSAR approaches. For the further interpretation of the data, Landsat TM derived classifications of urban extend for 1990, 2000 and 2010 are used together with geomorphological data.

Results

Areas of strong subsidence largely correspond to structures built after the year 2000. They are found mostly in the South and South-West of the city, where the city expanded along existing main roads and often into areas already susceptible to flooding (such as flood plains and swamps). Other clusters of strong subsidence can be found in the city's densely populated informal settlements. In addition, several major infrastructures such as the city's railway line and newly built central railway station are subsiding at an accelerated rate. Built-up areas that date back pre-2000 are largely stable. These areas correspond mostly to natural levees.

A multitude of factors seems to play a role in the observed deformation patterns. The post-2000 building boom occurred largely in areas not optimally suited for this purpose since the best building ground was already occupied. Secondly, the building load of newly built residential and commercial areas and major infrastructure seems to be a main factor in the observed deformation. Finally, the densely populated informal settlements are amongst the most vulnerable communities since they occupy the worst building plots, are already seeing frequent flooding and furthermore experience some of the strongest observed rates of subsidence.

Outlook for the future

Multi-temporal InSAR is a useful input for the development of urban planning scenarios in the context of climate change and can help urban planners to identify particularly vulnerable communities. Our SBAS deformation maps describe large-scale motions associated with large infrastructure and urban structures. PSI can be used to analyse more localised, non-correlated deformation phenomena. The simultaneous use of InSAR and ancillary data (e.g. optical remote sensing products and geomorphological data) allows for a more detailed interpretation of the results.

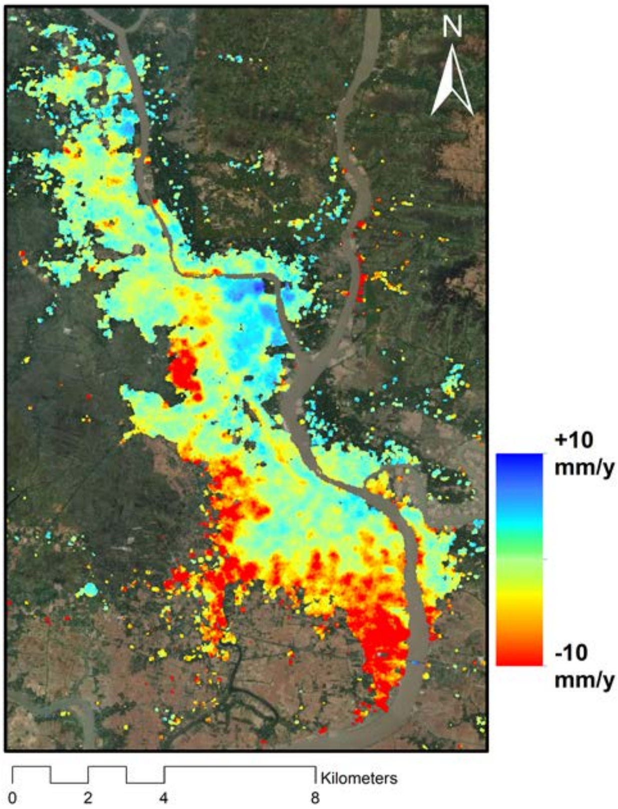

Figure (a) Vertical deformation velocity in Khulna in mm per year (10/2014-09/2020)

Acknowledgements

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Supporting urban sanitation management through the integration of EO-based indicators

EARSeL Liege 2021
Abstract
Corresponding Author:
barbara.riedler@sbg.ac.at

Barbara Riedler[1], Johannes Nödel[1], Rosi Siber[2], Nienke Andriessen[2], Linda Strande[2], Stefan Lang[1]

[1] University of Salzburg, Department of Geoinformatics Z_GIS, Austria
[2] Eawag, Switzerland

Keywords: Earth Observation, infrastructure planning, faecal sludge, priority areas, decision-support

The challenge

Sanitation refers to the provision of facilities and services for the safe disposal of human excrements and is included in SDG 6 “Ensuring the availability and sustainable management of water and sanitation for all”. With more than 2.5 billion people without appropriate facilities mainly living in cities, urban sanitation is critical to avoid harmful effects on human health and environment. Largely relying on onsite sanitation, the coordination of safe collection, treatment and disposal is essential. This requires reliable, up-to-date information that can be provided by EO data through its wide availability and objectivity. This is of particular importance in areas difficult to access and large, growing cities with urban sprawl. To facilitate the planning of faecal sludge management (FSM), priority areas where improvements are urgently needed can be identified using EO-based indicators, additionally enabling regular monitoring, evaluation of measures and targeted in-situ sampling.

Methodology

In close collaboration with urban sanitation experts, eight EO-related indicators relevant for FSM in Lusaka, Zambia were identified, covering demographic, environmental and technical aspects: 1) Building density, 2) Building size, 3) Building use, 4) Urban greenness, 5) Groundwater vulnerability, 6) Distance to water, 7) Street conditions and 8) Distance to treatment plants.

Some indicator were directly derived from VHR satellite imagery, e.g. NDVI for Urban greenness and NDWI for the identification of water bodies; others such as Groundwater vulnerability and locations of treatment plants are based on local data. For Building use and Street conditions OpenStreetMap data and local expert knowledge, such as conditions required for different emptying methods (street width, underground, action radius of emptier) were integrated. Building density and Building size are based on building footprints, extracted through integration of an automatic OBIA approach, manual delineation and existing datasets.

With the overall aim of supporting decision-making, the aggregation into a composite index allows an easy interpretation of results. Required steps such as harmonization, descriptive statistics, expert-based weighting and aggregation of single indicators were implemented. As administrative boundaries often do not represent real-world conditions, spatial regionalization based on the same indicator set resulted in homogenous city zones, in this case priority areas for FSM.

Results

As an example for supporting urban sanitation management, priority areas for FSM in Lusaka, Zambia were demarcated through the integration of EO-based indicators. Wide parts of Lusaka use onsite sanitation with irregular emptying schedules, potentially causing health-related problems.

The eight identified indicators covering the whole city extend show distinctive geographical pattern and provide useful information on its own, such as the identification of inaccessible areas for emptying by trucks. They can be used and integrated in political decision-making processes by local experts for improving urban sanitation in Lusaka, e.g. for the coordination of emptying practices, the planning of sewer systems or the installation of new treatment plants.

Priority areas delineated through regionalization on basis of the same indicators and subsequent aggregation to a composite index reveal hotspots of need for interventions. In the case of Lusaka, such high-priority areas can be found in the low-income residential area Kanyama in the west, residential areas southeast of the city centre and the commercial strip along Kafue Road to the southwest. These hotspots are characterized by high building density, assuming high population density; small building sizes in combination with a low portion of vegetation, serving as proxies for low income; poor street conditions, preventing the use of trucks for emptying onsite sanitation systems and highly vulnerable groundwater conditions.

Outlook for the future

This study shows that the integration of EO-based indicators can support urban sanitation, providing an up-to-date overview, potentially allowing regular monitoring and the evaluation of impact of measures. A big advantage lies in the delineation of homogenous city areas independent of district boundaries that often do not reveal patterns of population distribution or infrastructure availability. While the composite index is easy to interpret, additional information about influence of single indicators could facilitate the targeted implementation of interventions. The approach can easily be transferred to other cities with site-specific adjustments, such as the integration of elevation models, minor in Lusaka, but important for other cities e.g. for the assessemnt of natural hazard risk areas. The described methods can also support related challenges in FSM such as a citywide estimation of faecal sludge characteristics and can be used for other infrastructure planning.

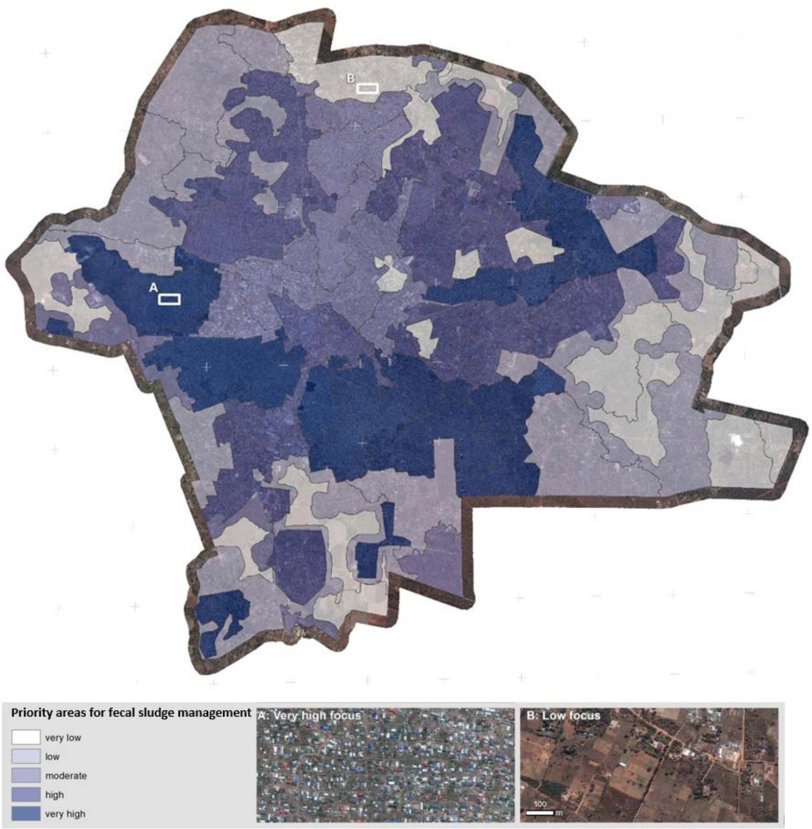

Figure Potential priority areas for faecal sludge management in Lusaka, Zambia

e-shape: Fostering and bridging the European Earth Observation ecosystem

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Abstract
Corresponding Author:
francesca.piatto@earsc.org

Francesca Piatto[1]

[1] European Association of Remote Sensing Companies (EARSC), Brussels, Belgium

Keywords: Earth Observation, Horizon2020, EuroGEO, e-shape, Copernicus

The challenge

This abstract focuses on the development and coordinated approach to support research communities bringing their innovative ideas to serve policy makers and boost innovation in the field of Sustainable Development Goals and environmental policies. EuroGEO [1] is the European Commission's programme aimed at supporting this vision through e-shape[2], the main implementing project that showcases the strength and contributions of European EO capabilities with and for the users. e-shape raises visibility and understand of the EO markets across a wide range of applications represented by the 27 pilots grouped into 7 showcases (food security and agriculture, health, renewable energy, ecosystem, water resources, disasters, and climate). The abstract will present and analyse one of the pilots, the nextSENSE service and its development process of scaling up from research to business service, bringing significant socio-economic and environmental benefits to its respective user communities.

Methodology

nextSENSE service sets up a low carbon environment with existing and new EO techniques dealing with accurate, nowcast[3], short-term[4] and long-term[5] forecast estimations of solar energy. e-shape supports its design and development through co-design, a toolbox providing the engagement of specific user communities in the service operational workflows. The co-design of nextSENSE with energy producers in Egypt (Benban solar farm) and Greece (Public Power Corporation on Renewables) as well as with electricity handling entities in Greece (Independent Power Transmission Operator) was based on the new European Energy Target Model which has as a main scope the energy market liberalization and the creation of a single competitive electricity market. The main characteristic of this model has to do with the continuous intraday energy trading, so the operational exploitation of the space technology and the nextSENSE service is able to provide accurate solar energy short-term forecasts, crucial in the energy market, where on-the-spot energy prices are defined by supply and demand equilibriums. As a result, if the energy suppliers can have such accurate estimations for the distributed solar energy production from solar systems, this information provides them with a comprehensive advantage with clear economic benefits for their intraday and day-to-day market operations. This is the reason why nextSENSE was co-designed directly with decision makers.

Results

Currently the nextSENSE pilot is finalising the first co-design with existing users -independent TSO, Ministry of Energy, and public power corporation - and engaging with new users at international scale. To this direction, NOA in collaboration with the World Radiation Center in Switzerland (PMOD/WRC), developed the nextSENSE webservice, which is able to control in real-time the solar energy production, and balance the distributed energy supply and demand in collaboration with the local and regional electricity handling entities. This system is based on fast radiative transfer models, cloud motion vector for accurate forecasts up to 3 hours ahead, numerical weather prediction models for 1 day ahead forecasts followed by the subsequent uncertainties, and high-performance computing for massive outputs. The result is an estimation of the solar systems energy production which applies to all scale solar plants, from big solar farms to small and medium rooftop PV installations at urban environments.

Outlook for the future

e-shape helps develop the pilots themselves to reach a TRL 8-9 level. In the coming year, these will be available to the EO community.

NextSENSE will engage with related stakeholders and end-users, with a view to uptake the commercialisation and internationalisation of the service in the related service industry (Solea | Solar Energy Applications) also through the novel of sustainability booster (see below figure 1, commercialisation phase)

In a broader vision, an onboarding process has been established to ensure the legacy of the e-shape project, "bringing new needs" and the latest advances in the EO. This process will allow further 5 new pilots in 2021 to access the e-shape consortium and support EuroGEO vision; they will also benefit from the experience gained during the project, including co-design methodologies, deployment support, users' uptake, capacity building & liaison, sustainability & upscaling, communication, dissemination & Help Desk.

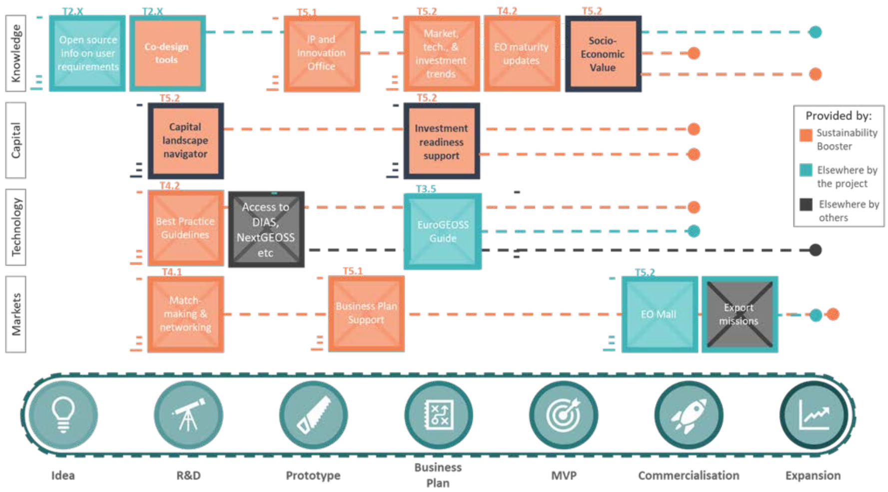

Figure 1: Overview of the support measures provided by e-shape

[1]e-shape: EuroGEO showcases: Applications powered by Europe
[2] EuroGEO is the European component of GEO, a worldwide network working to build a Global Earth Observation System of Systems (GEOSS).
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Remote sensing as support to cartography of the quality of water at the prefecture of Mohammedia (Morocco)

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Abstract
Corresponding Author:
rachidaelmorabet@yahoo.fr

Rachida EL MORABET[1], Larbi BARHAZI[1], Soufiane BOUHAFA[1]

[1] UNIVERSITY HASSAN II OF CASABLANCA, DEPARTMENT OF GEOGRAPHY, MOROCCO.

Keywords : Sustainability, Water Resources, Water quality, Hydro-geomorphological, Spatial distribution

The challenge

Sustainability of adequate quantity and quality of water resources is one of the major global concerns in present time. The increase in water demand arises owing to population increase, demographic growth and constraints of global changes.

The advent of industrial revolution and modern agricultural activities along with urbanization have altered water quality rendering it unfit for primary human consumption or other secondary purposes. The Mohammedia prefecture is currently experiencing a boom in development in terms of intensive artificial irrigation-based agriculture, industrialization along with urbanization especially development of new city "Zenata" within the prefecture. This development brings along increased water demand thereby causing increased depletion of existing water resources in terms of quantity and degrading the water quality. The deterioration of water quality will thereby also impact the associated socio-ecological systems.

Methodology

The study reviews the published studies on the quantitative and qualitative evolution of water with respect to global changes, trough electronic databases, scientific publications, national and institutional reports.

The water resource was analyzed on the basis of quality and quantity. The quantification was done using piezometry. The quality was analyzed in terms of physio-chemical, biological and hydro-geomorphological parameters.

Analysis of the results was supported by high-resolution mapping of the land cover using Pleiades image classifications

This analysis was carried out at different dates in order to overcome the lack of recent data on the extension of precarious habitat areas at the prefecture level.

Results

The key findings can be summarized as follows: the quality of groundwater in the Prefecture of Mohammedia is deteriorating due to high mineralization and high nitrate content generated by agricultural activity; and the infiltration of the leachate produced by the two landfills (the disinfected landfill and the current controlled landfill) in the Prefecture into the water table is further compromising the quality of this water resource.

Outlook for the future

The scope of study was greatly restricted primarily due to non-uniform parameters being employed for water quality analysis. Hence, this study recommends a quality analysis of all water resources in the Prefecture of Mohammedia for based on similar parameters. This will ensure true presentation of water quality, thus helping policy and decision makers and governing agencies in adopting and implementing future local planning and development frameworks, with the ultimate outcome to ensure a sustainable management of water resources capable of meeting current and future demands.

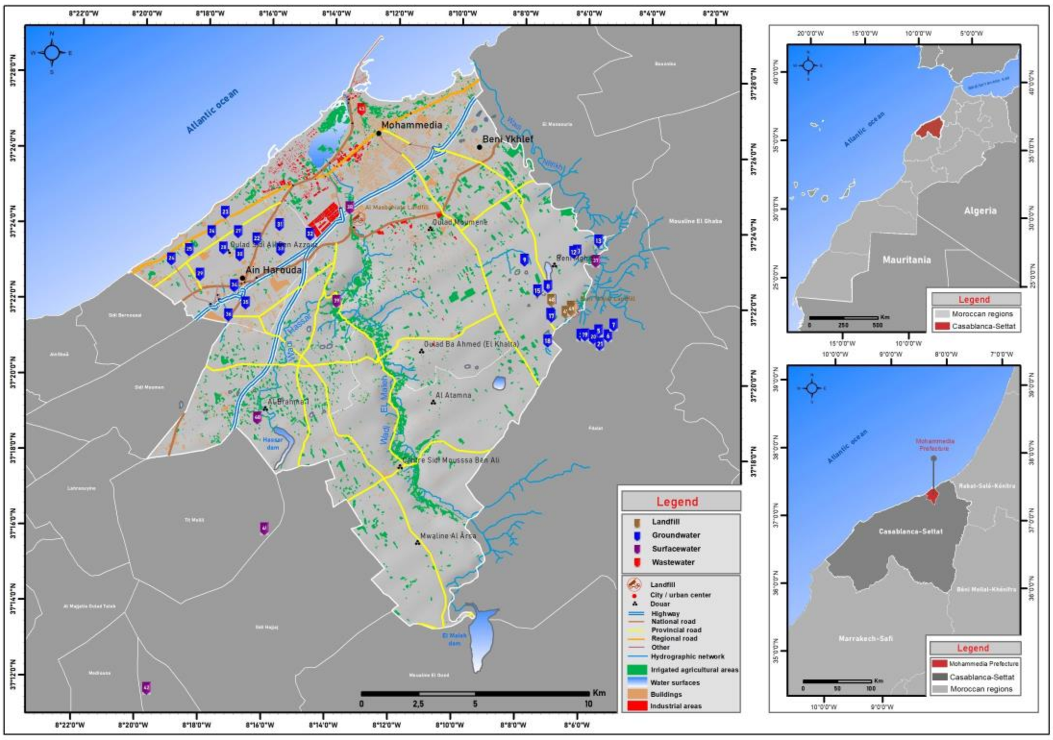

Figure: Samples location considered
Source: Developed by the authors

Vegetation Dynamics in African Drylands: A Remote Sensing Based Assessment Using the Vegetation Degradation Index in an Agro-Pastoral Region of Botswana

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Abstract
Corresponding Author:
felicia.akinyemi@gmail.com

Felicia Olufunmilayo Akinyemi[1], Margaret O. Kgomo[2]

[1]University of Bern, Institute of Geography, Switzerland
[2]Department of Wildlife and National Parks, Serowe, Botswana

Keywords: Land degradation, Vegetation Degradation Index (VDI), Normalized Difference Vegetation Index (NDVI), Shannon Diversity Index, Remote sensing

The challenge

Knowledge about how changes in vegetation conditions relate to its degradation is often lacking, although needed to sustainably manage rangeland resources in drylands. With African drylands (43% of Africa's land area) projected to increase (5 - 8%) by 2080 (FAO 2017), developing rangeland management options is imperative. Vegetation monitoring for rangeland management is necessary as vegetation plays an important regulatory role. Changes in vegetation conditions and degradation are induced both by climatic and human factors. Although vegetation degradation is a major process of environmental change, its dynamics, drivers, and impacts in Botswana are not well understood except in the cattle-based systems. Currently, vegetation degradation research in Botswana is limited. This study contributes to developing land management options by assessing vegetation dynamics and degradation in Palapye, an agro-pastoral region of high economic and biodiversity importance in eastern Botswana.

Methodology

This study combined the use of the Remote Sensing (RS) based Vegetation Degradation Index (VDI) with field-based plant species data for validating vegetation degradation levels in a dryland context. Validation of RS based land degradation assessments with ground data is grossly missing in many studies.

The VDI was applied to 18-year (1986–2016) time series of annual Normalized Difference Vegetation Index (ANDVI) images to establish vegetation degradation levels, i.e. relatively undegraded, low degradation, medium degradation, and high degradation. As a regression-based method, the VDI requires establishing the linear relationship between the ANDVI and time. Afterwards, the estimated slope of the trend line is fitted to each pixel using the ordinary least square method. The VDI was evaluated by separating change in ANDVI from no change at the 0.05 significance level using the F-test. Therefore, if VDI is < 0, i.e. negative, there is a decreasing trend of ANDVI. These negative values were multiplied by -100 to derive positive values, which were then categorised into the four land degradation classes. Otherwise, ANDVI is not changed or an increasing trend (regeneration) if VDI is > 0.

Working at nine sites, the aim is to explain variations in the four vegetation degradation levels. Species occurrence, richness, density, and diversity were computed for each site. Our study examined how species metrics, rainfall, slope aspects related to varying vegetation degradation levels.

Results

Vegetation Degradation

44.3% of the study area was classified as relatively undegraded, 51.3% as low degradation, 4.35% as medium degradation, and 0.05% as highly degraded. Approximately 11% of the study area had statistically significant negative trends in ANDVI. Areas classified as medium to highly degraded, such as in the north-west and south of Palapye, are mostly erosion sites with exposed rock outcrops and/or burrow pits. Areas of negative trends signifying decreasing ANDVI, areas of significant trends, and the VDI categories under which they fall are depicted in Fig. 1a, b, c.

Species composition and density

A total of 3444 individual tree and shrub species occurred in the entire study area (nine sites). The presence of the most occurring species at multiple sites is depicted in Fig. 2. Species richness, diversity, rainfall explained 49% of the variance in degradation levels. Species diversity and richness were negatively associated with VDI, highest in Moeng (a relatively undegraded site), whereas they were lowest in Lesenopole (a low degradation site). A probable reason for low diversity at Lesenopole is that Colophospermum mopane contributed 87% of trees. The non-occurrence of some species such as Sclerocarya birrea and Lonchocarpus capassa on highly degraded sites suggests a link between species composition and the level of degradation. The relationship of slope aspect with VDI is positive and significant suggesting it has an influence on vegetation degradation.

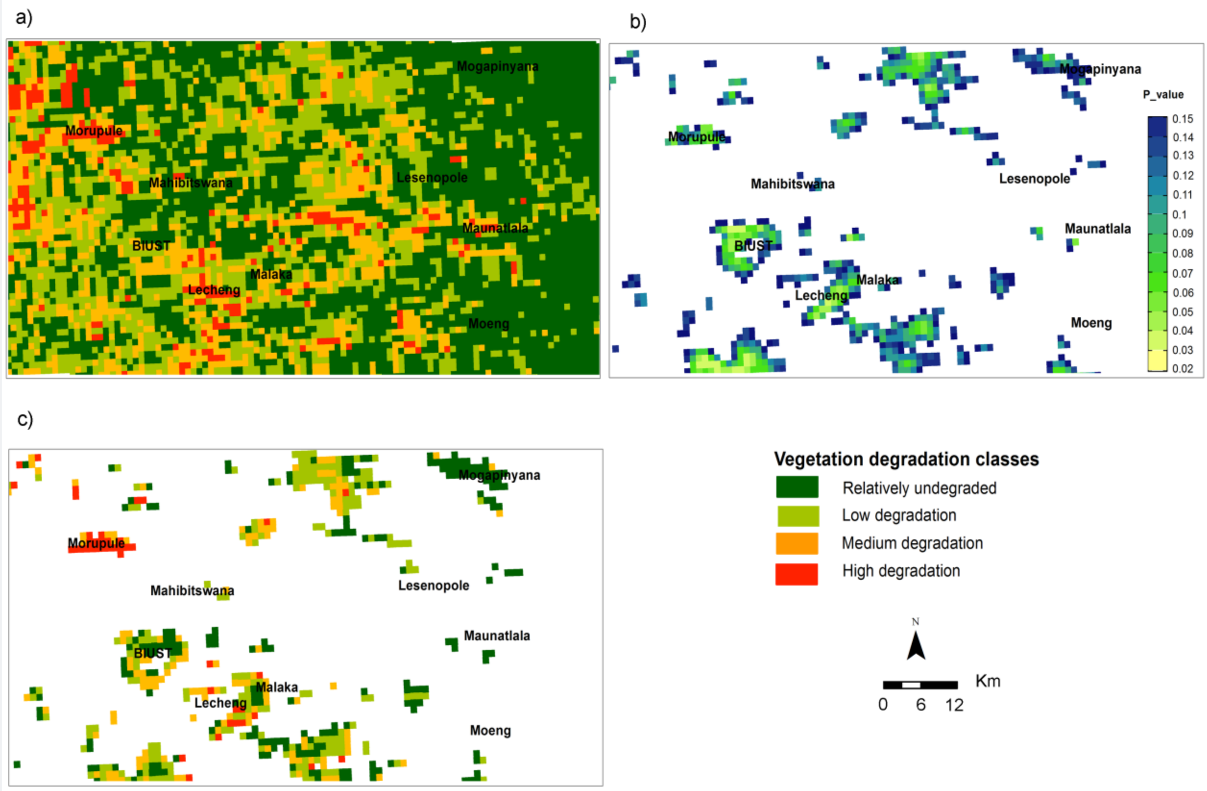

Figure 1 Vegetation degradation. (a) Vegetation Degradation Index (VDI) map, (b) significant negative trends in ANDVI by p value, and (c) by VDI

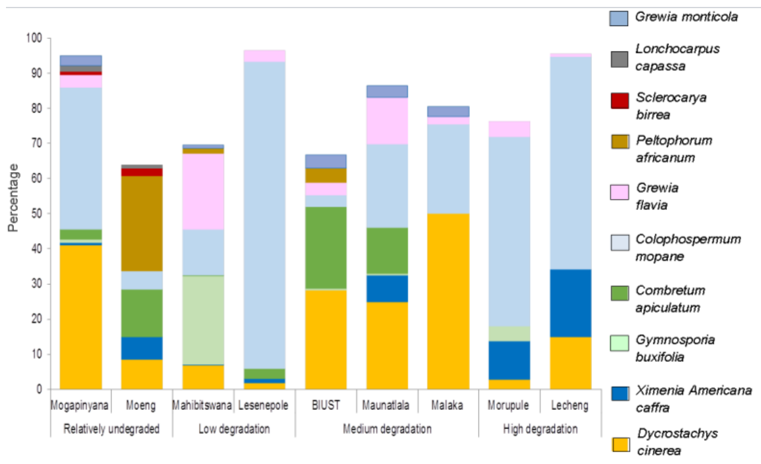

Figure 2 Presence of the densest plant species on multiple sites

Outlook for the future

The suggested link between species composition and vegetation degradation levels should be further explored in order to decipher how vegetation degradation influences species composition, diversity, etc. within the context of the local land management practices. A better understanding of such influences could be of importance in developing suitable land management options in this and similar dryland regions.

Although the level of vegetation degradation was found to be relatively low in this region, it is essential to curtail the negativity of human activities on the environment as these have the potential to exacerbate negative climatic impacts, particularly from drought. Incorporating remote sensing and geostatistical modelling with plant species metrics enabled vegetation degradation assessment in an African dryland context. This study's findings provide future research with input for identifying probable factors driving vegetation degradation in drylands in and beyond Africa.

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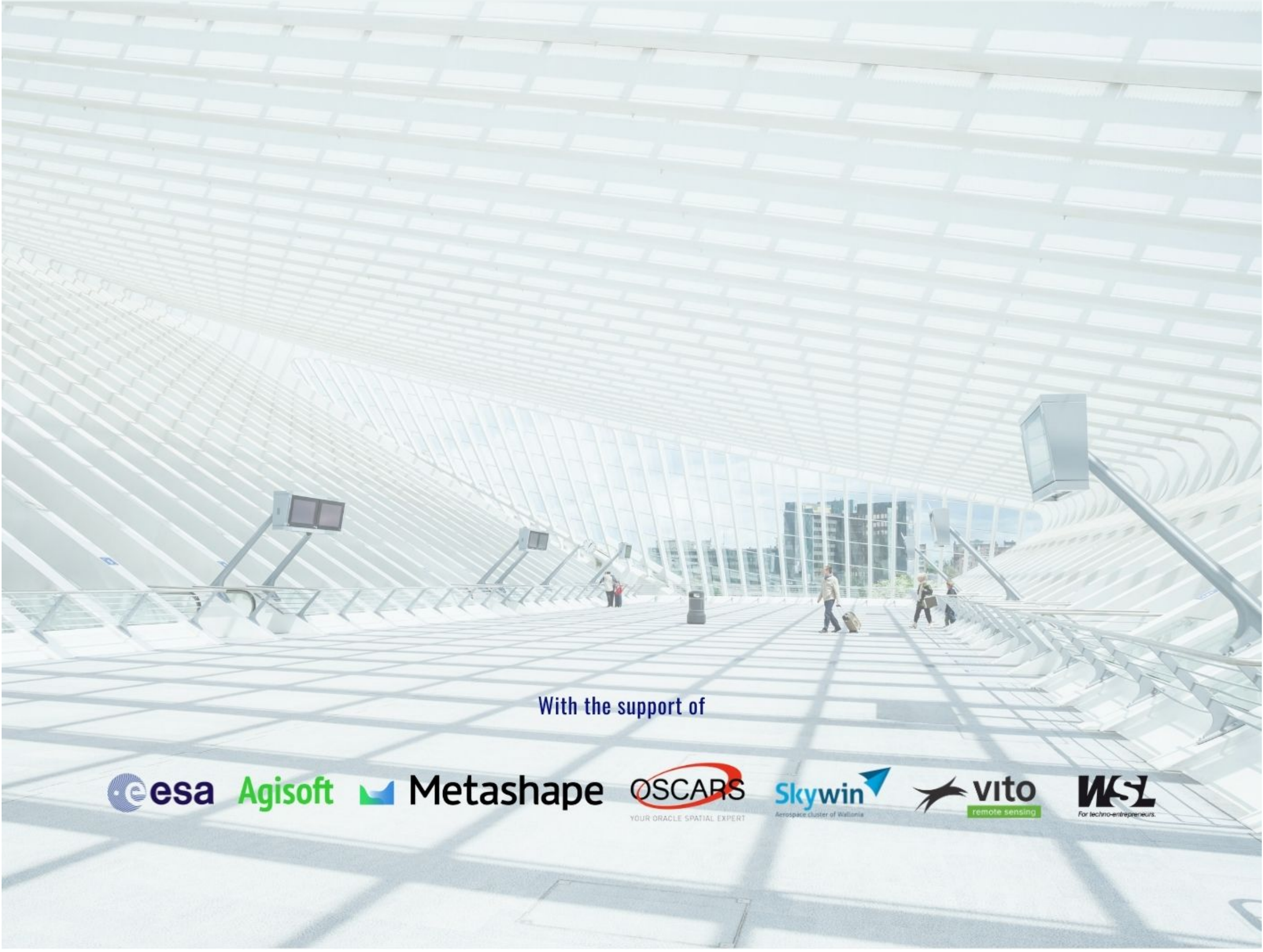

With the support of