FIG WORKING WEEK 2023
28 May - 1 June 2023 Orlando Florida USA
Protecting Our World, Conquering New Frontiers

Artificial Intelligence Techniques for Extracting Impervious Surface Areas from Satellite Imagery

Darion David Mahadeo
Department of Geomatics Engineering and Land Management
The University of the West Indies St Augustine, Trinidad and Tobago

(TRINIDAD AND TOBAGO)

Organized By NSPS FIG INTERNATIONAL FEDERATION OF SURVEYORS
Diamond Sponsors esri THE SCIENCE OF WHERE Trimble

Outline of Presentation

- **Background** and **Motivation**
- Research **Problem**
- Basis for **solution**
- General **Methodological** Workflow (derived)
- **Results**
- What our paper will **discuss**...
- What our paper will **conclude**...
- Justification and **Significance** of Research

Urbanization and Impervious Surfaces

- Urbanization is a phenomenon that is globally growing at an accelerating rate
- Result in construction and development of Impervious Surfaces (IS)
- IS are artificial hard areas that does not allow water to seep into the ground and are recognized as **“built-up”**, **“developed”** or **“urban areas”**

Buildings

Parking Lots

Roads

Sidewalks and Pavements

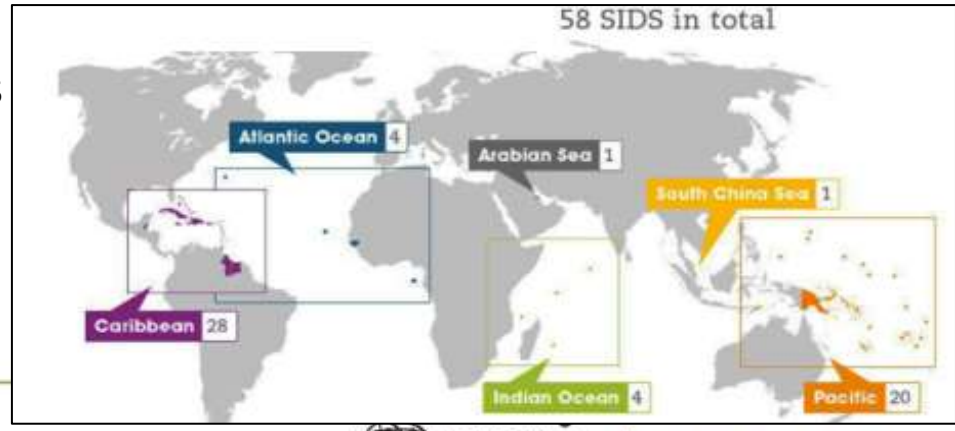
- IS are key quantifiable indicators of urbanization.
- IS information is important to assist in quantifying urbanization and have proper urban planning and environmental management.

Direct Results of Urbanization

- Construction and development usually includes removal of the Earth's natural land covers which disturbs local ecological systems

Small Island Developing States (SIDS)

- Small size and Remoteness
- Exposure to Global Environmental Changes
- “Hotspots” of Climate Change
- Emits the least carbon into the atmosphere
- Environmental and Socio-economic vulnerabilities for development challenges
- Currently less resilient and less prosperous than larger developed countries
- Limited Resources
- Struggling to meet Sustainable Development Goals
- Requires assistance from businesses, academia, and society.



Caribbean SIDS

- Natural Disasters (Tropical Location)
- Low Elevations
- Difference in size, geology terrain, landscape, vegetation types
- “the highest debt percentage (76% of their GDP in 2014)”






- Poor Building and Infrastructural Development

- Unplanned Development in Urban Settlements

- Geospatial Data and Resource Challenges

Research Problem: How can we get Impervious Surface Area Information, needed to address the urbanization issues?

- We need imagery **data**….
- We need to **extract** the impervious surface features from the **data** – providing us information…..

Basis for Solution:

- ❑ Open-source satellite imagery: **Landsat 8** and **Sentinel-2**
- ❑ Artificial Intelligence for feature Extraction – **Machine Learning** and **Deep Learning**

General Methodological Workflow

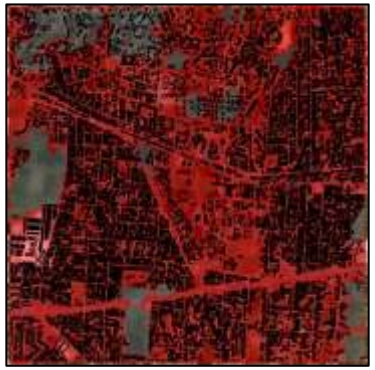
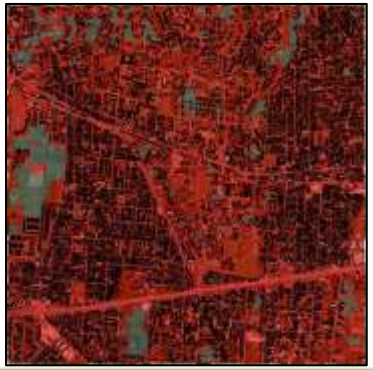
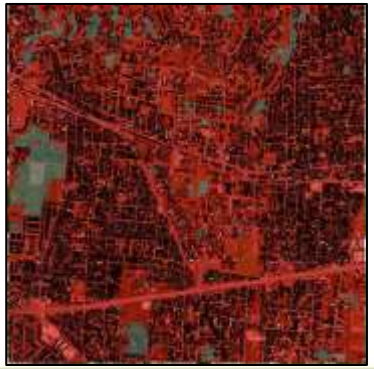
Perform case studies in Trinidad (proof of concept) – Areas of different urban characteristics

1. Data Collection
2. Model Creation, Design and Training
3. Data Processing
4. Results
5. Accuracy Assessment, Testing and Comparison
6. Analysis, Findings and Main Contribution

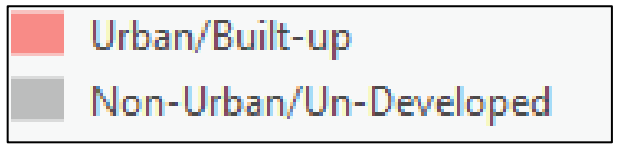
(Ollivierre 2016)

Tested afterwards in some Caribbean SIDS – in islands of varying geologies and geographies, e.g., Volcanic Islands, Coral Islands, and Limestone Islands.

Results: Visuals

	MLC	*RF*	*SVM*	*U-NET*	
Landsat 8					
Sentinel-2					

ESRI's High resolution World Imagery



Classification Results: Statistics

Actual Labels	Predicted Labels	
	Impervious	Permeable
Impervious	TP	FN
Permeable	FP	TN

Confusion Matrix

Landsat 8					Sentinel 2				
Method	**TP**	**TN**	**FP**	**FN**	**Method**	**TP**	**TN**	**FP**	**FN**
MLC	7481	715	190	1155	**MLC**	76802	5311	1470	2799
RF	8075	584	325	557	**RF**	77625	5071	1600	2086
SVM	8118	576	333	514	**SVM**	78420	5305	1470	1187
UNET	8047	588	318	588	**UNET**	64271	7250	395	14466

Accuracy Measures and Assessment

Accuracy Assessment:

Precision = TP/TP+FP

Recall = TP/TP+FN

Accuracy = TP+TN/TP+FN+TN+FP

F-score = 2 x recall x precision/recall + precision

Mean intersection over union (MIOU) = TP/FP+FN+TP

AI Method	Satellite	Technique	Accuracy	MIOU	F-Score	Recall	Precision
Machine Learning	Landsat 8	*MLC*	0.8590	0.8476	0.9175	0.8663	0.9752
		RF	0.9076	0.9015	0.9482	0.9355	0.9613
		SVM	0.9112	0.9055	0.9504	0.9405	0.9606
	Sentinel-2	*MLC*	0.9506	0.9473	0.9730	0.9648	0.9812
		RF	0.9573	0.9547	0.9768	0.9738	0.9798
		SVM	0.9692	0.9672	0.9833	0.9851	0.9816
Deep Learning	Landsat 8	*U-Net*	0.9050	0.8988	0.9467	0.9319	**0.9620**
	Sentinel-2	*U-Net*	0.8280	0.8122	0.8964	0.8163	**0.9939**

Discussed Points in our paper

- What **data** was needed?
- How data was **acquired**?
- Why and what AI image **classification techniques** were chosen?
- Steps of **Data Processing**?
- **Suitable accuracy measures** adopted?
- How was accuracy **measured**?
- **Performance** of AI techniques
- **Importance** of Research and relevance of addressing **urbanization issues**.

Concluded points in our paper

- ✓**References** to **key** journal articles and papers used
- ✓Suggestion on **software consideration**
- ✓Revealing the technique with the **best performance**
- ✓Comments on AI (**machine** learning and **deep** learning)
- ✓Suggestion on **enhancing** results for **unique** environments
- ✓ **Recommendations**

Justification/Significance of the Research

Affordable Solution (wider user population)

Land Use & Environmental **Planning**

Disaster Management

The United Nations SDGs **11, 13,** and **15**

Generate **Fundamental** Geospatial Datasets

Body of Knowledge in Surveying, Land Information and Geoinformatics

The End – Check out our paper!!!

Artificial Intelligence Techniques for Extracting Impervious Surface Areas from Satellite Imagery (Paper ID: #12090)

Darion D. Mahadeo and Raid Al-Tahir

Department of Geomatics Engineering and Land Management
The University of the West Indies St Augustine, Trinidad and Tobago