







ÉCOLE NATIONALE DES SCIENCES GÉOGRAPHIQUES



## TOWARDS AN IMPROVED MONITORING AND CONTROLLING OF KIGALI CITY MASTER PLAN (KCMP) IMPLEMENTATION USING HIGH SPATIAL RESOLUTION OPTICAL SATELLITES IMAGES AND DEEP LEARNING

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## OUTLINE

- 1. Context
- 2. Problem statement
- 3. Research objective
- 4. Methodology
- 5. Results
- 6. Conclusion and recommandations



# **1. CONTEXT**





Avenue de l'Assemble Nationale



Road Cleaning in Kigali



- ✤ Kigali: Capital city of Rwanda
- Population: 1,135 million in 2012
- Cleanest and greenest city in Africa

## The Kigali City Master Plan (KCMP)

KCMP was established in 2013 to streamline urban development, land use planning and management



Land Use Zoning (KCMP, 2013)



## **Process for issuance of Construction Permit**



## **2. PROBLEM STATEMENT**



**Source:** Assessment and evaluation of the national land use and development master plan implementation (2011-2016)

Increase of illegal houses due to the lack of an efficient and effective monitoring and controlling of KCMP implementation.

### **Consequences of Illegal constructions**



Informal settlements in Kimisagara (CoK)



Flooding in Nyabugogo (CoK) during rain season

### **3. RESEARCH OBJECTIVE**

Improving the monitoring and controlling of KCMP implementation using high spatial resolution optical satellites images and Deep Learning





Map of Kigali City

### Bumbogo Sector Land Use KCMP Zoning

### **4. METHODOLOGY**



WorldView optical satellites images provided by Digital Globe with 45cm of spatial resolution were used

# **Deep Learning (DL)**

DL which is a subfield of artificial intelligence based on convolutional neural networks with many hidden layers was used to detect house

roofs.

### Following are the four steps followed when detecting house roofs using DL:



# **Deep Learning (Cont'd)**

### How does Deep Learning work?



**DL layers:** 

- Input layer: Image
- Hidden layers: Extracts abstract elements of image
- Output layer: Display results

### **Hidden Layers:**

- 1<sup>st</sup> hidden layer identifies edges.
- 2<sup>nd</sup> hidden layer searches corners and extends contours.
- **3**<sup>rd</sup> **hidden layer** detects whole parts of specific objects. It finds specific collections of contours and corners.

### Importation of detected roofs

House roofs detected using DL were imported to an empty image for classification



Detected roofs

**Empty image** 

## **ArcGIS Pro Tools**



The tool **<u>Difference</u>** in ArcGIS Pro was used to differenciate two classified images for change detection.

### The tool <u>**Raster to Polygon**</u> in ArcGIS Pro was used to change raster (image) to polygon



### **5. RESULTS**

# House roofs detected using DL (Image of 2012)



# House roofs detected using DL (Image of 2017)



Detected house roofs were imported to an empty image created in Python for image classification



Classified image of 2012

Roof Other

![](_page_15_Picture_5.jpeg)

Classified image of 2017

![](_page_16_Figure_1.jpeg)

### Legend

Removed houses in the last five years

Newly constructed houses or existing houses but modified in the last five years

### **Overlay of detected changes layer with 2012 image**

![](_page_17_Picture_2.jpeg)

#### Legend

Removed houses in the last five years

Newly constructed houses or existing houses but modified in the last five years

### **Geographical location of detected changes**

![](_page_18_Picture_2.jpeg)

#### Legend

Removed houses in the last five years

Newly constructed houses or existing houses but modified in the last five years

UPI: Unique Parcel Identification (Rwanda Land Use Management Authority)

Overlay of detected changes Layer, UPI Layer and KCMP Zoning

![](_page_19_Picture_2.jpeg)

![](_page_19_Figure_3.jpeg)

### Overlay of three layers verifies if KCMP Zoning has been respected

An illustration of an existing house in 2012 that was modified in the last five years

![](_page_20_Picture_2.jpeg)

a: 2012 b: 2017 An illustration of two houses that were constructed in one Plot/Parcel in the last five (5) years

![](_page_20_Picture_5.jpeg)

### Detected changes between 2012 and 2017 vs. KCMP Zoning

Plots	Detcted changes	Categories				Total
		P1	P3	R1A	R1B	
422	Removed houses in the last 5 years	0	0	11	6	17
	Newly constructed houses or existing houses in 2012 but modified in the last five (5) years	13	7	517	233	770

P1 and P3 are KCMP Zoning Protected	I
Areas	

- P1 : Passive recreational district
- P3 : Agriculture
- R1B : Rural residential district
- R1A : Mixed single family residential district

## 6. CONCLUSION AND RECOMMANDATIONS

### Conclusion

The method developed using High Spatial Resolution Optical Satellites Images and Deep Learning has helped to find out that 2.6% (i.e. 20 out of 770 houses) of newly constructed houses in the last 5 years are located in the protected area as per KCMP Zoning (2013).

### Recommendations

- City of Kigali (CoK) to adopt the developed method for an efficient and effective monitoring and controlling of KCMP implementation.
- Further studies or researches to generalize this same work to all other cities of the Rwanda.

## TAKE HOME MESSAGE

- CoK has established a clear and detailled Master Plan.
- KCMP Protected Zoning underwent violations in the last 5 years.
- The developed method is efficient and effective when it comes to monitoring and controlling of KCMP implementation.

THANK YOU

![](_page_24_Picture_1.jpeg)