



Monitoring the Urban Sprawl of Denpasar-Bali Greater Area based on the Synthetic Aperture Radar (SAR) Data

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- ✓ Introduction
- ✓ Study Area
- ✓ Outline of SAR
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- ✓ Results and Discussions
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Introduction



What is Urban Sprawl and why do we need to monitor it?

Why do we need to monitor Urban Sprawl in Denpasar Greater Area Bali?

What is SAR data and why do we use it?

Introduction



What is Urban Sprawl?

Definitions:

Urban sprawl, **the rapid expansion** of the geographic extent of cities and towns, often characterized by low-density residential housing, single-use zoning, and increased reliance on the private automobile for transportation [1].

Urban sprawl is a form of **unplanned urban** and suburban development that takes place over a large area and creates a low-density environment with a high segregation between residential and commercial areas with **harmful impacts** on the people living in these areas [2].

Negative effects of Urban Sprawl:

- The development of urban sprawl increases the need for transport and reduces the land available for agriculture
- Urban sprawl limits social interactions due to a lack of public spaces like parks and playgrounds.
- Commuting from suburbs to city centers in urban sprawl leads to increased traffic congestion and pollution.
- Urban sprawl adversely affects both the social life of residents and the economic well-being of cities.

solutions

Need to understand the urban development to minimize the urban sprawl

Mapping the Urban Footprint is Important

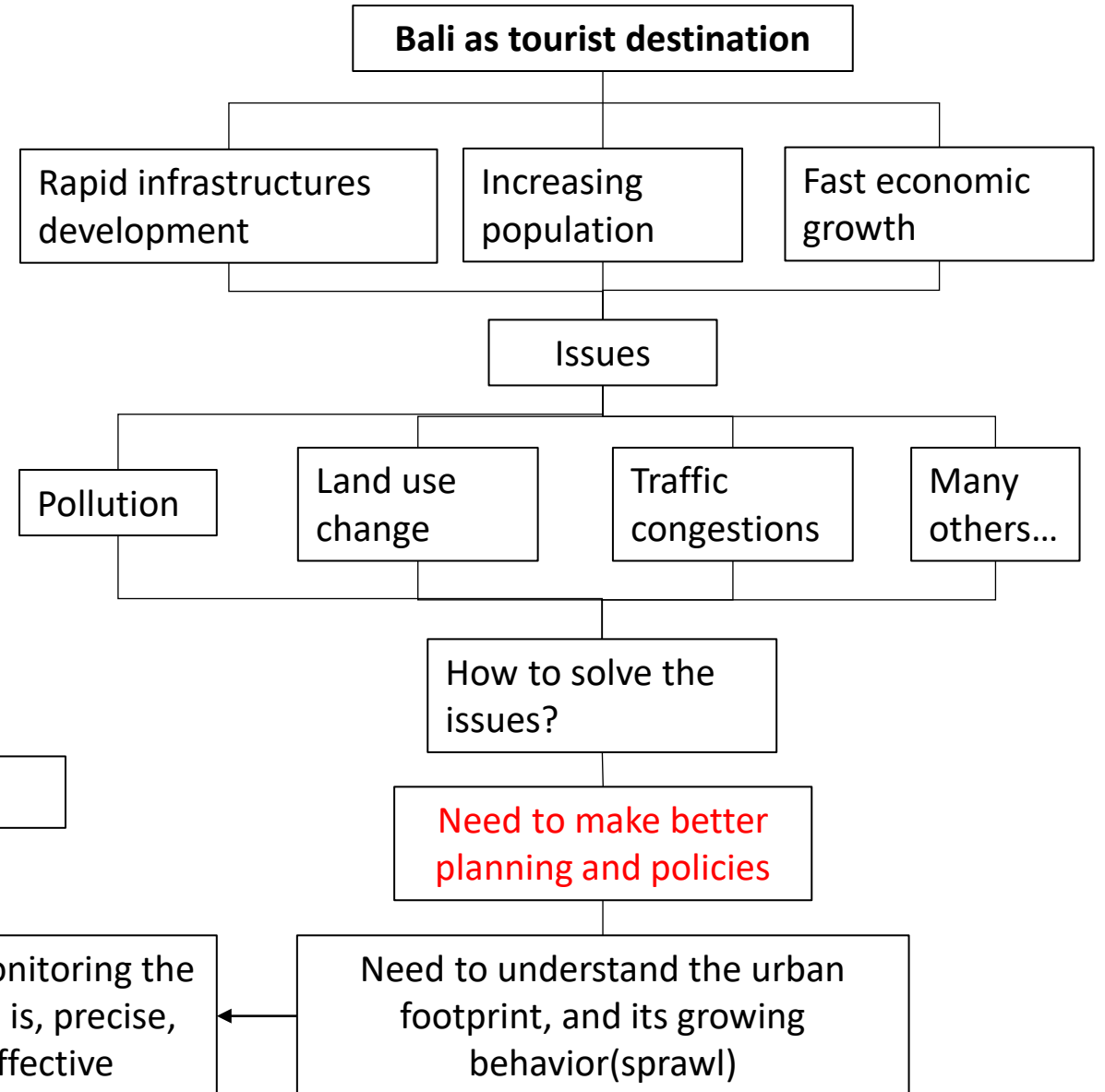
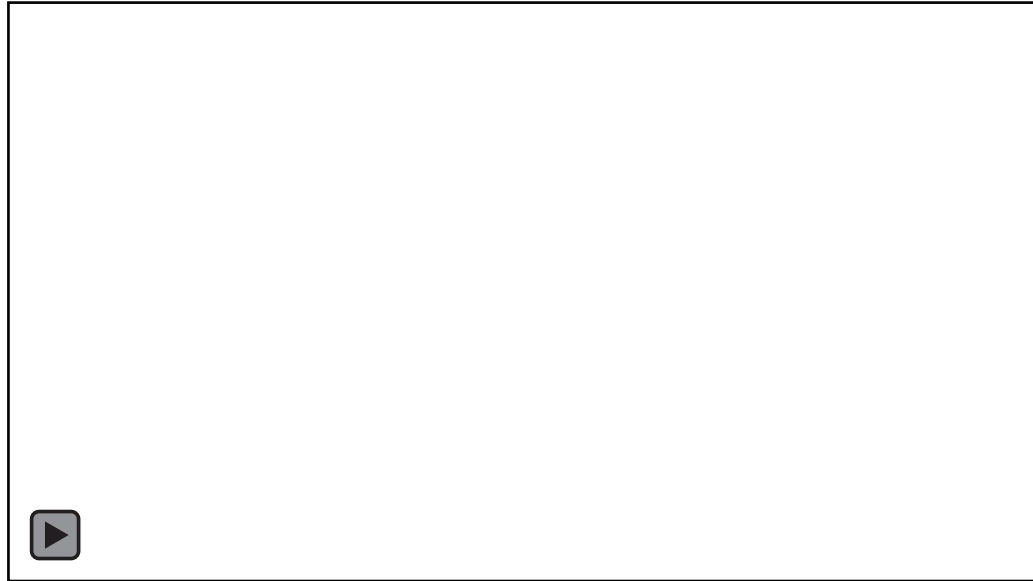
[1] <https://www.britannica.com/topic/urban-sprawl>

[2] <https://campuspress.yale.edu/ledger/urban-sprawl-a-growing-problem/#:~:text=The%20development%20of%20urban%20sprawl,being%20imported%20from%20other%20countries.>

Introduction



Why Denpasar Greater Area, Bali?



Study Area

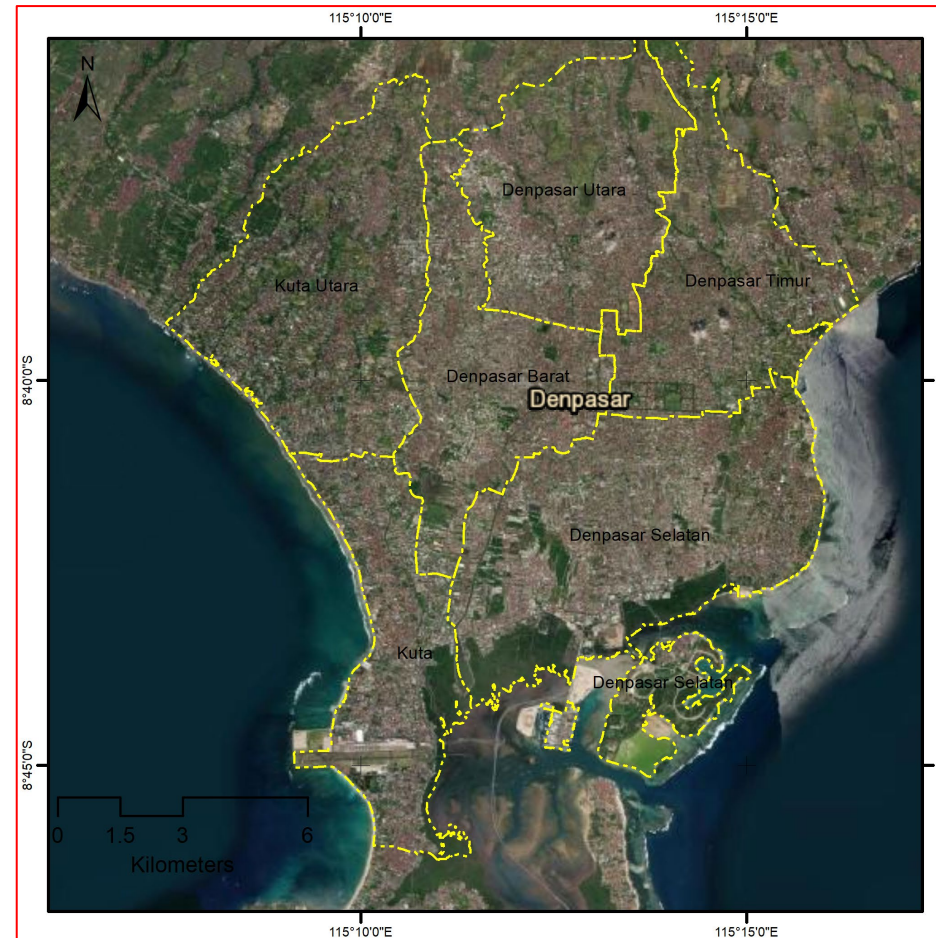


This study will concentrate in southern Bali, including city of Denpasar and parts of Badung. Figures show the location of study area.

6 districts :

- Denpasar Utara
- Denpasar Timur
- Denpasar Selatan
- Denpasar Barat
- Kuta Utara
- Kuta

Size: 180.4 SQKM
Population: 1,149,517
(BPS, 2020)



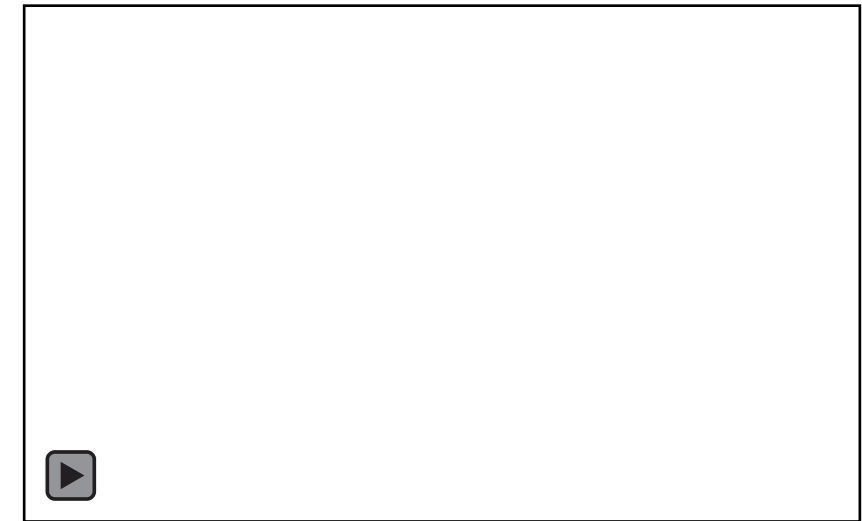
What and Why SAR?

What is SAR?

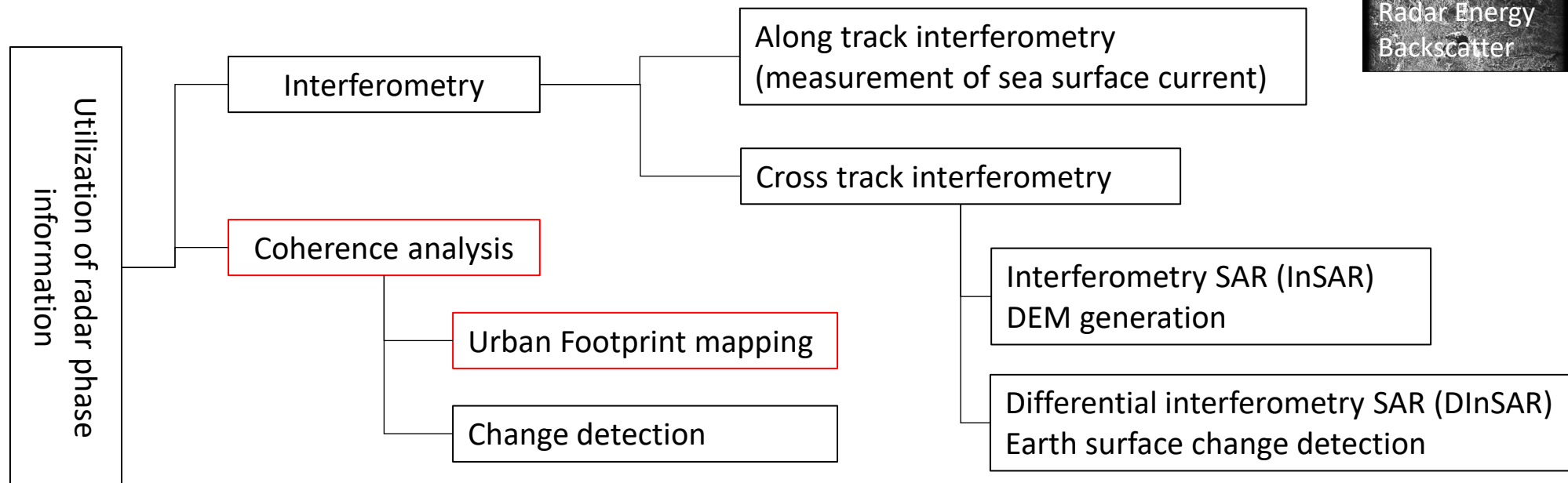
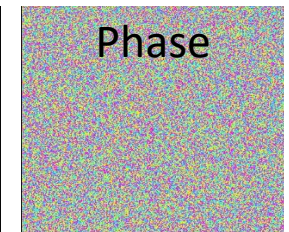
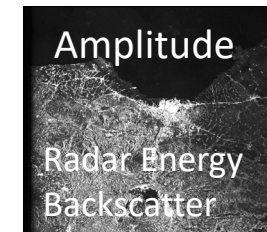
A **Synthetic Aperture Radar (SAR)**, or SAR, is a coherent mostly airborne or space-borne side looking radar system which utilizes the flight path of the platform to simulate an extremely large antenna or aperture electronically, and that generates high-resolution remote sensing imagery.

Why is SAR?

SAR is an active system which operates day and night regardless of weather condition. (EM wave used by SAR able to penetrate the clouds)

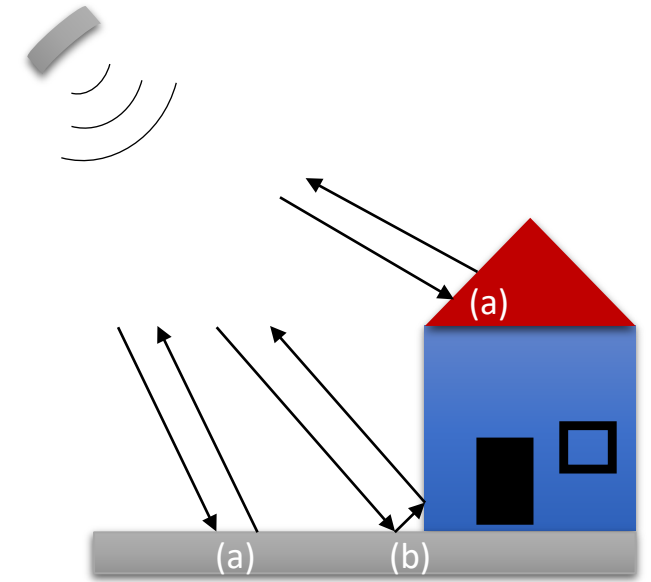


Animation belong to JAXA



Basic characteristics of urban areas in SAR data

- High backscatter: predominance of single- and double-bounce
 - High phase stability of anthropogenic structures between SAR images
 - Orientation of buildings to azimuth angle affects backscatter
 - Strong double-bounce scattering results in certain image texture for urban areas
 - Heterogeneity and texture can be used to map urban footprint
- Automated discrimination between urban / non-urban for large areas based on texture thresholds

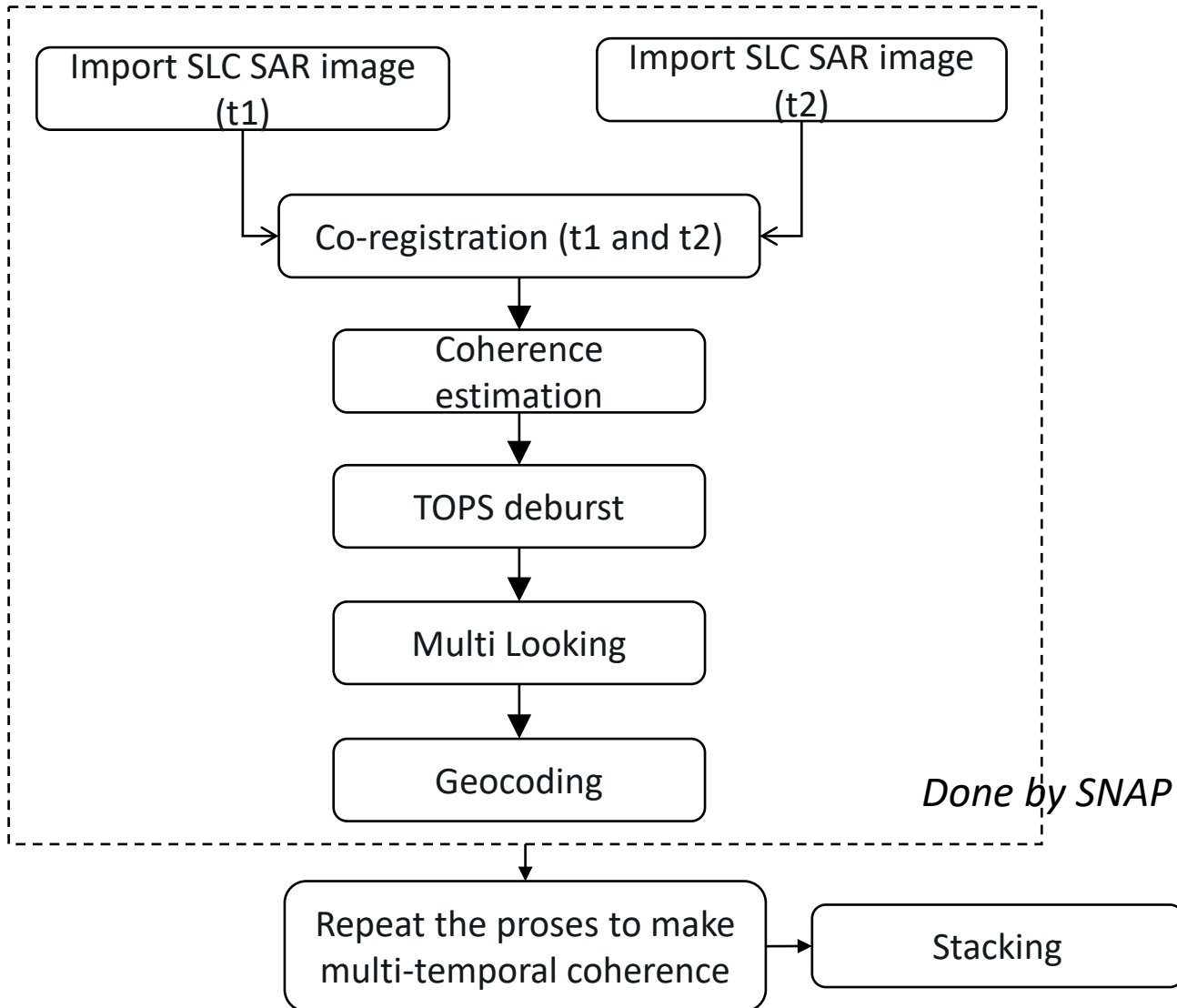


Single- (a) and double-bounce (b) as general scattering mechanisms in urban areas

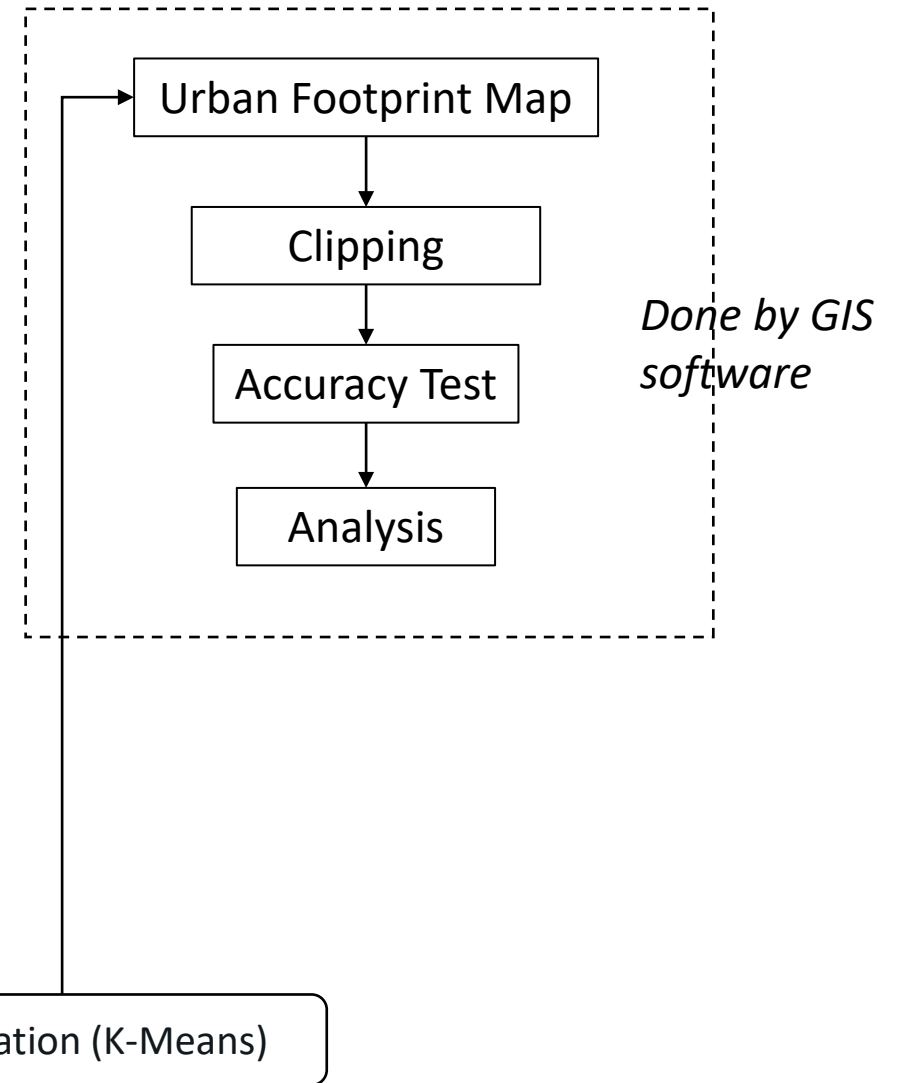
METHOD



Processing



Post-Processing







Data





SAR Data

This study using the Sentinel-1A Data. Sentinel-1A is a European radar imaging satellite that provides imagery in all weather and light conditions. It was launched in 2014 as part of the European Union's Copernicus program. The data freely available and downloaded from: <https://search.asf.alaska.edu/>

List of Sentinel-1 data use to map the urban footprint during 2016 period:

-  S1A_IW_SLC__1SDV_20160716T215255_20160716T215314_012179_012E3B_F1E0.zip
-  S1A_IW_SLC__1SDV_20160809T215257_20160809T215315_012529_0139C3_F108.zip
-  S1A_IW_SLC__1SDV_20160902T215258_20160902T215316_012879_01457C_749A.zip
-  S1A_IW_SLC__1SDV_20160926T215259_20160926T215317_013229_0150DE_183E.zip

List of Sentinel-1 data use to map the urban footprint during 2022 period:

-  S1A_IW_SLC__1SDV_20220311T215318_20220311T215347_042279_050A1A_390C.zip
-  S1A_IW_SLC__1SDV_20220323T215319_20220323T215347_042454_051012_0AED.zip
-  S1A_IW_SLC__1SDV_20220404T215319_20220404T215348_042629_051603_FA38.zip
-  S1A_IW_SLC__1SDV_20220428T215320_20220428T215349_042979_05219D_B02D.zip

4 Descending data for each period, and 6 pairs generated



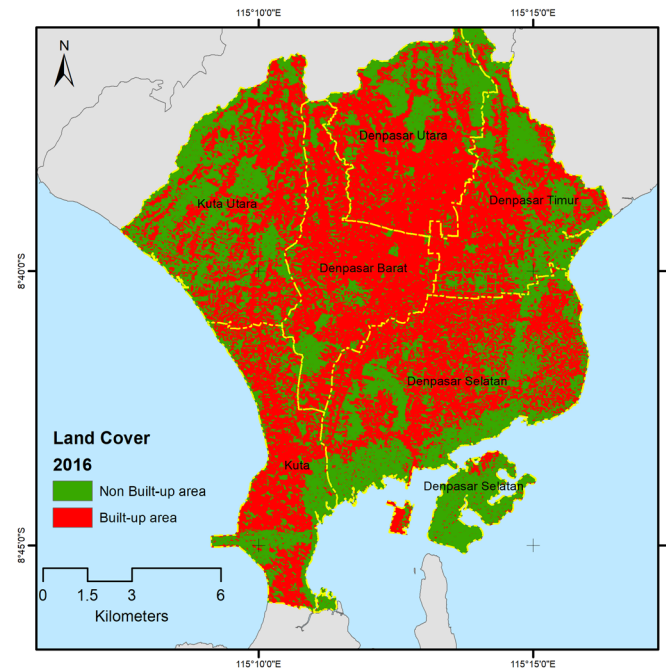
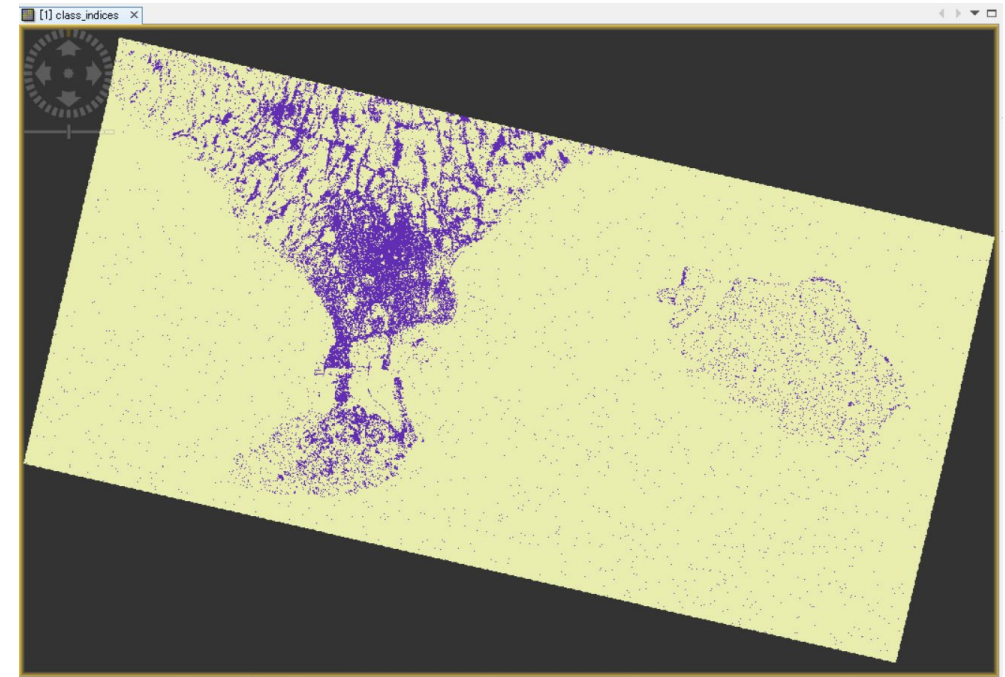
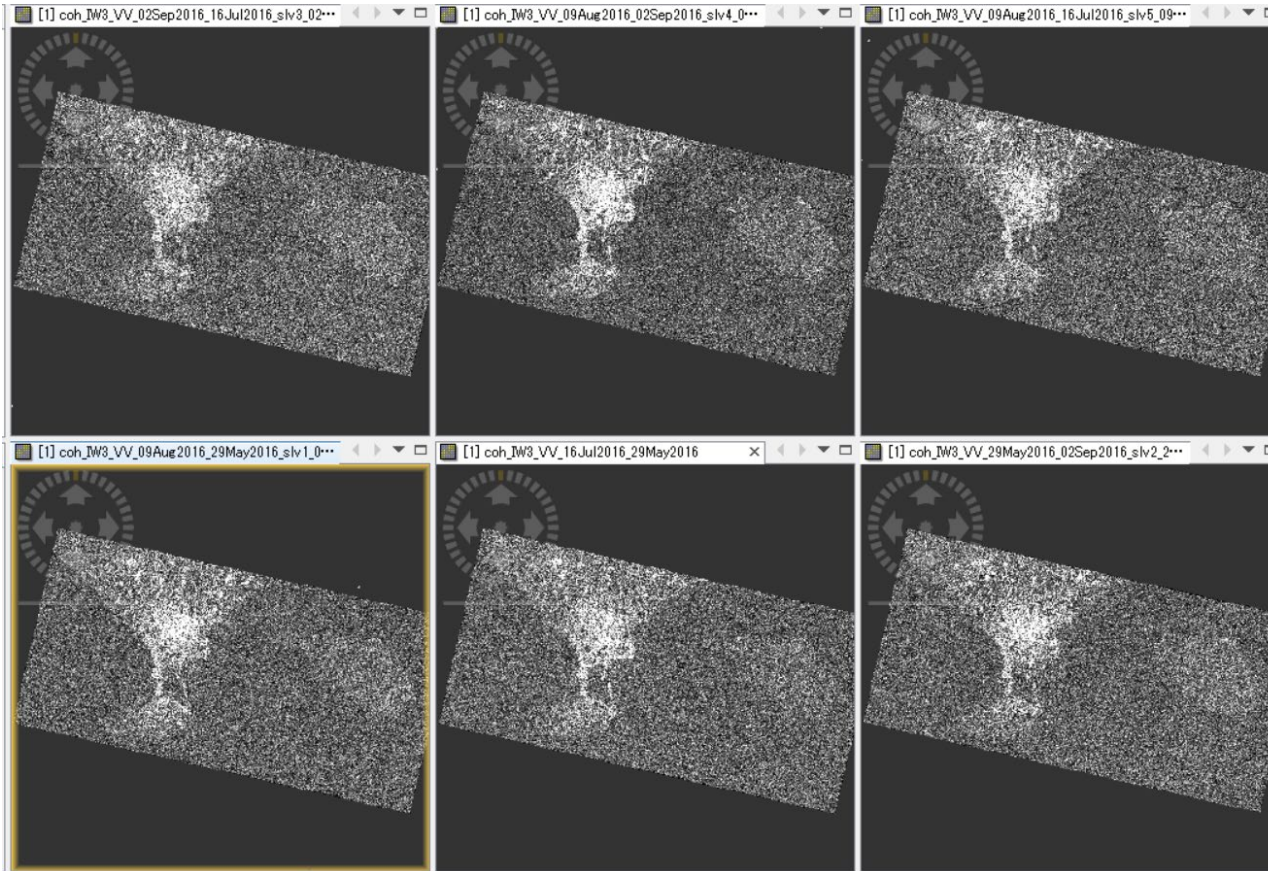
Ground truth Data

579 ground data collected for each periods in order to test the accuracy of classification results. Figure below shows the location of ground truth data.



Results and Discussions

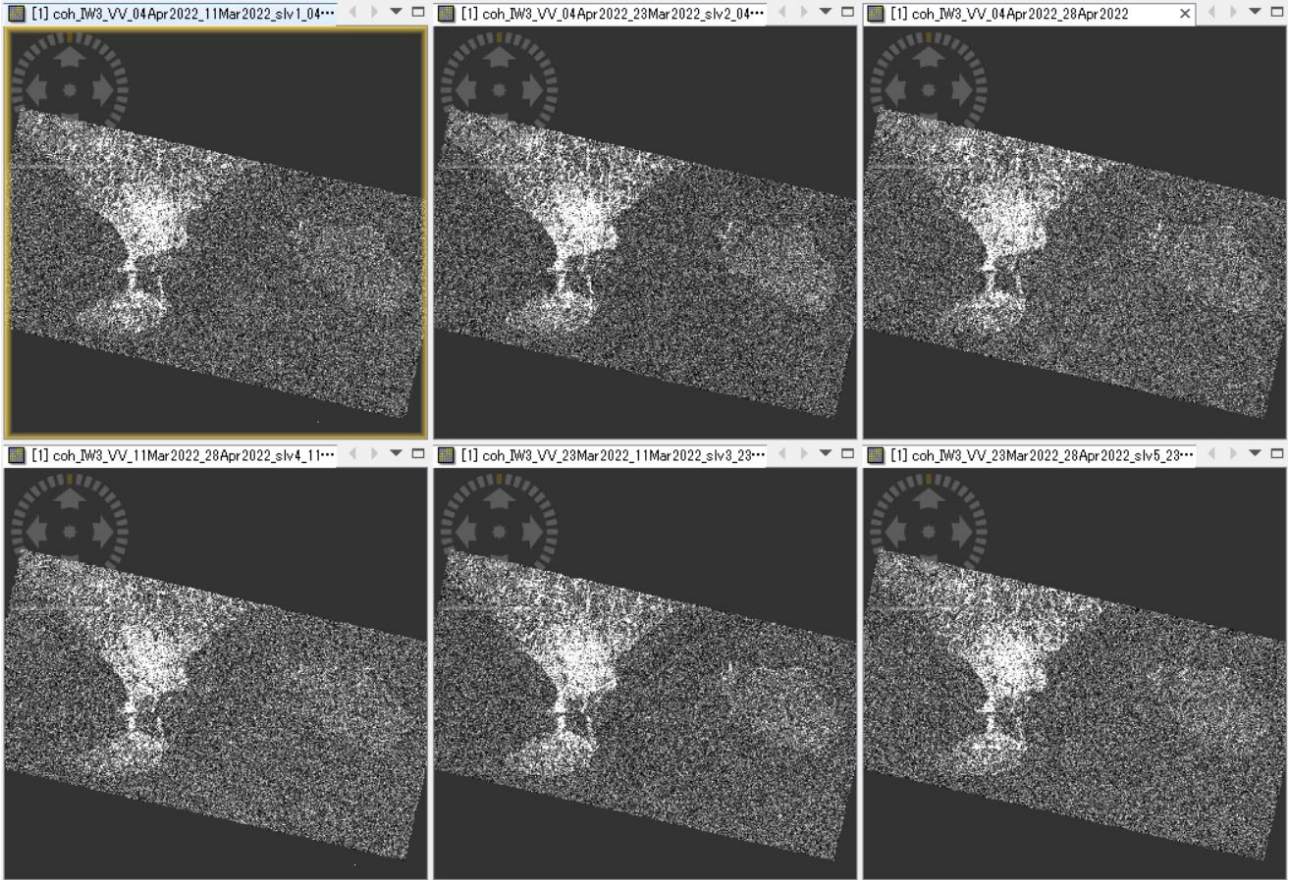
Coherence stacked for 2016 Data



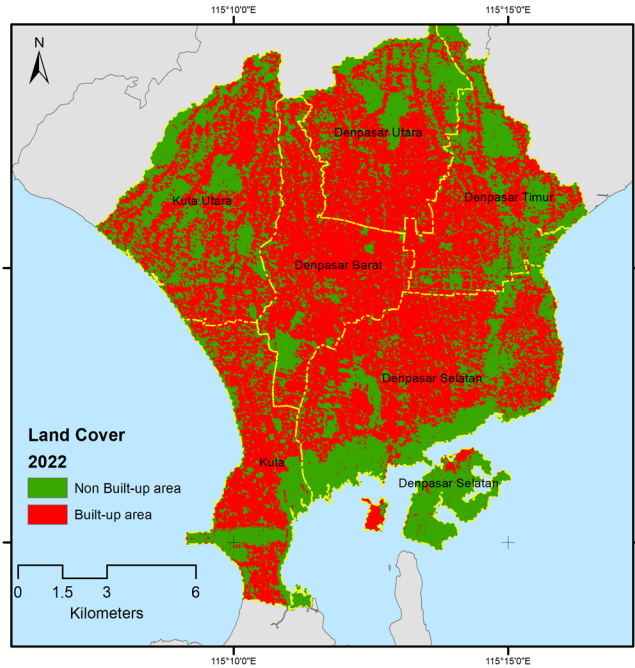
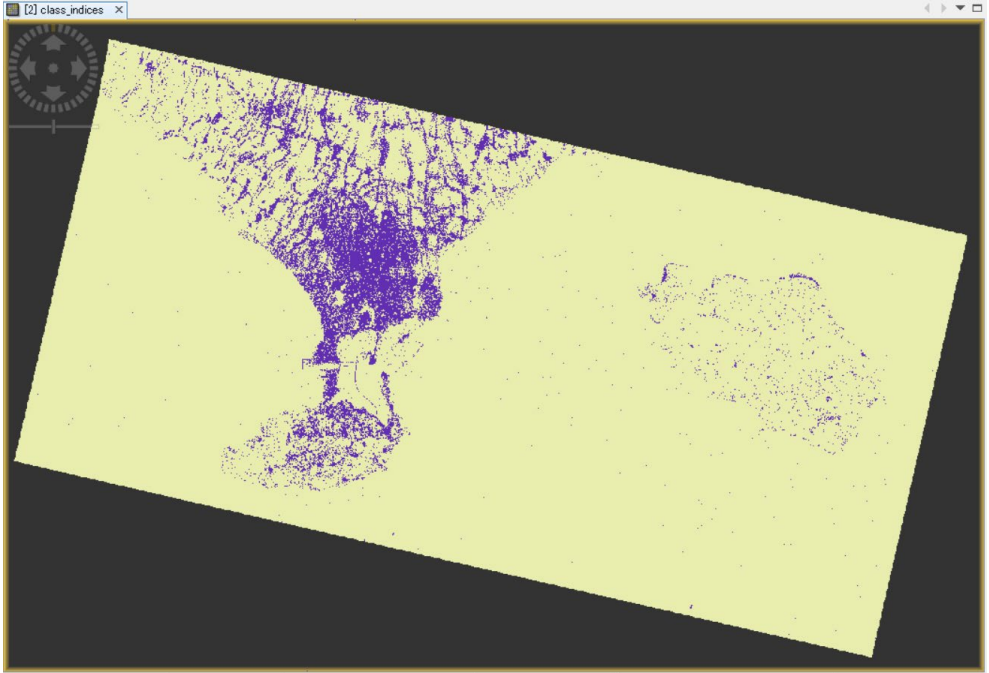
| | Area (Sqkm) |
|--------|-------------|
| Non-BU | 77.399 |
| BU | 103.021 |

| SAR Data | 7/16/2016 | 8/9/2016 | 9/2/2016 |
|-----------|-----------|----------|----------|
| 7/16/2016 | | | |
| 8/9/2016 | 24 | | |
| 9/2/2016 | 48 | 24 | |
| 9/26/2016 | 72 | 48 | 24 |

Coherence stacked for 2022 Data



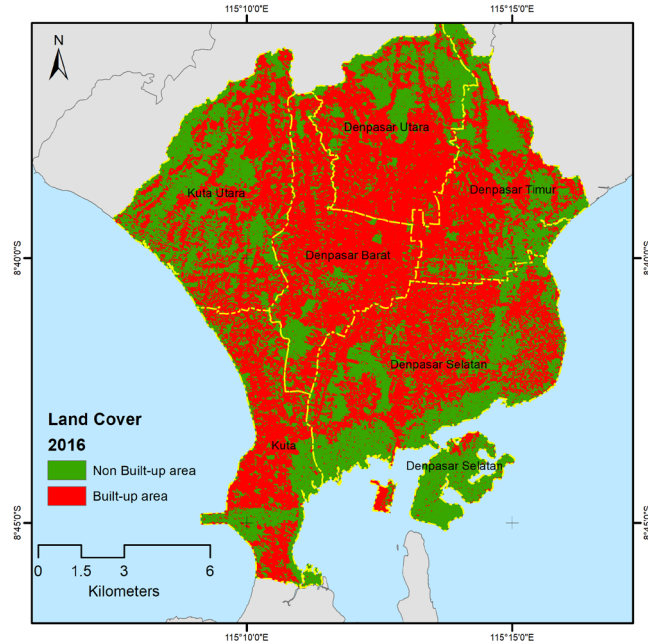
| SAR Data | 3/11/2022 | 3/23/2022 | 4/4/2022 |
|-----------|-----------|-----------|----------|
| 3/11/2022 | | | |
| 3/23/2022 | 12 | | |
| 4/4/2022 | 24 | 12 | |
| 4/28/2022 | 48 | 36 | 24 |



| | Area (Sqkm) |
|--------|-------------|
| Non-BU | 73.023 |
| BU | 107.386 |

ACCURACY TEST

2016

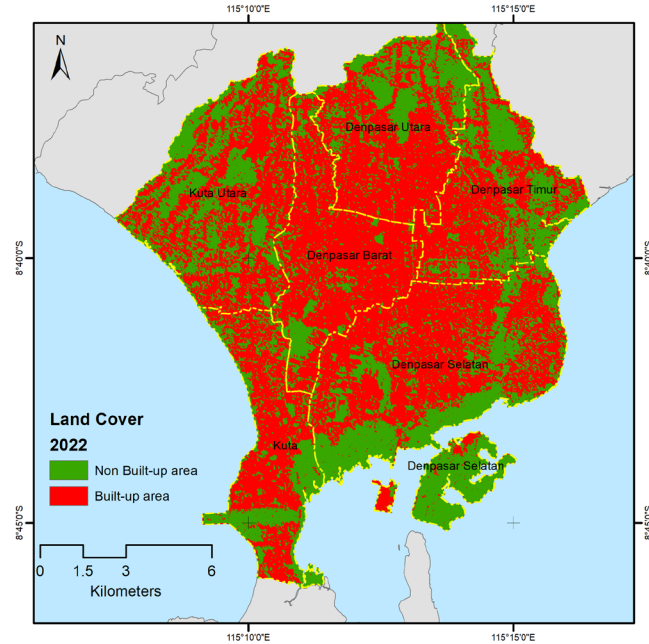


| | Actual | | |
|------------|---------------|--------|-----|
| | Built-Up (BU) | Non-BU | |
| Prediction | BU | 274 | 24 |
| | Non-BU | 25 | 256 |

| | Producer Accuracy | User Accuracy |
|--------|-------------------|---------------|
| BU | 91.6 | 91.9 |
| Non-BU | 91.4 | 91.1 |

| | |
|--------------------------|-------------|
| Over all accuracy | 91.5 |
| Khat | 0.8 |

2022



| | Actual | | |
|------------|---------------|--------|-----|
| | Built-Up (BU) | Non-BU | |
| Prediction | BU | 289 | 21 |
| | Non-BU | 18 | 251 |

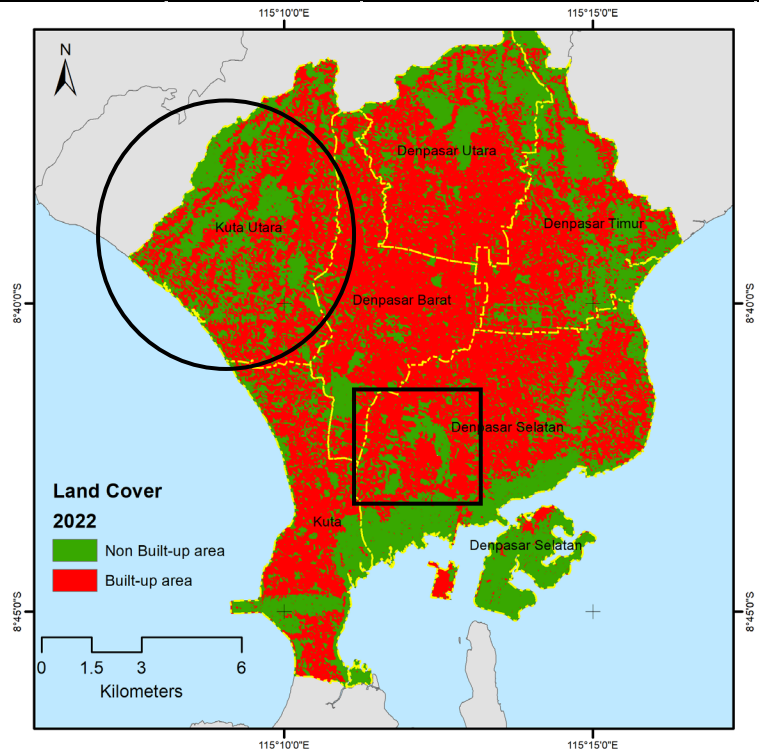
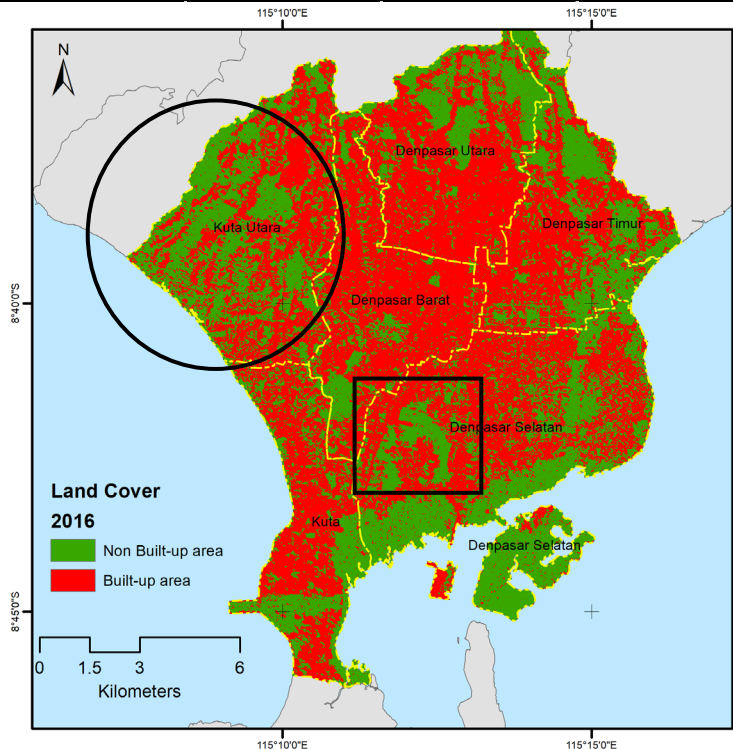
| | Producer Accuracy | User Accuracy |
|-----|-------------------|---------------|
| BU | 94.1 | 93.2 |
| Non | 92.3 | 93.3 |

| | |
|--------------------------|-------------|
| Over all accuracy | 93.3 |
| Khat | 0.9 |



Comparison of Urban Footprint map in 2016 and 2022

| District | Area 2016 (SQKM) | | | Area 2022 (SQKM) | | | Non BU Change 2016-2022 (sqkm) | Non-BU change/year |
|------------------|------------------|----------------|--------|------------------|----------------|---------------|--------------------------------|--------------------|
| | Non-BU | BU | BU % | Non-BU | BU | BU % | | |
| Denpasar Utara | 9.211 | 17.278 | 65.227 | 9.618 | 16.871 | 63.692 | 0.407 | 6.776 |
| Denpasar Timur | 11.837 | 14.031 | 54.241 | 12.110 | 13.753 | 53.176 | 0.274 | 4.562 |
| Denpasar Selatan | 24.809 | 23.685 | 48.842 | 22.197 | 26.291 | 54.222 | -2.612 | -43.532 |
| Denpasar Barat | 5.656 | 18.656 | 76.736 | 5.042 | 19.270 | 79.260 | -0.614 | -10.227 |
| Kuta | 8.404 | 12.316 | 59.441 | 8.336 | 12.385 | 59.769 | -0.068 | -1.127 |
| Kuta Utara | 17.482 | 17.055 | 49.382 | 15.720 | 18.816 | 54.482 | -1.763 | -29.377 |
| Total | 77.399 | 103.021 | | 73.023 | 107.386 | 59.524 | -4.376 | -72.926 |

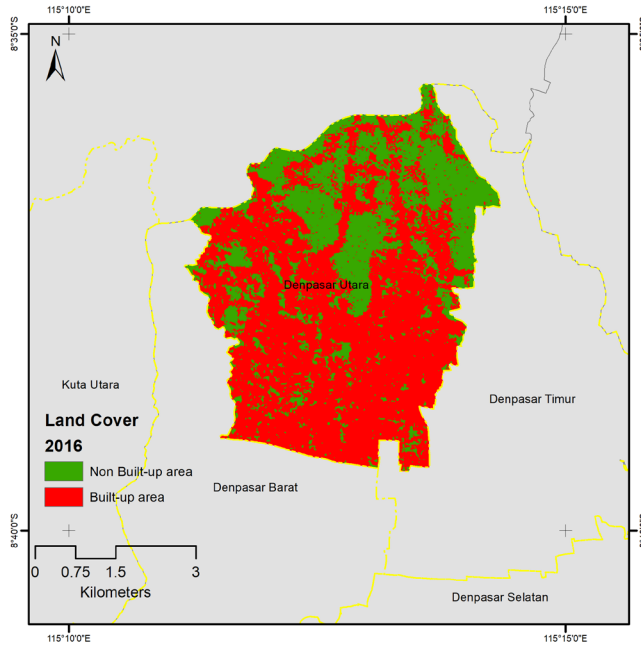


Comparison of Urban Footprint map in 2016 and 2022 by District

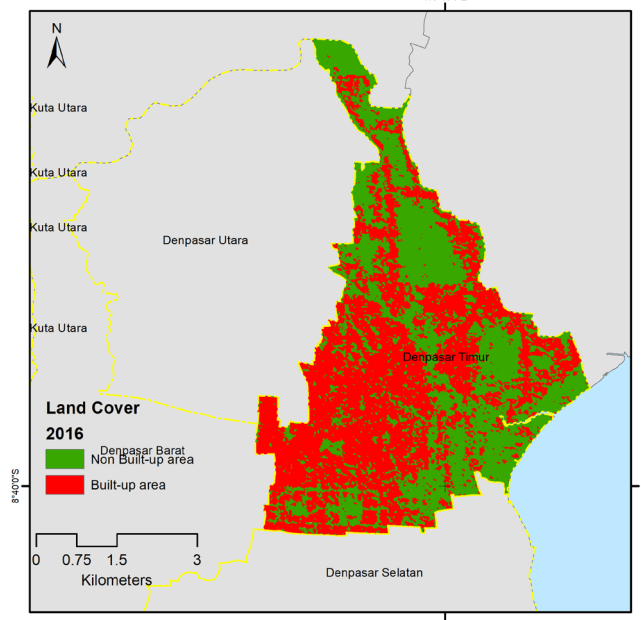


2016

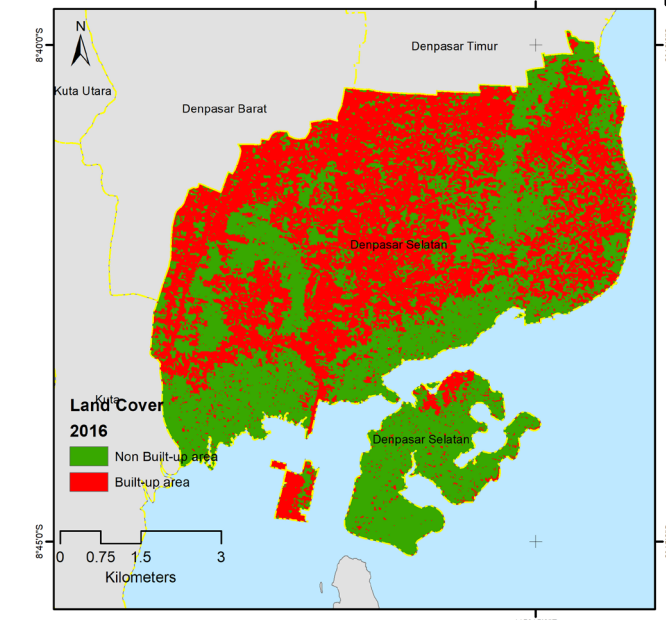
Denpasar Utara



Denpasar Timur

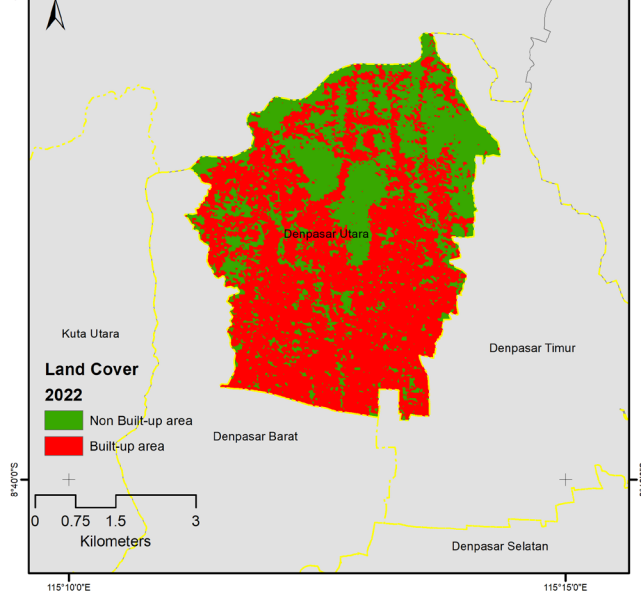


Denpasar Selatan

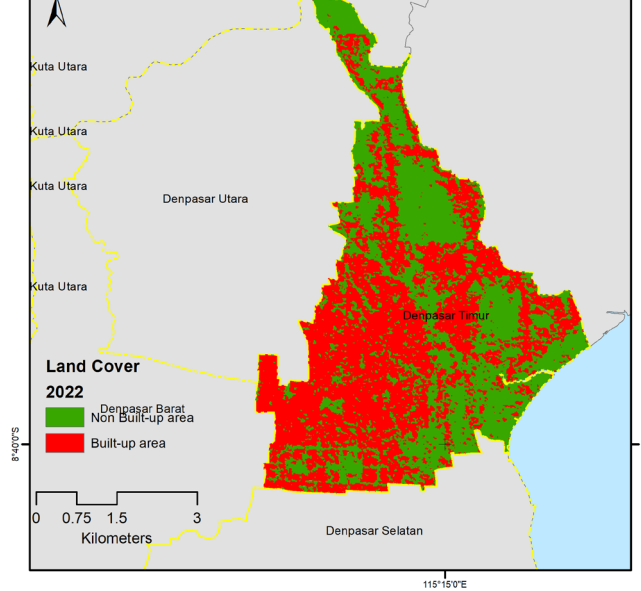


2022

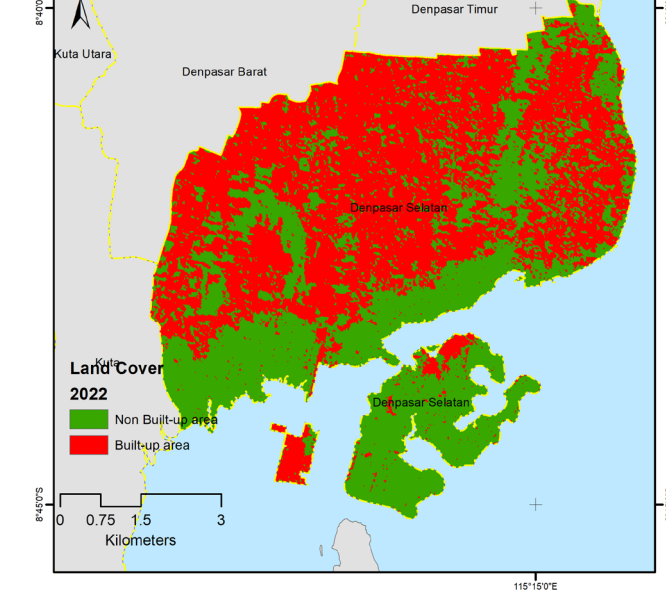
Denpasar Utara



Denpasar Timur



Denpasar Selatan

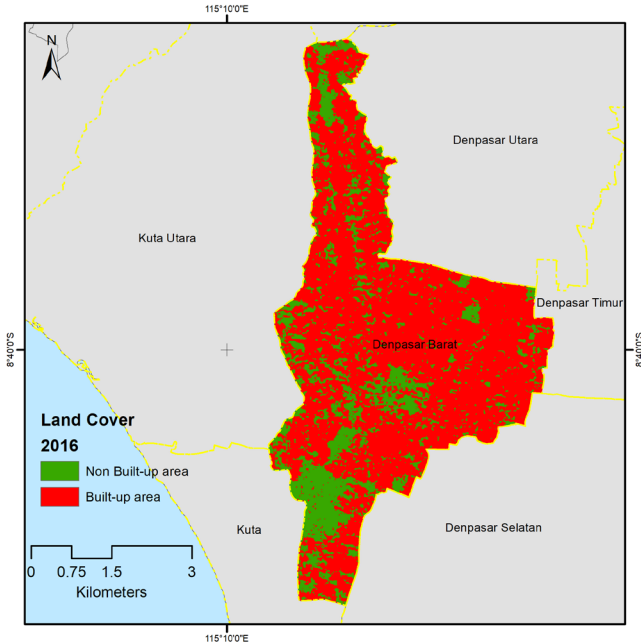


Comparison of Urban Footprint map in 2016 and 2022 by District

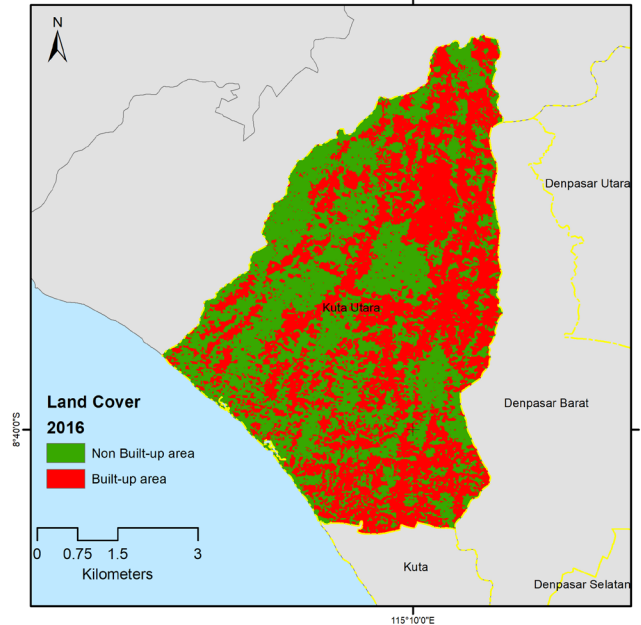


Denpasar Barat

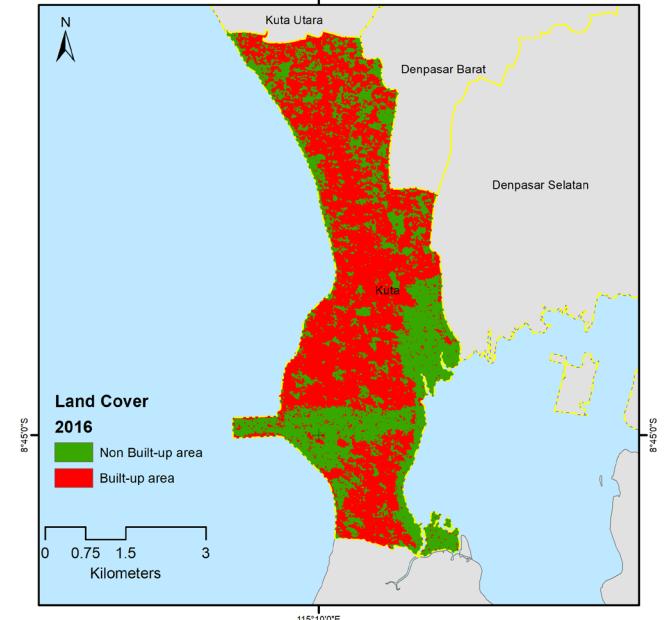
2016



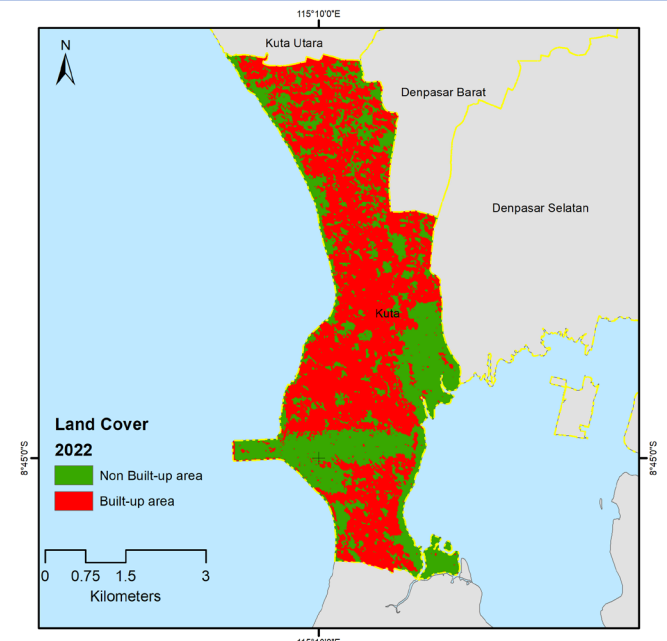
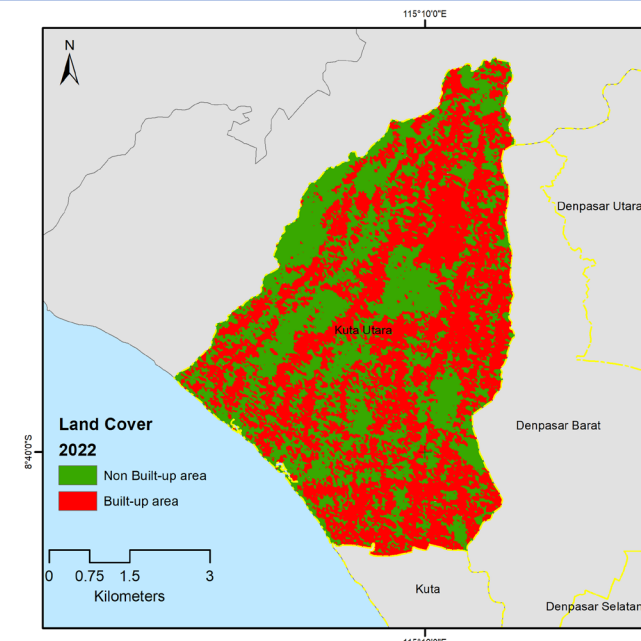
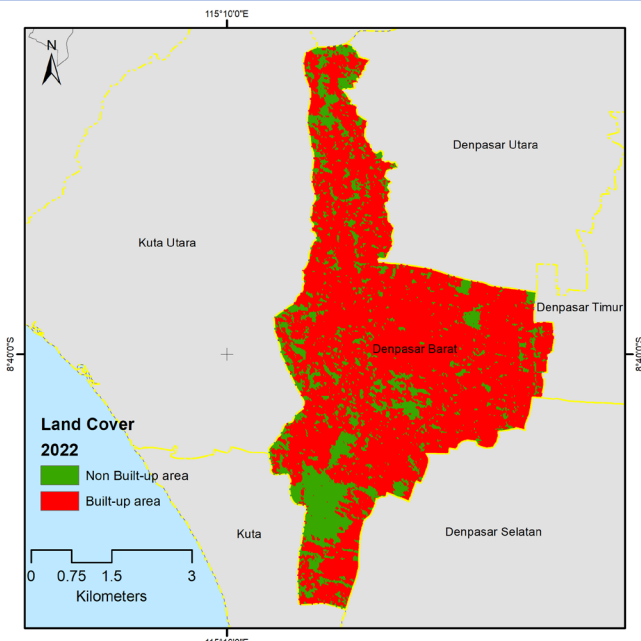
Kuta Utara



Kuta

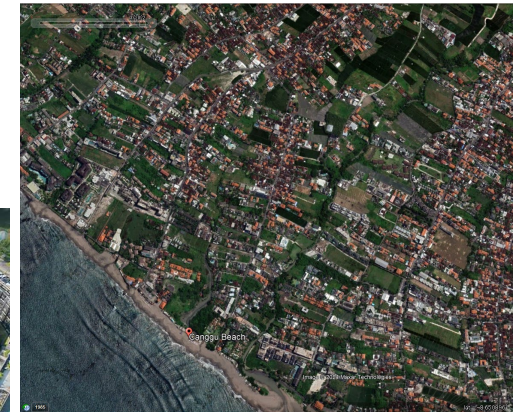
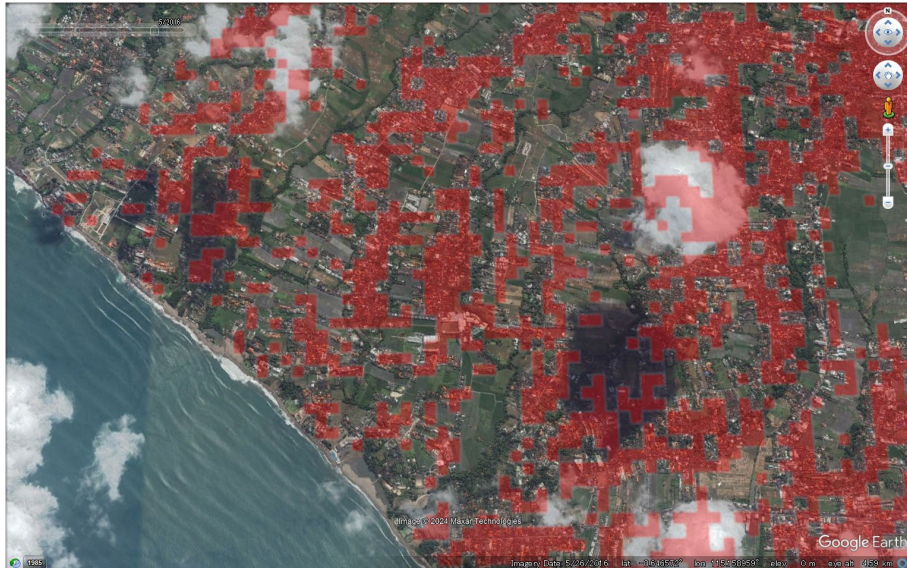


2022



Urban Sprawl in Kuta Utara District

The land use change from rice field to the built-up area mostly found in Kuta Utara District, which is “International village” Canggu located.



HOME BALI LIFE JOIN

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Conclusions



1. Mapping and monitoring Urban Sprawl is crucial for developing better planning and policies. Utilizing SAR data and unsupervised classification methods (such as K-Means) for mapping urban footprint offers several advantages compared to using optical imagery with conventional method.
2. The application of SAR data with multi-temporal coherence and K-means classification method in the Denpasar greater area for the years 2016 and 2022 achieved high accuracy, with 91.5% and 93.3%, respectively.
3. A notable change in land use to built-up areas of 4,376 sq km was identified during the period 2016-2022, averaging 72.9 hectares per year. Urban sprawl was predominantly observed towards North Kuta District, aligning with current on-site conditions where a massive shift from agricultural to built-up land use is evident, accompanied by severe traffic congestion other environmental issues.
4. The future optimization of SAR data applications in mapping land-use changes should focus on seeking simpler and faster processing methods with consistent accuracy.

Acknowledgement

All Sentinel-1 Data used in this research are provided by European Space Agency (ESA) and downloaded from Alaska Satellite Facility (ASF), The author would like to thank both institutions.



THANK YOU



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