

Creation of 10-m LULC Maps for Viet Nam from 2017 to 2022 Using a Time-Feature Convolutional Neural Network

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*: **Presenter**

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Our group's activities at University of Tsukuba, Japan

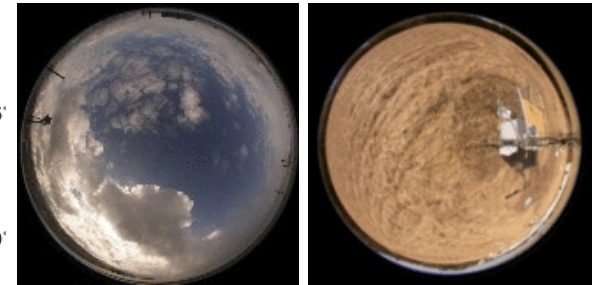
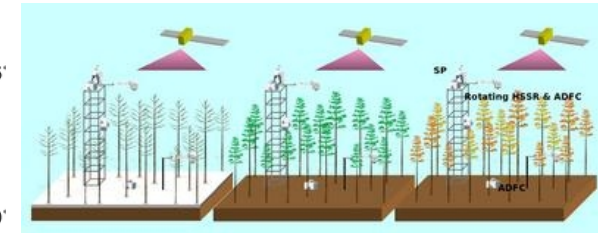
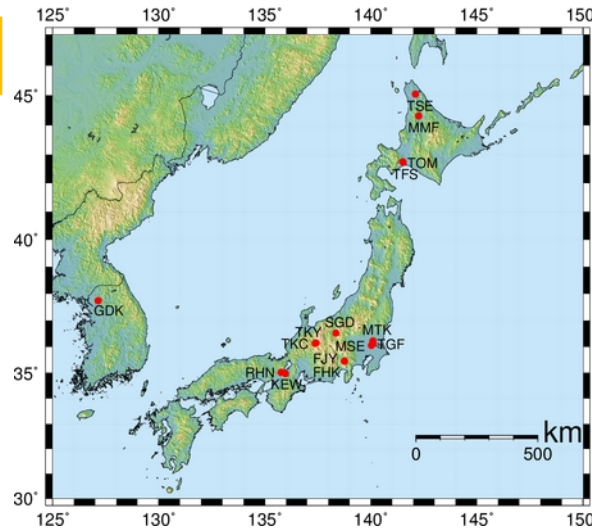
Research topics

- Phenological Eyes Networks (PEN)
- Sensor validation tasks (GCOM-C project, JAXA)
- Land Use Land Cover mapping
 - + Viet Nam
 - + Japan
 - + Thailand
 - + Bangladesh

Our
group



JAXA
EORC



<http://www.pheno-eye.org/>

LULC changes are main causes of many environmental issues

Conversion of forests to urban/built-up or cropland



Biodiversity loss, habitat disruption, exacerbated climate change, natural disasters
(Betts et al., Nature, 2017)

Conversion of cropland to urban/built-up



Agriculture productivity, food security,
(Anwar et al., Remote Sensing, 2023)

Decrease open land due to urbanization > increase household waste water



Reduction of ground water quality
(Ahmad et al. Scientific Reports, 2021)

Increase of solar panel



Change the earth surface's albedo and heat exchange with atmosphere
(brennan et al., Scientific Reports, 2014)

LULC mapping is an important but a challenging task

- Temporal coverage
- Spatial coverage
- Spatial resolution
- Accuracy
- Number of categories
- ...

Existing global LULC maps

Old products

recent products



	MCD12Q1	GLC2000	GLCNMO	GlobCover	ESA-CCI	FROM_GLC	CGLS-LC100	GLC_FS30	ESRI	ESA	DW
Time of Maps	2001 -2020	2000	2003, 2008, 2013	2004-2006, 2009	1992 -2015	2001, 2010, 2015, 2017	2015 - 2019	2015	2017 - 2021	2020, 2021	2015 – current
Number of Category	17	22	20	22	22	7, 11	23	9	10	11	9
Spatial Resolution (m)	500	1000	1000, 500, 500	300	300	250, 250, 30, 10	100	30	10	10	10
Max. Overall Acc. (%)	73.6	-	77.9	67.5	75.4	75.2	80.5	82.5	75	80.7	-



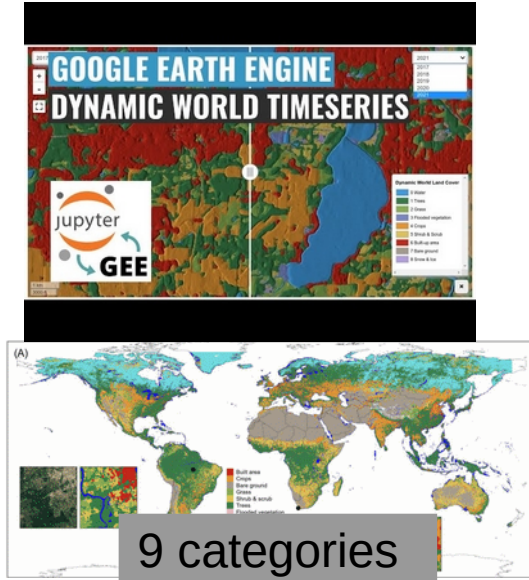
➤ Increase of spatial resolution (1000 m >>> 10 m)

A big contribution of Sentinel-2 and Sentinel-1

- MCD12Q1: MODIS Land Cover Type Product
- GLC2000: Global Land Cover
- GLCNMO: Land Cover GLCNMO Global
- GlobCover: GlobCover land Cover Maps
- ESA-CCI: ESA Climate Change Initiative Land Cover
- FROM_GLC: Finer Resolution Observation and Monitoring-Global Land Cover

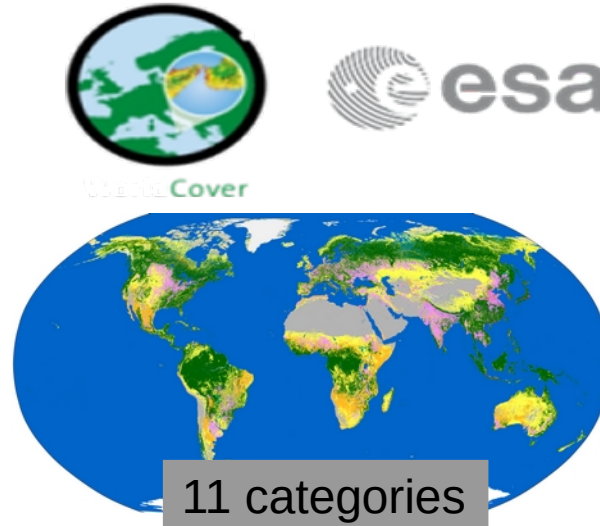
- CGLS-LC100: Copernicus Global Land Service (CGLS-LC100)
- GLC_FS30: Global Land Cover Product with Fine Classification System
- DW: Dynamic World
- ESA: ESA World Cover
- ESRI: ESRI Land Cover

Recent global LULC maps



LEGEND

- Water
- Trees
- Grass
- Flooded vegetation
- Crops
- Shrub and scrub
- Built
- Bare
- Snow and ice

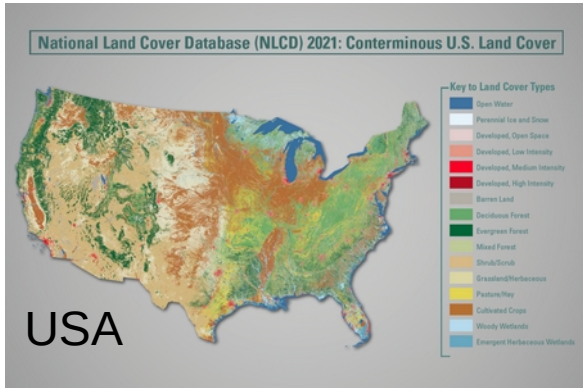


- Tree cover
- Shrubland
- Grassland
- Cropland
- Built-up
- Bare / sparse vegetation
- Snow and ice
- Permanent water bodies
- Herbaceous wetland
- Mangroves
- Moss and lichen



- Water
- Trees
- Grass
- Flooded Vegetation
- Crops
- Scrub/Shrub
- Built Area
- Bare Ground
- Snow/Ice
- Clouds

Some countries have produced their own LULC maps



National Land Cover Database
30m, 16 categories



2022
10m, 14 categories
JAXA-EORC



2017, 10 m, 13 categories,
<https://s2glc.cbk.waw.pl/>

The importance of LULC mapping for Vietnam

- Total area: **330,000 km²**
- Forest cover: **42 %** total area
- Economic growth rate: **8.0 % (2022)**
- **One of ten** countries with the richest biodiversity

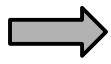


- To 2030: **reduce greenhouse emissions by 70%** and **increase carbon sinks by 20%** compare to business-as-usual scenario (BAU)

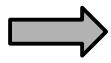
LULC maps



Land use planning and management



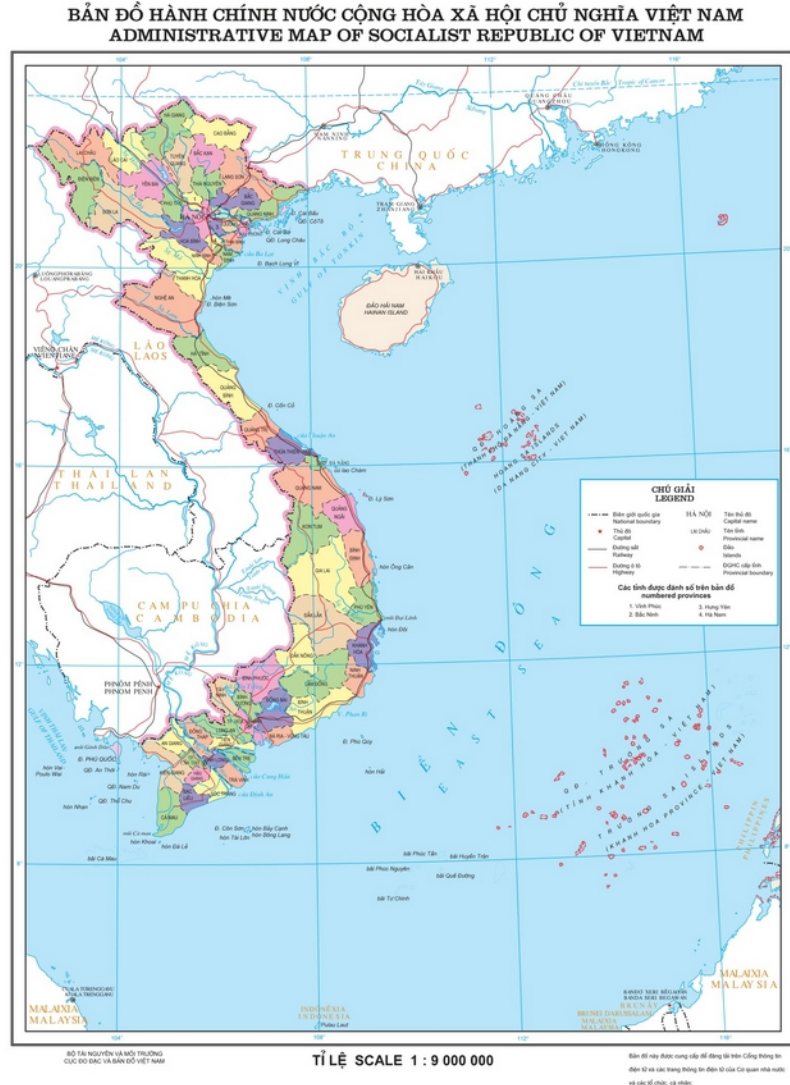
Biodiversity evaluation and conservation



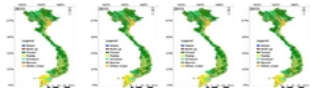
SDG of Forest and Land use sector



Various applications: biomass estimation, disaster countermeasure, REDD+, etc.

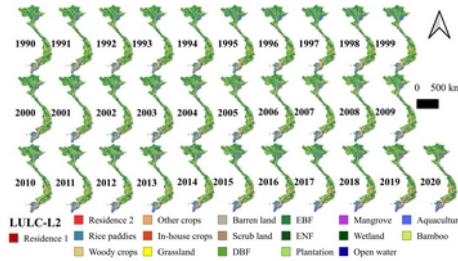


Existing Nation-wide LULC maps of Vietnam



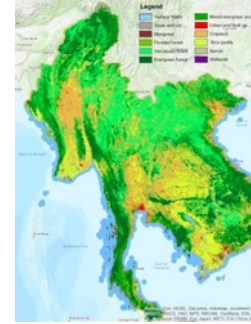
50 m (2015 - 2018)

7 categories,
OA: 79%

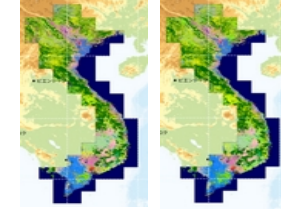


30 m (1990 - 2020)

17 categories,
OA: 77.6% -
84.7%



30 m (2000 - 2017)
18 categories
OA: 94%



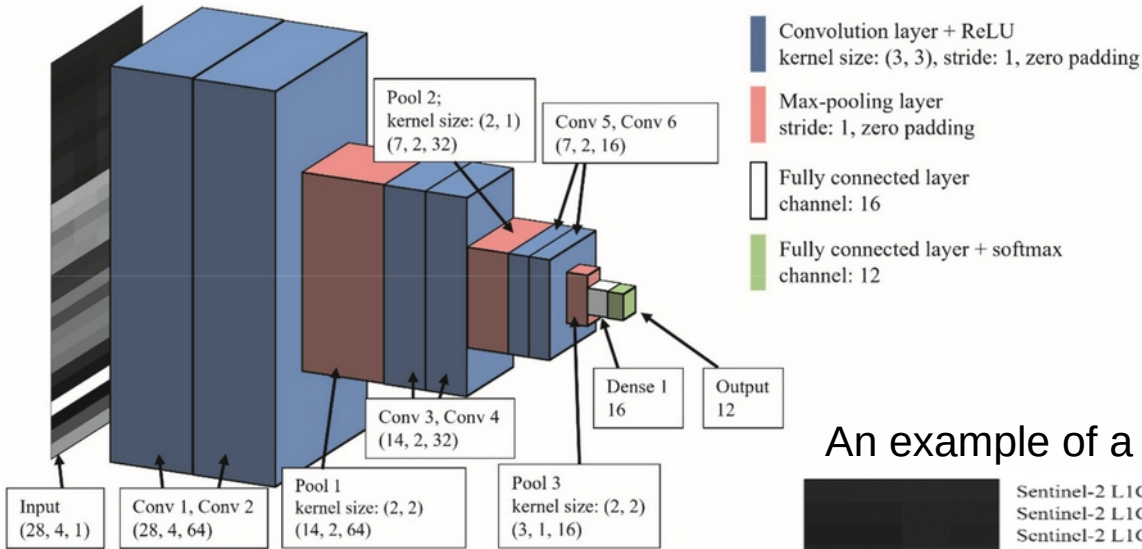
10 m (2007 & 2016)
12 categories,
OA: ~85%

This study's plan

10 m (2017- 2022)

> 12 categories,
OA: > 90%

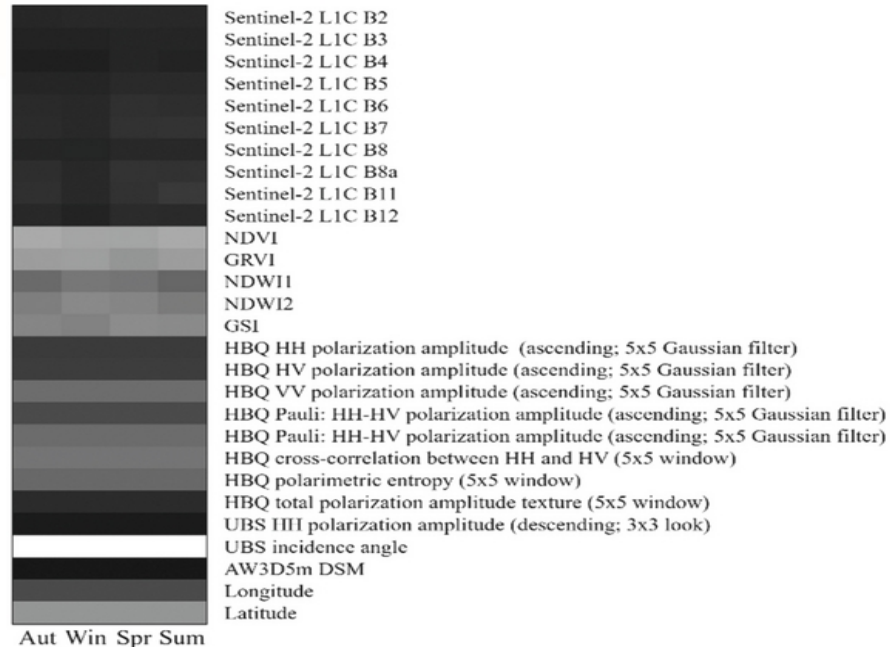
JAXA has been developing a new CNN for using multi-temporal data



Structure of CNN model used for producing LULC map of Japan v.21.11

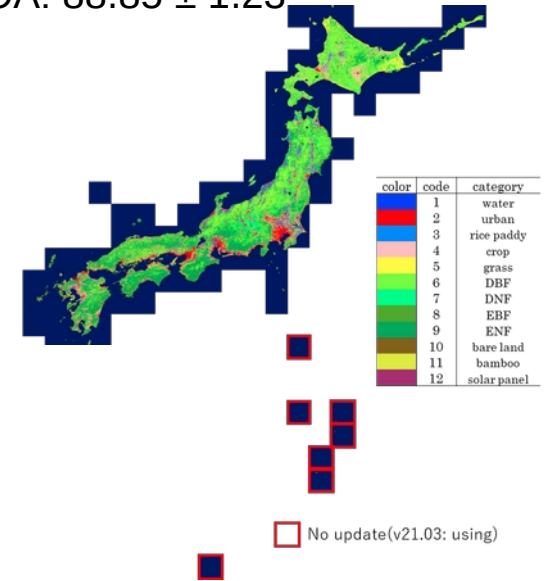
(Hirayama et al., 2022)

An example of a training data

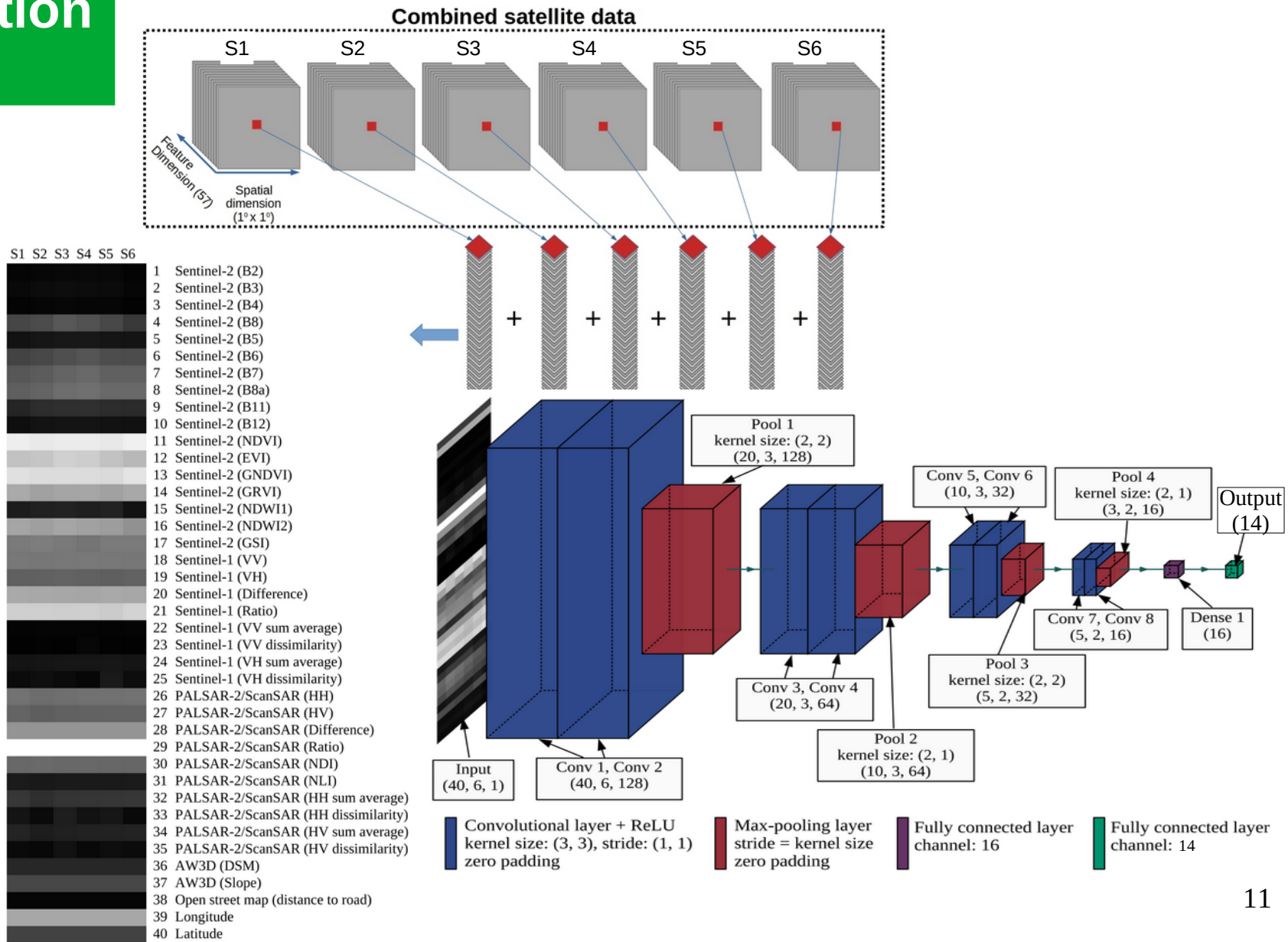


LULC map of Japan ver. 21.11
12 categories

OA: 88.85 ± 1.23



Classification Algorithm

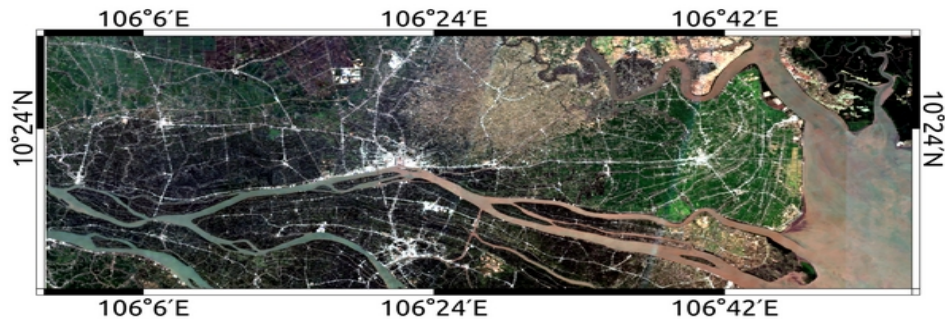


Satellite data used to produce time-series LULC maps

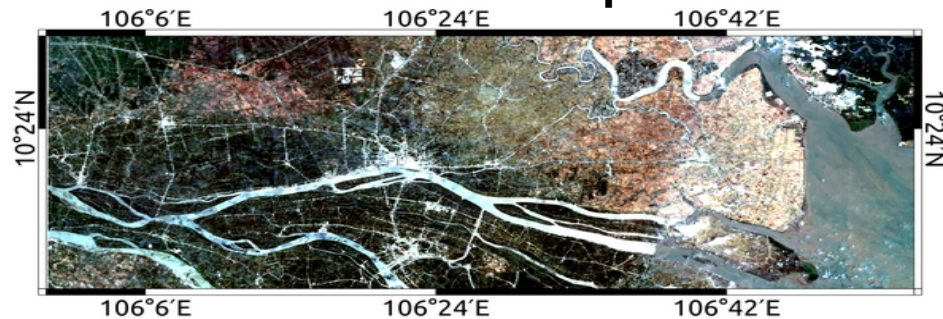
No	Data	Spatial resolution / bands	Time/Seasons
1	Sentinel-2 (level 2A, level 1C)	10 m (B2, B3, B4, B8) 20 m (B5, B6, B7, B8A, B11, B12) NDVI, EVI, GNDVI, GRVI, NDWI1, NDWI2, GSI	S1. 20XX/01/01-20XX/02/29 S2. 20XX/03/01-20XX/04/30 S3. 20XX/05/01-20XX/06/30 S4. 20XX/07/01-20XX/08/31 S5. 20XX/09/01-20XX/10/31 S6. 20XX/11/01-20XX/12/31 (XX: 17-22)
2	Sentinel-1 GRD	10 m (VV, VH, VV-VH, VV/VH, VV_savg, VV_diss, VH_savg, VH_diss)	
3	PALSR-2/ScanSAR	25 m (HH, HV, HH-HV, HH/HV, NDI, NLI, HH_savg, HH_diss, HV_savg, HH_diss)	
4	ALOS AW3D DSM	30 m (DSM, Slope)	-
5	OpenstreetMap	Distance to Road	2017-2022

The problem of cloud in Sentinel-2 images in Vietnam

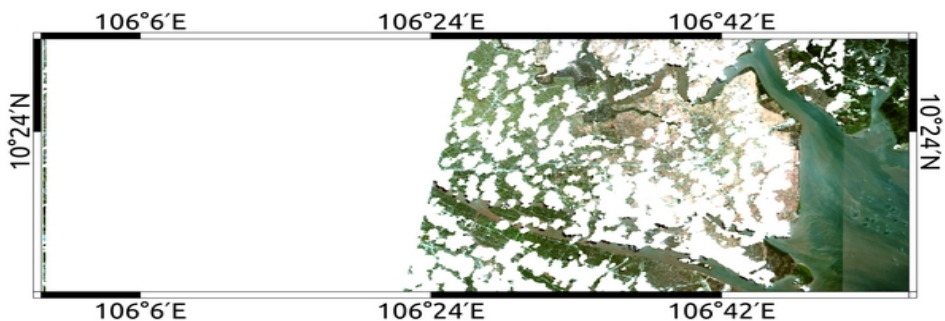
S1: Jan. & Feb.



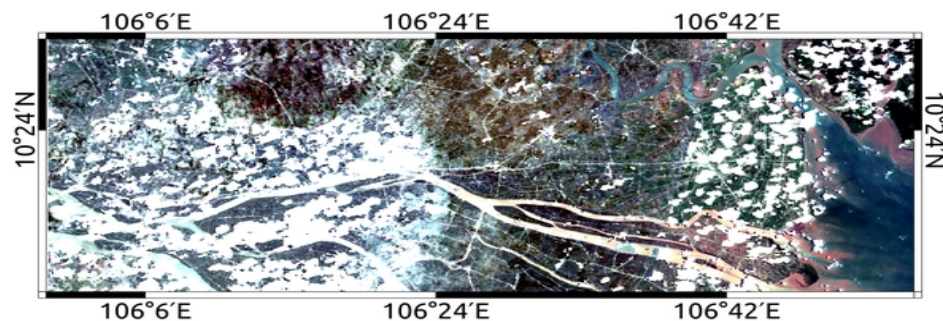
S2: Mar. & Apr.



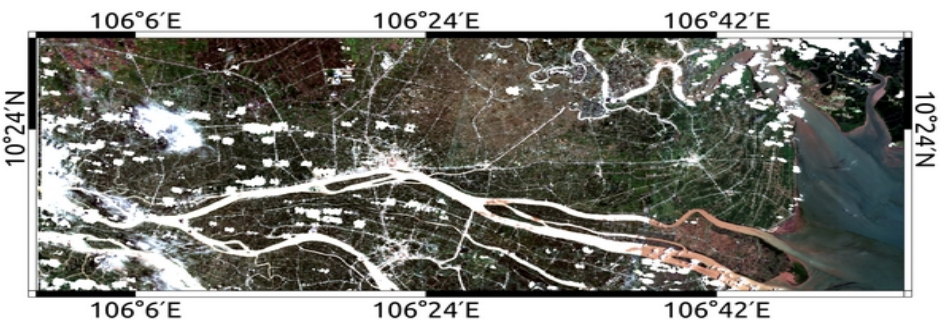
S3: May & June



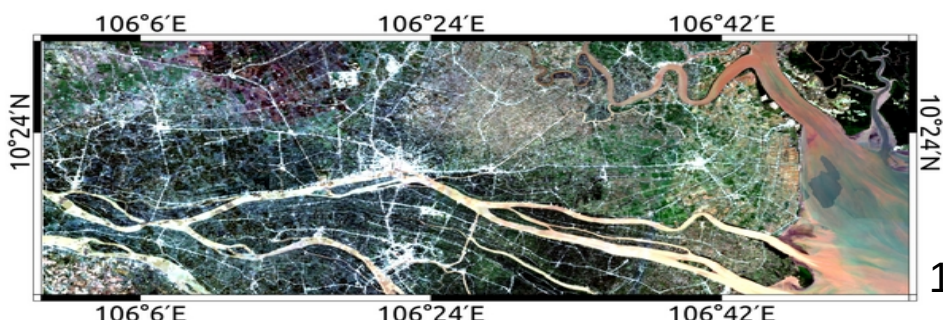
S4: July & Aug.



S5: Sep. & Oct.



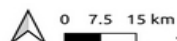
S6: Nov. & Dec.



Example of making cloud-free time-series images for 2020

Images used

Normal approach

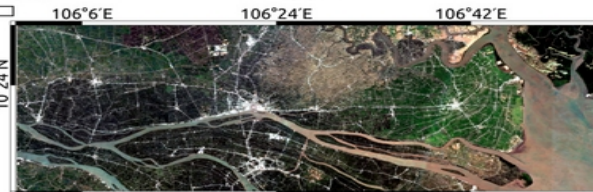


Our approach

Images used

2020/01
2020/02

S1



2020/01 x 2, 2020/02 x 2
2020/03 x 1
2019/01 x 1, 2019/02 x 1
2021/01 x 1, 2021/02 x 1

2020/03
2020/04

S2



2020/03 x 2, 2020/04 x 2
2020/02 x 1, 2020/05 x 1
2019/03 x 1, 2019/04 x 1
2021/03 x 1, 2021/04 x 1

2020/05
2020/06

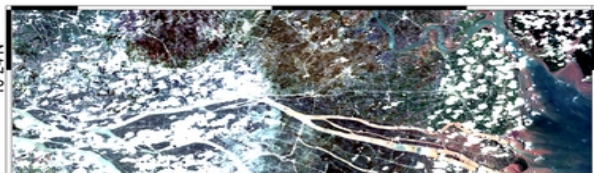
S3



2020/05 x 2, 2020/06 x 2
2020/04 x 1, 2020/07 x 1
2019/05 x 1, 2019/06 x 1
2019/04 x 1, 2019/07 x 1
2021/05 x 1, 2021/06 x 1
2021/04 x 1, 2021/07 x 1

2020/07
2020/08

S4



2020/07 x 2, 2020/08 x 2
2020/06 x 1, 2020/09 x 1
2019/07 x 1, 2019/08 x 1
2019/06 x 1, 2019/09 x 1
2021/07 x 1, 2021/08 x 1
2021/06 x 1, 2021/09 x 1

2020/09
2020/10

S5



2020/09 x 2, 2020/10 x 2
2020/08 x 1, 2020/11 x 1
2019/09 x 1, 2019/10 x 1
2019/08 x 1, 2019/11 x 1
2021/09 x 1, 2021/10 x 1
2021/08 x 1, 2021/11 x 1

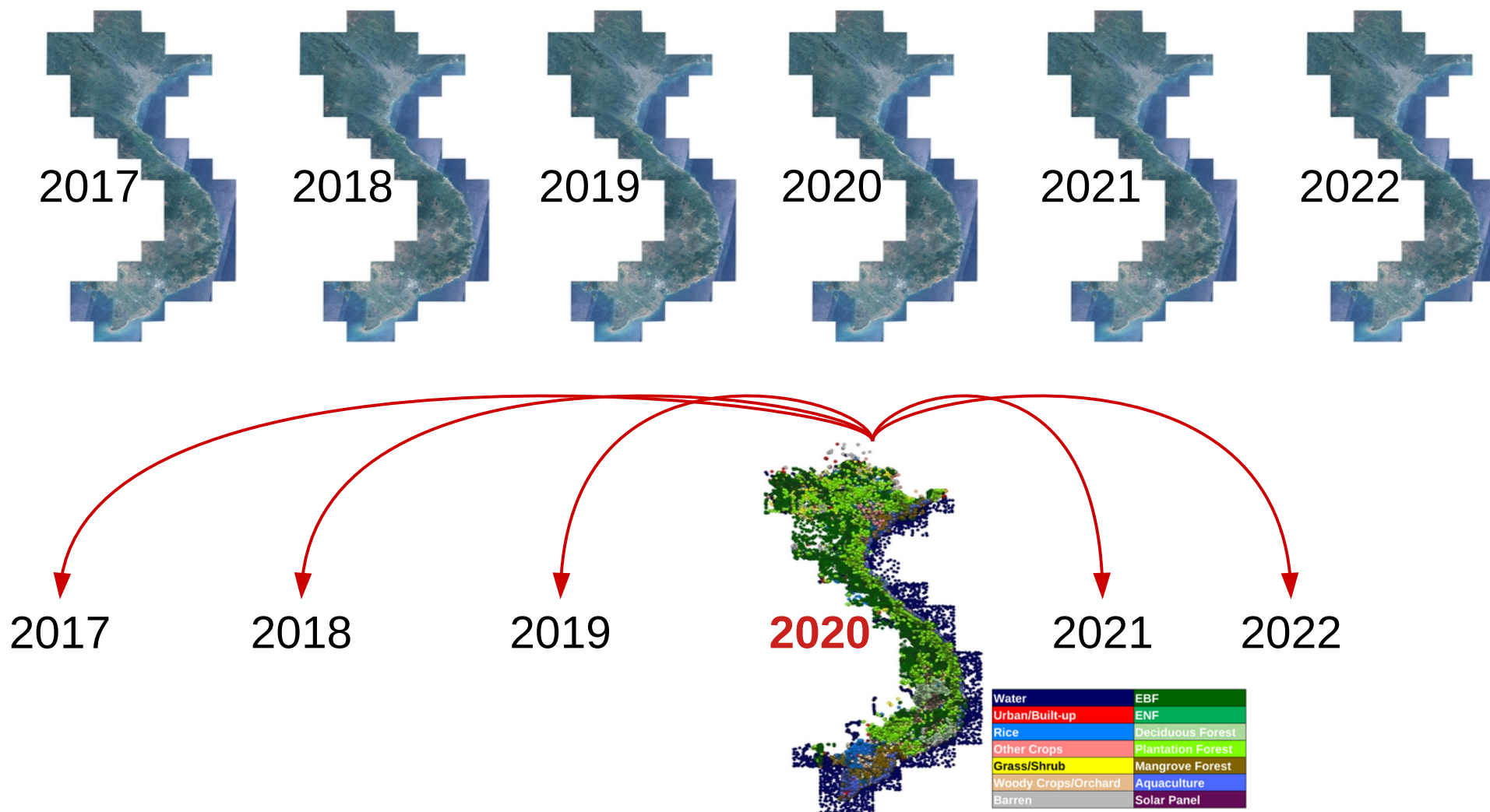
2020/11
2020/12

S6



2020/11 x 2, 2020/12 x 2
2020/10 x 1
2019/11 x 1, 2019/12 x 1
2021/11 x 1, 2021/12 x 1

Producing time series of reference data



170,000 reference data for 2020 have been collected by visual interpretation on Google earth, Sentinel-2, Planet's scope

Method for reference data migration



The migration of training samples towards dynamic global land cover mapping

Huabing Huang^{a,b,c,*}, Jie Wang^{b,d}, Caixia Liu^b, Lu Liang^e, Congcong Li^f, Peng Gong^{d,*}

<https://doi.org/10.1016/j.isprsjprs.2020.01.010>

Received 21 October 2018; Received in revised form 6 December 2019; Accepted 9 January 2020

2020 (t_1)



$X_{i(t_1)}$

X_1

X_2

⋮

⋮

⋮

X_N

Target year (t_2)



$Y_{i(t_2)}$

Y_1

Y_2

⋮

⋮

⋮

Y_N

$$\theta = \cos^{-1} \frac{\sum_{i=1}^N X_{i(t_1)} Y_{i(t_2)}}{\sqrt{\sum_{i=1}^N (X_{i(t_1)})^2 \sum_{i=1}^N (Y_{i(t_2)})^2}},$$
$$SAD = \cos(\theta) \quad (1)$$

$$ED = \sqrt{\sum_{i=1}^N (X_{i(t_1)} - Y_{i(t_2)})^2} \quad (2)$$

SAD: Spectral similarity

SAD \rightarrow 1 : LULC no change

ED: Spectral distance

ED \rightarrow 0 : LULC no change

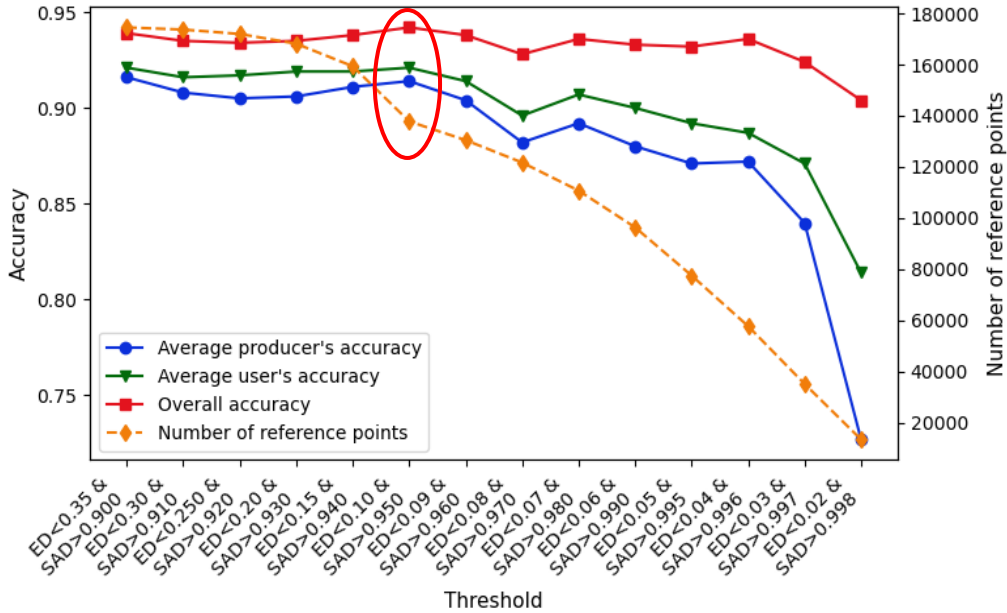
i : is the target pixel (red point)

$X_{i(t_1)}$: is reference spectra at time t_1

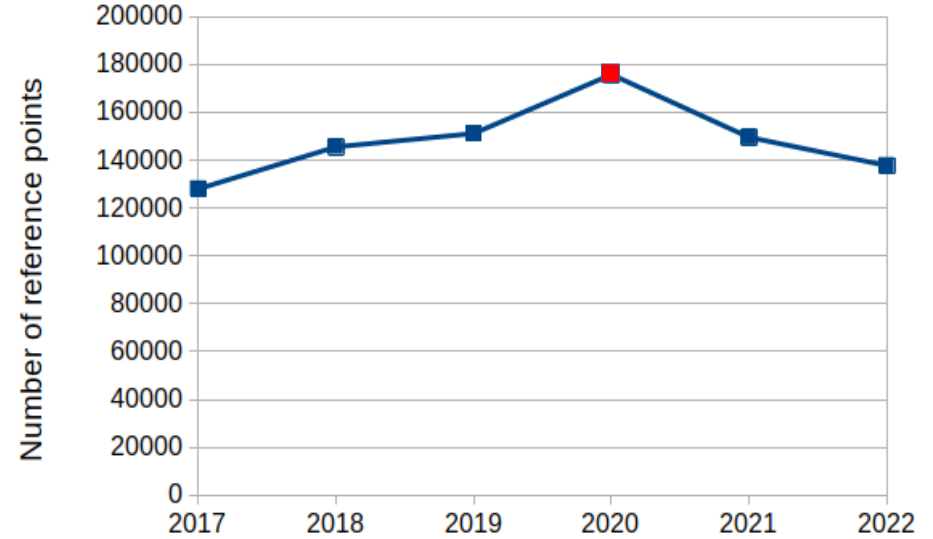
$Y_{i(t_2)}$: is the target spectra at time t_2

N : is number of bands

The selection of threshold value for reference data migration

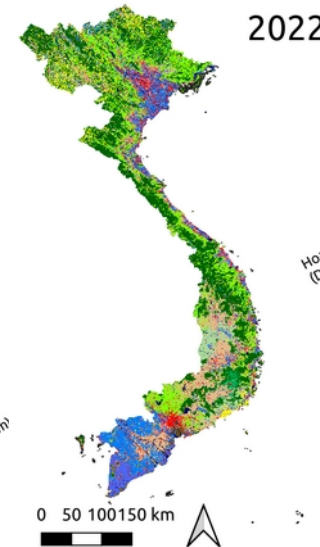
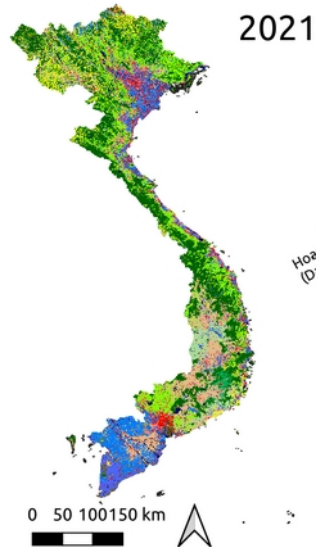
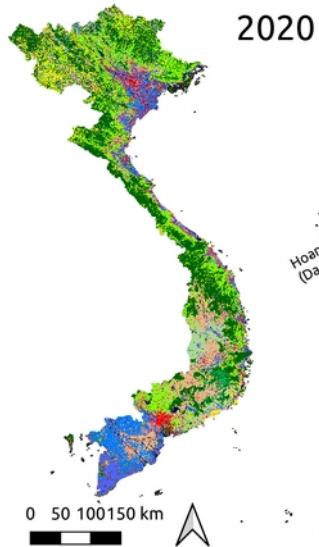
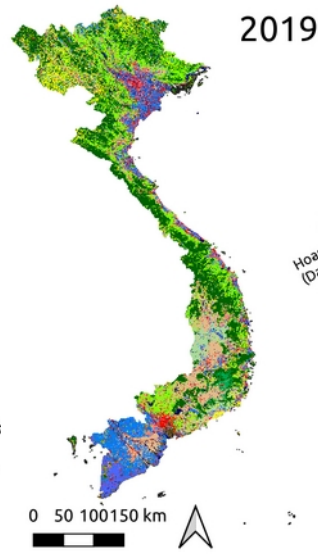
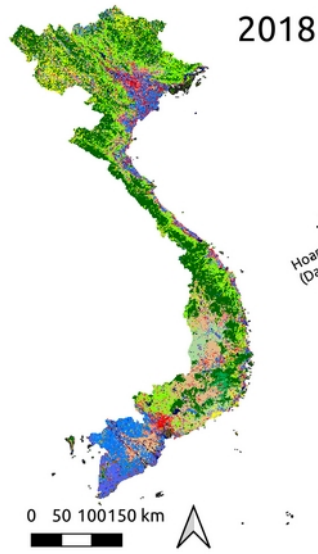
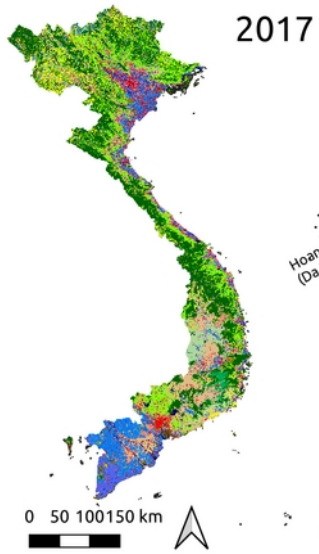


Variation of accuracy by thresholds value sets of ED and SAD



Number of reference data by years
Selected thresholds: ED < 0.1 & SAD > 0.95

14-category LULC maps for Vietnam from 2017-2022

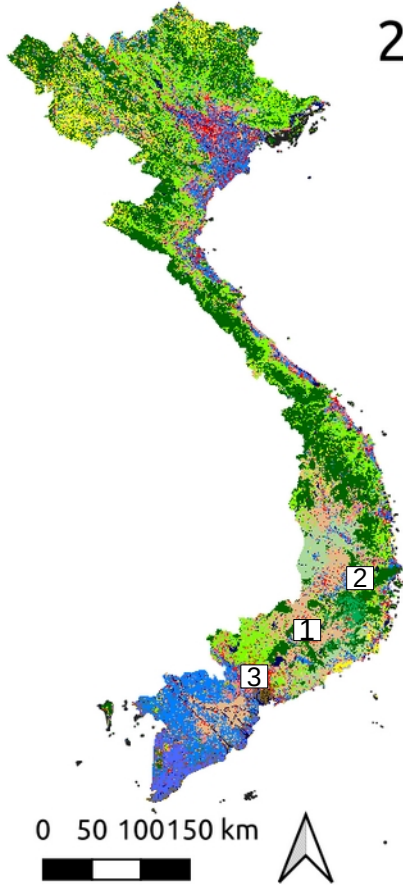


	Overall Acc.	User's Acc.	Prod.'s Acc
2017	92.3 ± 0.2	92.9 ± 0.3	86.9 ± 0.8
2018	92.4 ± 0.2	92.7 ± 0.9	86.6 ± 0.7
2019	92.7 ± 0.2	93.2 ± 0.2	88.8 ± 0.4
2020	92.4 ± 0.1	93.0 ± 0.2	89.3 ± 0.5
2021	92.4 ± 0.2	93.0 ± 0.2	91.2 ± 0.3
2022	91.5 ± 0.2	92.0 ± 0.2	87.3 ± 0.9

Water	EBF
Urban/Built-up	ENF
Rice	Deciduous Forest
Other Crops	Plantation Forest
Grass/Shrub	Mangrove Forest
Woody Crops/Orchard	Aquaculture
Barren	Solar Panel

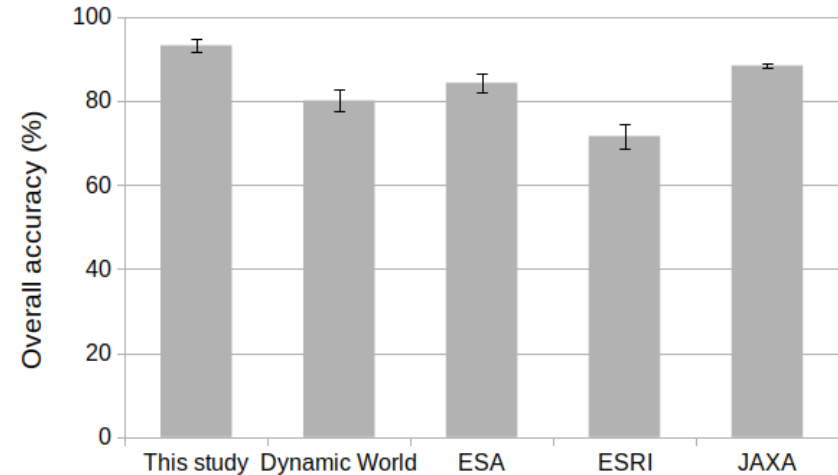
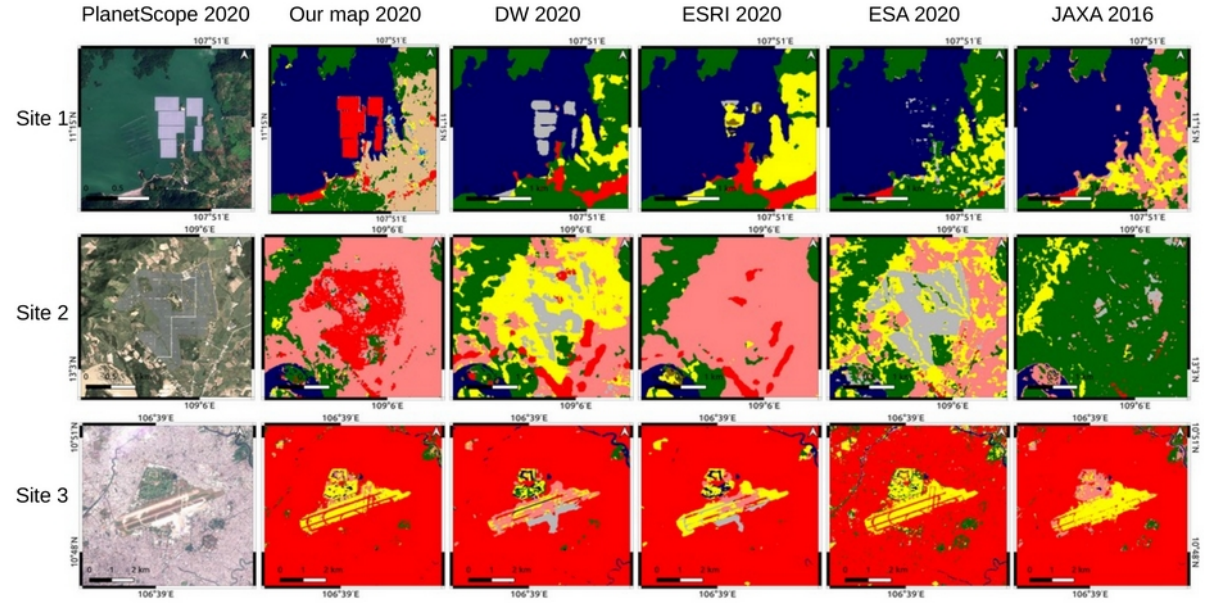
A comparison with other LULC products

2020



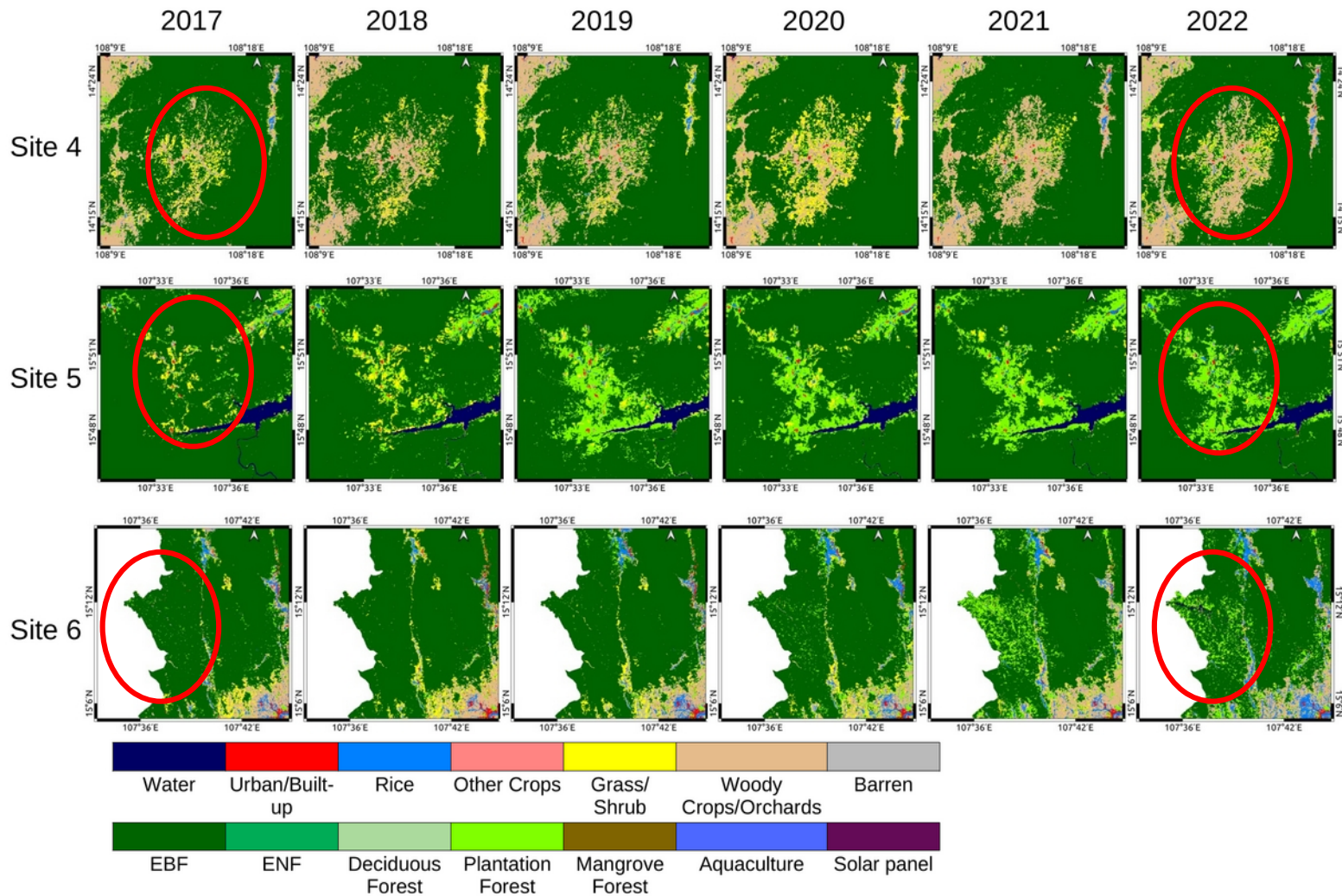
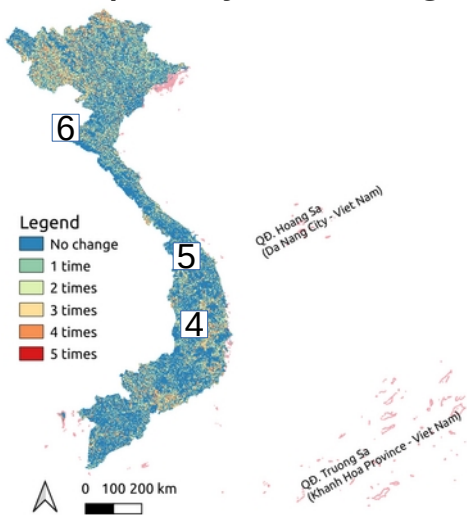
Hoang Sa Islands
(Da Nang City - Viet Nam)

Truong Sa Islands
(Khanh Hoa Province - Viet Nam)

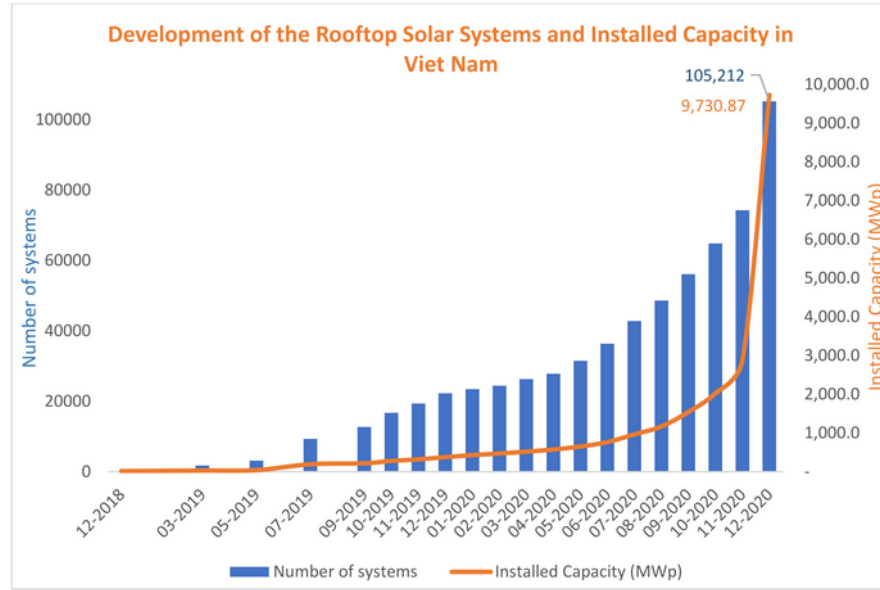
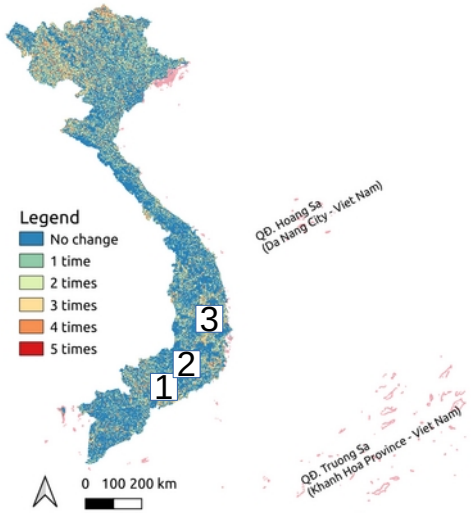


Examples of LULC changes in Vietnam from 2017-2022

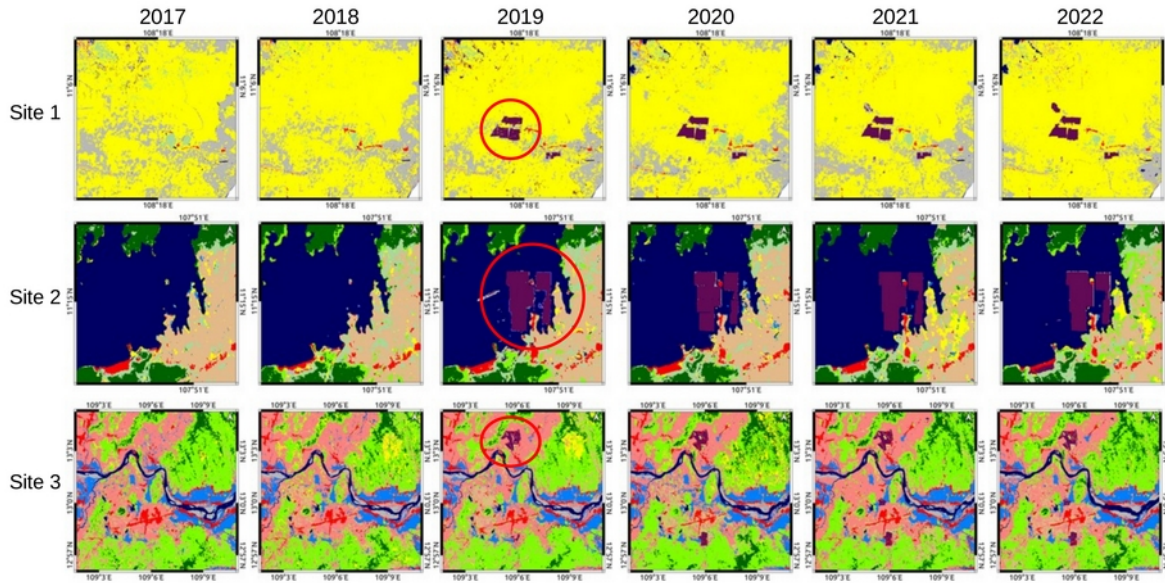
Frequency of change



The rapid increase of solar panel facilities



Reported by Viet Nam Energy Partnership Group, 2020



Water	EBF
Urban/Built-up	ENF
Rice	Deciduous Forest
Other Crops	Plantation Forest
Grass/Shrub	Mangrove Forest
Woody Crops/Orchard	Aquaculture
Barren	Solar Panel

Published Data on JAXA's website

ALOS-4 ALOS-3 ALOS-2 ALOS JERS-1 Dataset Image Library RA & Meetings

High-Resolution Land-Use and Land-Cover Map of Vietnam for 2020
(Released in September 2023 / Version 23.09) Downloads

Full Screen You can switch layers with check boxes.

JAXA High-Resolution Land-Use and Land-Cover Map

- Water
- Urban/Built-up
- Rice
- Other Crops
- Grass/Shrub
- Woody Crops/Orchards
- Barren
- Evergreen Forest
- Deciduous Forest
- Plantation Forest
- Mangrove Forest
- Aquaculture

Download product

ALOS-4 ALOS-3 ALOS-2 ALOS JERS-1 Dataset Image Library RA & Meetings

Full Screen You can switch layers with check boxes.

- High developed areas
- Low developed areas
- Rice paddies
- Woody crops
- Other croplands
- In-house crops
- Grassland/Herbaceous vegetation
- Barren land
- Scrub/Shrub
- Deciduous broadleaf forest
- Evergreen broadleaf forest
- Evergreen needle-leaf forest
- Plantation land
- Mangrove
- Inland wetland
- Open water
- Aquaculture
- Bamboo area

ver.21.09 Level-2 [Browse overlay]

2020 2010 2000 1990

2019 2009 1999

2018 2008 1998

2017 2007 1997

2016 2006 1996

2015 2005 1995

2014 2004 1994

2013 2003 1993

2012 2002 1992

2011 2001 1991

ALOS-4 ALOS-3 ALOS-2 ALOS JERS-1 Dataset Image Library RA & Meetings

Annual Land-Use and Land-Cover Maps of Vietnam from 2015 to 2018
(Released in August 2019 / Version 19.08) Downloads

Full Screen You can switch layers with check boxes.

- Water
- Built-up
- Forest
- Paddy
- Orchards
- Barren
- Other crops

Download product

ALOS-4 ALOS-3 ALOS-2 ALOS JERS-1 Dataset Image Library RA & Meetings

Full Screen You can switch layers with check boxes.

- Water
- Urban/Built-up
- Rice
- Other crops
- Grass/Shrub
- Orchard/Crop mosaic
- Barren
- Evergreen Broadleaf Forest
- Coniferous Forest
- Deciduous Forest
- Plantation Forest
- Mangrove

ver.21.04 Level-2 [Browse overlay]

2016(ver.20.06)

2007(ver.21.04)


OSI Map

Conclusions and Recommendations

- The new CNN model showed good capability to produce a high accuracy LULC maps, especially, in preserving the shape of objects
- Accuracy assessment using ~40,000 points showed high accuracy of more than 90% for all maps from 2017-2022.
- Deforestation was detected in some places, corresponding with the fact that deforestation has been occurring in Vietnam.
- Solar panel facilities has been rapidly increasing since 2019

Suggestions for future studies:

- More investigation on the contributed factors to accuracy of LULC maps, such as temporal profile of satellite data, arrangement of feature (bands, indices), number of features, combination of different satellite images.
- The contribution of number of training data to accuracy of LULC maps
- Improving the classification algorithm such as: model structure, model's-parameters optimization



Thank you for listening

HOPE