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Validation of SDG Indicator 15.4.2 (Mountain Green Cover Index)

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Verification of SDG15.4.2 Mountain Green Cover Index (MGCI) (Draft)

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Abstract

UN and National Statistical Offices (NSOs) are beginning to use Earth Observation (EO) and geospatial information as a new data source to produce UN SDG indicators. The Food and Agriculture Organization (FAO) has computed SDG 15.4.2 (Mountain Green Cover Index: MGCI) for countries using satellite-based global land cover data and has requested countries to verify the estimations. In this report, the methodology to reproduce FAO's estimated values was confirmed and the indicator was estimated using the data that Japan owns. The accuracy of the indicator was verified by comparing it with the FAO estimation. From this accuracy verification, it was found that FAO's estimation was overestimated for the Kapos mountain classes (Kapos 2, Kapos 3, and Kapos 4). Its rationale is provided from the quantitative and qualitative point of view and its alternative estimation together with statistical measures to verify and improve its accuracy are proposed.

Keywords: SDGs, Mountain Green Cover Index (MGCI), Earth observation data, geospatial information, land cover, Kapos mountain classification, classification accuracy.

This paper summarizes the results of verification conducted by the Working Group on Validation of Methods of Using Observation Data for SDG Indicators, which was launched under the Industry-Government-Academia Partnership Meeting for Promotion of the Use of Big Data held by the Ministry of Internal Affairs and Communications (MIC). We would like to express our gratitude to TSUMURA Akira, OGAWA Tomoaki, and ARITA Chika of the MIC as well as TADONO Takeo, OCHIAI Osamu, and HARADA Mariko of the Japan Aerospace Exploration Agency for their valuable advice. In addition, we would like to thank the Ministry of Foreign Affairs; Ministry of Education, Culture, Sports, Science and Technology; Ministry of Agriculture, Forestry and Fisheries (MAFF); and Ministry of the Environment (MOE) as cooperating ministries. We would also like to express our appreciation to the Biodiversity Center of Japan, Natural Environment Bureau, MOE for providing us with vegetation survey polygon data as well as the Statistics Department, Minister's Secretariat, MAFF for providing us with cropland lot data. Please note that the content of this paper and any opinions indicated herein belong to the authors personally and do not represent the official views of their affiliated organizations or the MIC. All possible errors are the authors' own.

Contents

1. Introduction

1.1 Backgrounds and purpose of SDG15.4.2 verification

The 2030 Agenda for Sustainable Development adopted at the UN Summit in September 2015 presents the resolution of international societies including the developing and developed countries to collaborate to solve issues toward sustainable development with a basic concept of "Leave no one behind" and set the SDGs as its core. Country leaders considered in agreeing to the agenda that it is necessary to promote sustainable development with a strategy based upon evidence and data. For that reason, 169 targets and 242 (232 when duplication is removed) indicators are set.

Article 76 of the Agenda2030 depicts the use of a wide range of data, including Earth observation and geospatial information. It should be noted that Japan proposed to include Earth observation and it was adopted in the negotiation of the text. Earth observation and geospatial information include satellite, aircraft, ships, ground-based observation data and model output data, which provide the possibility of monitoring at local, national, regional, and global scales, and across sectors. There are increasing expectations for the integration of Earth observation and geospatial information with statistical systems of UN and National Statistical Offices (NSOs). Earth observation satellite data has features to be able to monitor wide areas consistently and in repetition, but has inherent challenges that the data is huge and its analysis is complex. To use Earth observation satellite data for the computation of SDG indicators, it is essential to verify its accuracy and assess if it can be fit for the purpose.

The Inter-Agency Expert Group of SDG Indicators (IAEG-SDGs) for which the UN Statistical Division serves as secretariat, is responsible for the global indicator framework. The Working Group on Geospatial Information (WGGI) studies the use of satellite data and geospatial information for the indicator calculation and provides advices and guidance to the IAEG-SDGs. The Japan Space Exploration Agency (JAXA) is serving as co-chairs of the SDGs initiative, EO4SDG, of the intergovernmental Group on Earth Observations (GEO), together with NASA and Mexico's National Institute of Statistics and Geospatial Information (INEGI). JAXA was invited to the WGGI together with NASA and ESA and has been participating in the study of the application of Earth observation satellite data for the assessment of SDG indicators. In Japan, under "The Industry-Government-Academia Partnership Meeting for Promotion of the Use of Big Data"[MIC Big Data meeting], "The Working Group on Validation of Methods of Using Observation Data for SDG Indicators" was established to verify indicators based upon Earth observation data and geospatial information in cooperation with the Transdisciplinary Federation of Science and Technology (a federation of 34 societies including the Japan Statistical Society, and the Remote Sensing Society of Japan) and related ministries and agencies, to see if they can be authorized as data to be used for the government's SDG indicator calculation.

In 2020, FAO had calculated SDG15.4.2 of countries (June 29, 2020) using designated methodology and data and had requested countries to verify it. In this article, the results of verifying the FAO estimation using FAO's methodology and designated data are reported. In the metadata, it is recommended to use the country's own land cover data if it is available. In this report, the high-resolution land use and land cover data produced by JAXA and the Shuttle Radar Topography Mission (SRTM) data were used as alternative data to calculate

SDG15.4.2. Fundamental Geospatial Data/high-resolution DEM（10m resolution）made available by the Geospatial Information Authority of Japan (GSI) was used to verify the relevance of the SDG 15.4.2.

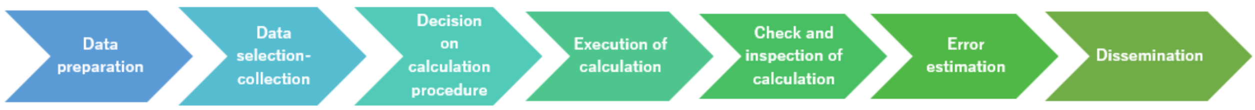
The purpose of SDG15.4.2 Mountain Green Cover Index (MGCI) is to assess the conservation of biodiversity recognizing the difference of vegetation according to the mountain classification, by calculating the MGCI for the mountain classes (Kapos mountain classification) considering their altitudes and slope ranges.

Particularly, in this work, a comparison between public values estimated by FAO and reproduced values based upon data Japan owns was made. Quantitative assessment was made to see how much difference exists between the two estimates and evaluation of the accuracy of FAO's public values. In addition, if a large difference is found in the FAO's estimates from the states of Japan, its quantitative and qualitative rationales, its corrected values, and methodologies are presented as the objective of this task.

1.2 Process of verification

As shown in Figure/Table 1(F/T-1), we introduced a workflow of the verification task consisting of seven steps such as data preparation, data selection-collection, decision on calculation procedure, execution of calculation, check and inspection of the calculation procedure, error estimation, and dissemination for calculating indicators. For contentiously improving verification task quality of SDG15.4.2, we introduced redundancy for each step by combining with other steps and repeating work. Our fundamental policy was to verify errors in the indicator estimates and to evaluate the errors, by multiple tasks done by different members of staff with different software programs.

Figure/Table-1（F/T-1) Concept of indicator calculation task



For the data preparation and the data selection-collection step, we performed data quality checks. Specifically, we tracked data corruption during data transfer by comparing data analysis results in different members and sites. In the decision of calculation procedure step, we compute indicators with different calculation software programs. Throughout the documentation of calculation procedures, we confirmed the reproducibility of the calculation or by comparing the calculation results of different software programs and also verified the calculation errors.

For the decision of the calculation procedure, execution of calculation, check, and inspection of the calculation procedure, and assessment of errors, we carefully introduced the following steps for the task.

In general, SDG indicators are calculated by integrating different data obtained from several different sources. For data to be used for the estimation of the indicators, although the meaning of data is similar, there exist some data sets provided by the different organizations with different measurement processes. For this reason, depending upon the data to be used, there is a possibility of producing a difference in the estimated indicators. This is an issue with data quality. To improve data reliability, we introduced data quality indicators quantitively defined and compared data with the same meaning from different data sources spatially. In particular, the Kapos mountain classification data and land use/land cover data are used for the MGCI calculation. Based upon the inferential statistics we computed the MGCI indicators by estimating population proportion from sample proportion of vegetation pixels calculated from land use/land cover map for specified Kapos mountain class. It is, therefore, important for the sake of assessing errors of the estimated value to estimate the sampling errors deriving from the limited amount of data. By calculating 95% confidence interval using data with different data quality from the theory of indicator calculation, we conducted a reliability assessment for each data used for the indicator estimation based upon not only point estimation but also confidence interval.

In addition, it is known that land use/land cover data identified from satellite imageries with some classification algorithms contain classification errors. The classification error can be quantitatively assessed by producing a confusion matrix that compares automatic classification results with those derived from classification based upon validation. We developed a statistical method to correct the estimated population proportion by using sample conditional probability obtained from the confusion matrix and we compute we computed the MGCI values with the developed correction method for reducing the influence of land cover classification errors.

The volume of satellite data is enormous, and it is very difficult to make a visual inspection to find data corruption when data corruption happens during data transfer. It is necessary to make sure that there is no data corruption occurring by taking measures to check parity at data transfer (check by data file size and file checksum) and data consistency check (comparison of estimation results at sending side and receiving side). In particular, we accessed the JAXA land cover data FTP site from different organizations and shared satellite data as tiles, we experienced that the number of tiles downloaded from the FTP site was smaller than the number of tiles to cover the whole of Japan (a tile is a basic unit of land cover data that covers 1 deg x 1deg area). Parity checks and data consistency checks were made repeatedly to cope with this issue. Throughout the whole analysis, frequent data volume checks were checked and compared, by comparing the numbers of pixels that belong to specific mountain classes before and after the data transfer, a consistency check was also made. This is an issue of workflow and operations during the calculation, and it was confirmed from this verification task that quality management of various process steps in counting, data management, and information system is just as important as data quality.

The indicator calculation requires the processing of multiple data with multiple computer programs and software and involves a lot of human manual operations which can introduce errors in the calculation. Such operational errors may strongly influence estimated values and their errors in the entire calculation results. To reduce the influence of operational errors, automatic execution of the task by programable computer software and error detection by multiple checks are necessary. There can be issues with computer software: e.g., errors in the algorithm of calculation software, software bugs, insufficient understanding of the application of calculation algorithm. Hence, it is extremely important to enhance the understanding of operators of software, software qualification, and prior verification using test data, capacity development of workers by training, seminar, and practices.

For the sake of count procedure check and inspection, and error evaluation, verification work was conducted incorporating the opinion of multiple verification task members and narrowing down areas to be verified at the Observation Data Promotion and Verification Working Group. The calculation task was conducted by different members and software in two control groups, independently checking errors in the calculation process and the calculation program, thereby ensuring reliability in the verification task.

This guidance document for disseminating the indicator was prepared from the verification work reports clarifying the quantitative results for the indicator verification and the indicator calculation procedure.

2. Outline of SDG15.4.2

2.1 Goal15, Target 15.4 and Indicator 15.4.2

Under Goal 15, target 15.4 aims at conservation of mountain ecosystems and set the indicator 15.4.2 Mountain Green Cover Index (MGCI) as follows; [MOFA Japan SDGs Action Platform]

Goal 15 ：
Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Target 15.4 ：
By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development.

Indicator 15.4.2： *Mountain Green Cover Index*

2.2 Outline of SDG15.4.2 metadata

For calculation of SDG15.4.2 Mountain Green Cover Index (MGCI), the Kapos mountain classification data and land cover data are necessary. The Kapos mountain classification data is produced from a digital elevation model (DEM) data derived from satellite data and made accessible by FAO and USGS.

Land cover data are produced from US Landsat data, JAXA’s ALOS data, ESA’s Sentinel data, etc. SDG15.4.2 may vary depending on the characteristics and quality of data to be used for the calculation.

The UN Food and Agriculture Organization (FAO), Custodian Agency of SDG15.4.2, 6released the latest metadata (February 14, 2021) which defines the methodology and data to be used for the indicator calculation [FAO HP].

The following section describes the data and methodology to be used for the indicator calculation.

2.3 Data to be used

2.3.1 Mountain classification data

F/T-2 shows altitude zones of the Kapos mountain classification and the ratio of the land areas of mountain classes for Japan. Kapos et al (2000) [Kapos(2000)] classified the mountain areas into 6 classes by altitude, slope and Local Elevation Range (LER). The mountain classes Kapos 2 to Kapos 6 are applicable to Japan where the altitude is lower than 4500m. Because of slope and LER requirements, flat areas in high altitude zone are excluded from the mountain areas.

The Kapos mountain classification data can be downloaded from FAO Mountain Partnership HP [FAO Kapos] and USGS site [USGS Kapos]. It should be noted that the reference to FAO's Kapos mountain classification data has been removed from the latest metadata.

F/T-2 Kapos mountain classification, its decisive factors, and the ratio of mountain classes in Japan

Mountain Class	Description	Ratio of mountain in Japan (%)
0	Elevation < 300 meters	54
1	Elevation > 4.500 meters	0
2	Elevation 3.500–4.500 meters	0
3	Elevation 2.500–3.500 meters	0
4	Elevation 1.500–2.500 meters and slope > 2	2
5	Elevation 1.000–1.500 meters and slope > 5 or local elevation range (LER 7 kilometers radius) > 300 meters	6
6	Elevation 300–1.000 meters and local elevation range (7 kilometers radius) > 300 meters	38

In Japan, Kapos 2 area exists only at the summit of Mt. Fuji and Kapos 3 areas are high altitude mountain areas. The ratio of Kapos 2 area and Kapos 3 area are approximately 0. Area of Kapos 0 which is under 300m altitude is 54%, ratios of Kapos 4, Kapos 5, and Kapos 6 areas are 2%, 6%, and 38% of the total land of Japan.

Two Kapos mountain classification data originated from satellite data analysis, one of FAO[FAO Kapos] and the other of USGS[USGS Kapos], are compared in mountain areas of Kapos classification in Japan to see the difference in their data characteristics. F/T-3 shows the ratio of areas of Kapos mountain classes against total land area (Statistical reports on the land area by prefectures and municipalities in Japan (MLIT GSI)) as of July 1, 2020, 377,976.94km^2[MLIT GSI land area report].

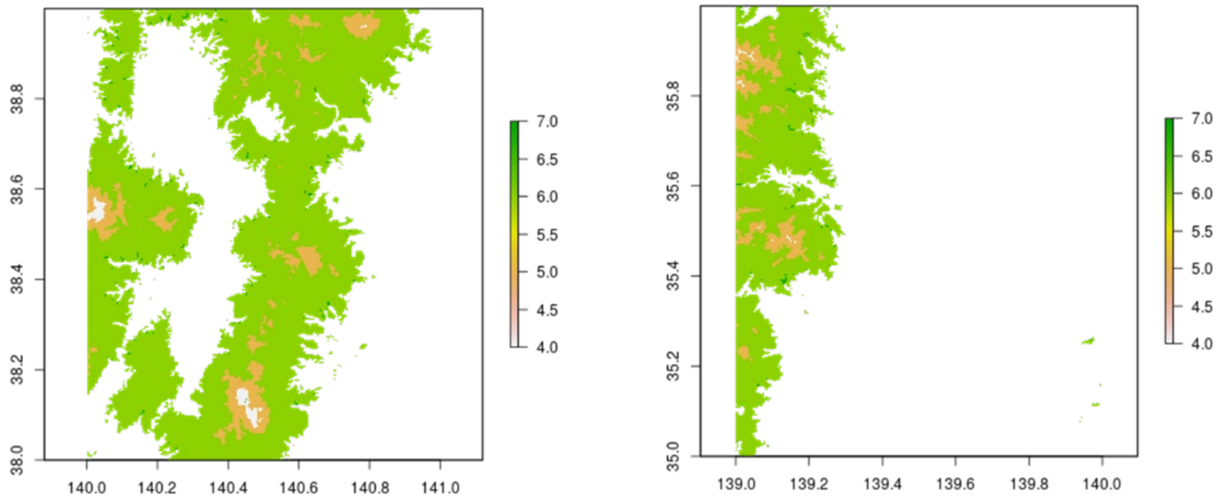
F/T-3 Areas of Kapos mountain classes and their ratios against the total land area of Japan

Kapos mountain classification	FAO Mountain (km^2)	USGS K1class data (km^2)
Kapos 2	1.94 (5.13×10^{-4} %)	1.73 (4.57×10^{-4} %)
Kapos 3	309.67 (0.0819%)	314.56 (0.0832%)
Kapos 4	7431.89 (1.966%)	7443.57 （1.969%)
Kapos 5	21970.27 (5.812%)	21914.79 (5.798%)
Kapos 6	143248.83 (37.90%)	145037.73 (38.37%)

F/T-3 shows that there exists a minor difference of data in the Kapos mountain classes made available independently by FAO and USGS. The ratios of Kapos 2 and Kapos 3 areas indicate extremely small areas exist. The Kapos 2 area is at the summit of Mt. Fuji with less than 2km^2 and the Kapos 3 areas are rare places at high altitude mountain summits which occupy only 310km^2 approximately.

Examples of tile (1 deg x 1deg) of USGS's Kapos mountain classification map are shown. F/T-4 are of Miyagi Prefecture (N38, E140) and Kanagawa Prefecture (N35 E139). It shows areas of the higher Kapos mountain class surrounded by those of lower mountain classes.

F/T-4 Examples of Kapos mountain classification maps provided by USGS: Miyagi Prefecture (left) and Kanagawa Prefecture (right)



2.3.2 Land cover data

Land cover areas are categorized as green areas and non-green areas. FAO uses land cover time series produced by the European Space Agency (ESA) under the Climate Change Initiative (CCI). The original CCI classes are re-classified into six IPCC classes and further into binary green/non-green classes. Previously FAO re-classified "Wetland" to non-green, but changed to green in the revised metadata (as of December 14, 2020).

F/T-5 ESA CCI land cover classification, IPCC classes and green/non-green categories

ESA CCI class	IPCC class	Green / Non green
50, 60, 61, 62, 70, 71, 72, 80, 81, 82, 90, 100	Forest[1]	Green
110, 120, 121, 122, 130, 140,	Grassland	Green
10,11, 12, 20, 30, 40	Cropland	Green
160, 170, 180	Wetland	Green
190	Settlement	Non Green
150, 151, 152, 153, 200, 201, 202, 210, 220	Other land	Non Green

[1] Please note, that here the term "Forest" refers to land cover, not necessarily land use.

2.3.3 Administrative unit data

Some different datasets are available for administrative unit data which defines the national border. The following links are examples of global administrative unit data. Country data can be downloaded from FAO's Global Administrative Units Layer (GAUL) site.

- FAO Global Administrative Units Layer (GAUL) https://data.europa.eu/euodp/data/dataset/jrc-10112-10004
- Divas-GIS https://www.diva-gis.org/gdata
- UN Second Administrative Level Boundaries (SALB) https://www.unsalb.org/

2.4 Methodology

2.4.1 Definition of Mountain Green Cover Index (MGCI)

The Mountain Green Cover Index is defined as

$$MGCI = \frac{Mountain\ Green\ Cover\ area}{Total\ \ Mountain\ Area} \times 100,$$

where Mountain Green Cover area is defined as total areas covered by Cropland, Grassland, Forest and Wetland land cover classes according to the latest metadata (February 14, 2021).

Initially, the metadata only included the definition of MGCI which calculates the ratio of areas of green cover and total mountain areas. The revised metadata (February 14, 2021) includes a computation method that is based upon the number of pixels.

$$MGCI = \frac{Number\ of\ Mountain\ Green\ Cover\ pixels}{Total\ Number\ of\ Mountain\ Area\ pixels} \times 100$$

In general, there exist several definitions for calculation methods of the area. The first one defines the area on the reference ellipsoid (Earth Ellipsoid which is fitted the surface of Earth's elevation 0m, namely geoid). This area definition has the merit that it does not depend upon land topography, but it has an issue that it does not represent the actual surface area of vegetation that grows on the land topography surface. The second one defines the surface area as area. When the surface area definition is adopted, generally area depends upon spatial resolution that observes the topographic ruggedness. The surface area simply increases if the topography is monitored with higher resolution (land surface ruggedness exists at micron order). Therefore, accurately calculating the surface area is not practical theoretically.

To avoid this issue of area definition, land cover classification by satellite image analysis can be considered as geospatially uniform sampling survey, land cover classification pixels can be considered as samples for population to estimate population proportion defining the MGCI, which is the methodology to use number of pixels.

2.4.2 Calculation method

The indicator value can be calculated as follows：

I. The ESA CCI land cover classes are reclassified into six IPCC classes and Green/Non-Green cover map.

II. The Kapos Elevation Ranges map is overlaid on top of the map resulting from step 1.

III. The zonal histogram is calculated for each country and regional grouping in such a way that the number of pixels belonging to green and non-green classes is counted within each elevation range.

IV. The ratio (%) between the sum of the green pixels and the total number of pixels (green plus non-green) falling within each Kapos is calculated to obtain MGCI values per each Kapos class.

V. The same procedure is used to calculate the distribution of the land cover classes as defined by IPCC within each elevation range.

3. Verification of FAO estimation

MGCI calculation results using ESA land cover data (300m resolution), Kapos mountain classification data (250m resolution), and FAO's Global Administrative Unit Layer data were shown for 2000, 2010, 2015 and 2018 together with the MGCI estimation by FAO as follows:

3.1 Estimation of MGCI by area

Procedure to calculate mountain green cover area and total mountain areas and MGCI using open and free QGIS software is shown as follows:

Using GAUL data of Japan, data of Japan are clipped from ESA land cover data and Kapos mountain classification data.

I. Using QGIS raster calculator, produce mask image of Kapos mountain classification, Kapos 1 to Kapos 6.

II. Land cover data are overlaid with each mountain class mask image and land cover data of Kapos 1 to Kapos 6 are produced.

III. Transform the raster image data to polygon data.

IV. Using QGIS GroupStats function, calculate areas of land covers data of Kapos 1 to Kapos 6.

V. The same procedure is used to calculate the distribution of the land cover classes as defined by IPCC within each elevation range.

F/T-6 Example of MGCI calculation of the Kapos mountain class from land cover data (The figure shows the case of Kapos 6)

Land cover data | Mountain class mask | Land cover for respective mountain class

The Result of MGCI calculation based upon area are shown in F/T-7

(a) change of re-classification of wetland from non-green to green category

In verifying the results of FAO's MGCI estimation as of Oct 2020, it was found that the sum of the green-cover categories (Forest, Cropland, Grassland) did not match with the MGCI for respective Kapos classes and also that FAO calculated the MGCI with wetland included in the green-cover. FAO clarified that wetland is included in the green category according to the IPCC standard and the inconsistency with the description of the metadata was identified.

When MGCI was re-calculated with wetland included in the green cover, a fairly good agreement with the FAO estimation was confirmed. After that, FAO revised the metadata as of December 14 2020 in which wetland was reclassified as green cover.

(b) change of application method of map projection

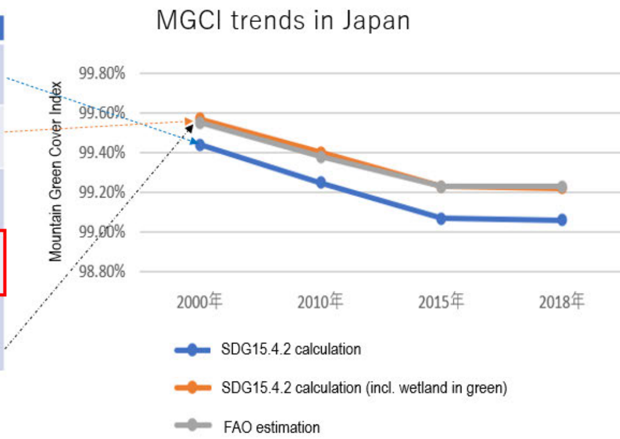
The UTM54 was used in the calculation of MGCI for Japan. However, UTM52/53/54 map projections should have been used to cover the entire area of Japan. Comparison of the calculated areas between when UTM 54 was applied and when UTM52/53/54 were applied and the impact on the MGCI calculation was assessed as shown in Supplement A.3. The MGCI calculated with UTM52/53/54 map projections is shown in F/T-7.

3.2 Estimation of MGCI by number of pixels

In the MGCI calculation based upon the area in 3.1, from mask images produced with I. land cover data and II. Kapos mountain classification data (Kapos 1 to Kapos 6), using QGIS zone histogram function, numbers of pixels for land covers were calculated and the ratio between the number of mountain green cover pixels and a total numbers of mountain areas pixels was calculated (F/T-7 and Annex F/T-2). The difference from the FAO estimation was within 0.1% and fairly good agreement with the FAO estimation was confirmed. From this, it was considered possible to reproduce the FAO estimation using the data and methodology defined in the metadata.

F/T-7 Summary of FAO estimation verification (left) and MGCI trend for Japan (right)

Year	2000	2010	2015	2018
SDG15.4.2 calculation	99.44 %	99.25 %	99.07 %	99.06 %
ditto (incl. wetland in green)	99.57%	99.40%	99.23%	99.22%
UTM52/53/54 applied to 3 regions	99.56%		99.23%	
Calculation based on number of pixels	99.56%	99.38%	99.22%	99.22%
(reference) FAO estimation	99.55 %	99.38 %	99.23 %	99.23 %



The SDG15.4.2 of Japan for 2015 is shown in F/T-8 from FAO's disseminated MGCI estimation [FAO SDG15.4.2 Data]. The Kapos 2 area (3500m-4500m) exists at the summit of Mt. Fuji and its area is approximately 1.98km^2. As reported in detail in Article 4, a report by the Ministry of the Environment [MOE report] indicates seasonal variability of vegetation at the mountain summit during summer time (June to November). It seems that vegetation of several percent to approximately 10% when moss is included exists. These are bare areas. For this, forest and cropland for the Kapos 2 area is 0 % and it may be relevant to estimate SDG15.4.2 for the Kapos 2 mountain class at several percent.

F/T-8 Public values of SDG15.4.2 for Japan by FAO (2015)

IPCC class	Kapos mountain class					
	1	2	3	4	5	6
Forest	0.00	20.00	58.89	89.37	94.16	91.10
Cropland	0.00	66.67	33.57	6.34	3.01	4.94
Grassland	0.00	0.00	6.95	3.57	2.03	3.01
Wetland	0.00	0.00	0.35	0.40	0.48	0.08
Settlement	0.00	0.00	0.00	0.00	0.02	0.51
Other land	0.00	13.33	0.24	0.32	0.28	0.36
MGCI(Overall)	0.00	86.67	99.76	99.68	99.69	99.13

4. Estimation of SDG15.4.2 using alternative data that Japan has

If countries have national land cover maps of higher spatial resolution and comparable or better quality, FAO advises using them, following the same methodology presented here, for the generation of MGCI values. In this analysis, the high-resolution land use and land cover map data of JAXA (hereafter "JAXA land cover data", 250m, 100m, 50m/30m resolutions) was used.

Matching the resolution of the JAXA land cover data, the Kapos mountain classification data accessible at

FAO Mountain Partnership HP (Kapos-FAO, 430m resolution), USGS's Kapos mountain classification data (Kapos-USGS, 250m resolution) and Kapos mountain classification data which were produced by JAXA from SRTM 90m DEM data (Kapos-SRTM, 90m resolution, see Supplement A.2) were used.

As for administrative unit data, FAO's GAUL is not relevant for Japan since its northern island territories, Ogasawara islands, Sakishima Islands, etc. are missing from the map. Here high-resolution coast line data provided by GSI (resolution higher than 10m, see Supplement A.1) and Global Map (1km resolution) [Global Map] and MLIT National Digital Information Administrative Area data [MLIT National Digital Information] were used.

4.1 Used data:

4.1.1 Land cover data

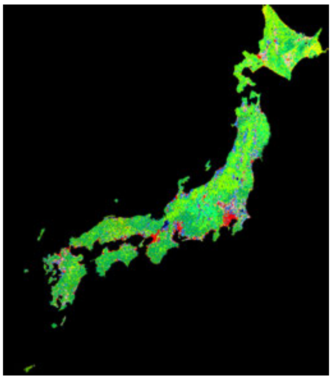
JAXA land cover data (2006-2011, 2014-2016 and 2018-2020, 250m, 100m and 50m/30m resolution, original resolution is 10m for 2006-2010 and 2018-2020, and 30m for 2014-2016) is used. F/T-9 shows JAXA land cover data, its relation with the IPCC classification and binary green/non-green classification for Japan.

https://www.eorc.jaxa.jp/ALOS/lulc/lulc_jindex.htm

F/T-9 JAXA land cover data, its relation with the IPCC classification and binary green/non-green classification for Japan

JAXA class (Digital number)	IPCC class	Green/Non green
6,7,8,9,11*	Forest	Green
5	Grassland	Green
3,4	Cropland	Green
Not applicable	Wetland	Green
2	Settlement	Non green
1, 10, 12＊	Other land	Non green

＊11(Bamboo) and 12 (Solar panels) are available only for 2018-2020



4.1.2 Mountain classification data

The Kapos-FAO mountain classification data (430m resolution) can be downloaded from FAO's Mountain Partnership HP [FAO Kapos]. Kapos-USGS mountain classification data (250m resolution) is made available by USGS. For Kapos-SRTM mountain classification data (90m resolution), please see Supplement A.2.

4.1.3 Administrative unit data

Japan coastline data (higher than 10m resolution), Global Map (1km resolution) and MLIT Land Digital Information administrative unit data were used. For the Japan coast line data, please see Supplement A.1.

4.2 Estimation of SDG 15.4.2 using JAXA land cover data

The summary of the SDG15.4.2 computation results is shown in F/T-10.

F/T-10 SDG15.4.2 computation result summary using JAXA land cover data

	Mountain classification data	Land cover data resolution	2006-2011	2014-2016	2018-2020
Calculation based on area	Kapos-FAO (430m)	250m	98.57 %	98.65 %	
		100m	98.37%	98.67%	
		100m	98.35%	98.63 %	
		50/30m	98.23%	98.61%	
Calculation based on number of pixels		250m	98.51%	98.62%	
		100m	98.31%	98.62%	
	Kapos-USGS (250m)	250m	98.52%	98.63%	98.48%
		100m	98.33%	98.63%	98.30%
	Kapos-SRTM (90m)	100m	98.32%	98.63%	98.30%
		50/30m	98.22%	98.63%	
(reference) FAO estimation		300m	(2010) 99.38 %	(2015) 99.23 %	(2018) 99.23%

Divided to three regions applying Kapos-SRTM mountain classification data

Index was calculated for all the resolutions by number of pixels. For higher resolution than 100m, Kapos-SRTM mountain classification data was used

The MGCI calculation using JAXA land cover data (2006-2011, 2014-2016, 2018-2020, 250m, 100m, 50m/30m resolution) resulted in 98.23-98.67% for calculation based upon area (FAO estimation: 99.23-99.38%) and 98.22-98.63% for calculation based upon number of pixels, more than 1% lower than FAO estimation (F/T-10). It also shows a trend in which MGCI becomes smaller as the resolution of land cover data and Kapos mountain classification data are higher.

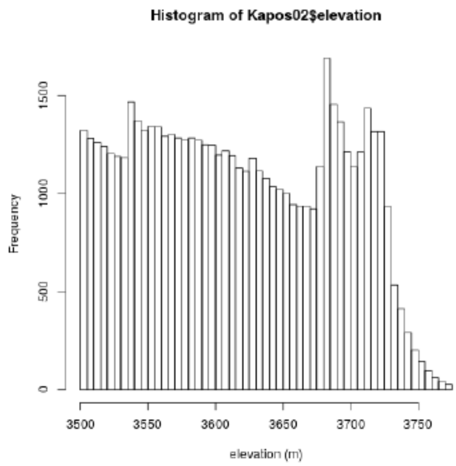
The MGCI for Kapos 2 mountain class (3500m-4500m) is 0, that of Kapos 3 mountain class (2500m-3500m) was considerably smaller than the FAO estimation. It seems that JAXA land cover data represents the real situation more accurately. The index for Kapos 4, Kapos 5 and Kapos 6 mountain classes, MGCI was smaller than the FAO estimation (Annex F/T-2 and Annex F/T-3).

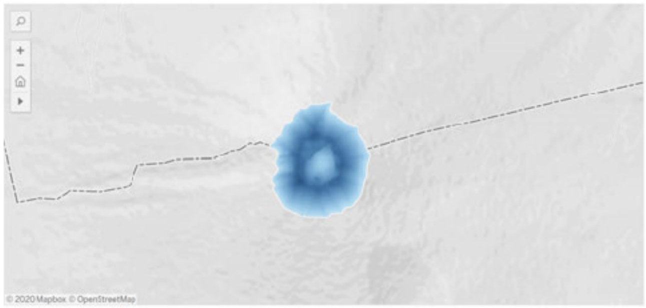
4.3 Comparison with FAO estimation

FAO disseminates the SDG15.4.2 estimations of countries every year [FAO Kapos DATA]. F/T-8 shows land cover ratio and mountain green cover ratio for 2015 Kapos mountain classes. From this table, in spite of the fact that the Kapos 2 mountain class (3500-4500m) in Japan only exists around the summit of Mt. Fuji and that the area is bare land with little vegetation cover, the MGCI is estimated at 86.67% and it also suggests that 66.67% cropland exists. This could be an overestimation. Similarly, for the Kapos 3 mountain class(2500m-3500m), the MGCI is 99.76% with forest occupying 58.89% and cropland 33.57%. The forest limit in Japan is 2500-2800m in Japan Alps and the Central Alps, 2000m in Kyushu and Shikoku Islands. Most of the Kapos 3 mountain class areas are located above the forest limit. However, forest and cropland occupy a larger ratio and there is a possibility that the MGCI is overestimated. For this discrepancy, there is a possibility that either vegetation classification data contains large classification errors or data are displaced in longitude and latitude.

To investigate this, the vicinity of the Mt. Fuji's summit which is an area of Kapos 2 mountain class was identified using GSI's Fundamental Geospatial Data 5A[GSI Fundamental Geospatial Data] . F/T-11 shows the Kapos 2 mountain class area covered with the 57245 grids (0.2 second deg. X 0.2 second deg.), of which area is 1.781510km^2 and its histogram.

F/T-11 Area of Kapos 2 mountain class in Japan. Extracted from GSI Fundamental Geospatial Data/Fundamental Geospatial Data 5A (0.2 sec deg x 0.2 sec deg)





Reference was made to the vegetation survey result based upon field observation at the summit of Mt. Fuji. There is a description referring to the area in the Monitoring site 1000 high mountain area survey 2008-2017 report (Biodiversity Center of Japan, Natural Environment Bureau, Ministry of the Environment). A field survey report of the MOE plots A, C, D was made. For subquadrat, average number of species are 0.4, 0.6, and 0.7 species, their vegetation cover ratio is 1.5%, 1.9% and 1.2% respectively, rock/sand ratio is 96.9%, 82.4% and 85.2% and in addition moss was seen for 1.6%, 15.8% and 12.5%. It is further reported that the area is frozen from November to May and seasonal variability of vegetation cover ratio was seen.

F/T-12 is a photo that shows the Mt. Fuji site in the report of the Biodiversity Center of Japan, Natural Environment Bureau, MOE. From this photo, it is understood that Mt. Fuji's summit is covered with rocks and sands and very little vegetation is seen among them.

F/T-12 Photo of the Mt. Fuji's summit (extracted from the Monitoring site 1000 Alpine zone survey 2008-2017 report)

6. Mt. Fuji site

Vicinity of the summit
photo taken on Aug 27, 2011

Among estimations disseminated by FAO, the MGCI for Kapos 2 mountain areas in Japan is 86.667% for 2000, 2015 and 2018. The estimation is very far from the scene of the Mt. Fuji's summit. From the estimation of the MOE Alpine zone observation site at Mt. Fuji summit, the estimation should be several percent in the summer time and 0 for the winter season because the area is frozen.

FAO used the ESA CCI land cover data of the Mt. Fuji summit for computing MGCI estimates. It was found that there is no error in spatial matching, but land covers classes for the Kapos 2 area of Mt. Fuji summit are water (3 pixels 7%), cropland or grassland (26 pixels, 66.6%), forest in mosaic (10 pixels, 25%). From this, land cover classification of ESA CCI data is far from reality and is identified as the cause of the overestimation of MGCI. In general, the Alpine zone above the forest limit is bare areas with no vegetation cover, and hence there is concern that the FAO estimation based upon the binary green/non-green classification using ESA CCI land cover data may be overestimated for Alpine areas generally.

5 Impact of sampling errors and classification errors on MGCI

In the methodology to compute the MGCI from the ratio of a number of green cover pixels to the total number of pixels, land cover pixels as identified by satellite observations can be considered as samples. Then, the population proportion for the MGCI is estimated by sample proportion. Further, land cover data produced by automatic classification from satellite images contains classification errors and its accuracy is evaluated from the confusion matrix. The purpose of this section is to clarify a mathematical statistical formalization to estimate the MGCI value from samples and to show an error correction method and 95% confidence interval, error assessment values of the MGCI empirically.

5.1 Estimation of population proportion by sample proportion

Suppose that the MGCI for each Kapos mountain classification is approximated as a ratio with the number of green cover pixels to the total number of pixels in each Kapos mountain classification area, where land classification grid data and Kapos mountain classification grid data are given as data products computed from satellite images. Then, sampled proportion $\hat{p}_i$ for the MGCI of the i-th Kapos mountain class can be given by the following equation,

$$\hat{p}_i = \frac{\sum_{t=1}^{N_i} X_i(t)}{N_i},$$

where N_i is the total number of pixels for the i-th Kapos mountain class areas and $X_i(t)$ is green cover classification at monitoring site t.

If monitoring site t located in the Kapos mountain class i is green, then one has $X_i(t)=1$, otherwise, $X_i(t)=0$.

Sample proportion $\hat{p}_i$ is the estimation of population proportion p_i for the i-th Kapos mountain class, where population proportion is the true MGCI.

Furthermore, $R(a|b)$ is defined as conditional probability of classified value (classified) a, which is represented as dichotomous variable a={1: green, 0: non-green} conditioning on real value (validated) b, which is represented as dichotomous variable b={1: green, 0: non-green}. Suppose that $X_i(t)$ is random variable as follows:

$$X_i = \begin{cases} 1 & w.p.\ R(1|1)p_i + R(1|0)\,(1-p_i) \\ 0 & w.p.\ R(0|0)(1-p_i) + R(0|1)p_i \end{cases}$$

This equation means that estimation errors in MGCI can be derived from two types of errors: sampling error and classification error. $R(a|b)$ can be computed as follows, where the confusion matrix is provided as in F/T-13.

$$R(0|0) = \frac{TN}{FP+TN},\ R(1|0) = \frac{FP}{FP+TN}$$

$$R(0|1) = \frac{FN}{TP+FN},\ R(1|1) = \frac{TP}{TP+FN}$$

where, TP, FP, TN, and FN are numbers of observations for the conditions matched in the 2 times 2 confusion matrix for the green/non-green binary classification.

F/T-13 Confusion matrix for green/non-green binary classification

		validated b	
	a / b	Green (b=1)	Non green (b=0)
classified a	Green (a=1)	TP	FP
	Non green (a=0)	FN	TN

The following characteristics are introduced from the definition of conditional probability.

$$R(a|b) = \frac{p_{AB}(a,b)}{p_B(b)},$$

$$p_{AB}(a,b) = R(a|b)p_B(b),$$
$$p_A(a) = \textstyle\sum_b p_{AB}(a,b) = \sum_b R(a|b)p_B(b),$$
$$p_A(1) = \textstyle\sum_{b=0,1} R(1|b)p_B(b) = R(1|1)p_B(1) + R(1|0)p_B(0),$$
$$p_A(0) = \textstyle\sum_{b=0,1} R(0|b)p_B(b) = R(0|0)p_B(0) + R(0|1)p_B(1),$$

where for the MGCI estimation for the i-th Kapos mountain class, we may set $p_B(1) = p_i$ and $p_B(0) = 1 - p_i$.

5.2 Formulation of MGCI estimation error

Suppose that $X_i(t)$ is the following the Bernoulli random variable.

$$X_i = \begin{cases} 1 & w.p.\ R(1|1)p_i + R(1|0)\,(1-p_i) \\ 0 & w.p.\ R(0|0)(1-p_i) + R(0|1)p_i \end{cases},$$

where

$$Z_i = \sum_{t=1}^{N_i} X_i(t).$$

Z_i is sampled from the binominal distribution $B(N_i, R(1|1)p_i + R(1|0)(1-p_i))$. If N_i is large enough, then the binominal distribution can be approximated with normal distribution with mean $N_i(R(1|1)p_i + R(1|0)\,(1-p_i))$ and variance $\left(R(1|1)p_i + R(1|0)\,(1-p_i)\right)(R(0|0)(1-p_i) + R(0|1)p_i)$. From this, sample proportion may be sampled from normal distribution with mean $R(1|1)p_i + R(1|0)\,(1-p_i)$ and variance $\left(R(1|1)p_i + R(1|0)\,(1-p_i)\right)(R(0|0)(1-p_i) + R(0|1)p_i)/N_i$. Thus, mean of the sample proportion $\mathrm{E}[\widehat{p_i}]$ is computed as,

$$\mathrm{E}[\widehat{p_i}] = R(1|1)p_i + R(1|0)\,(1-p_i).$$

From this equation, population proportion p_i is corrected as follows:

$$p_i = \frac{\mathrm{E}[\widehat{g_i}] - R(1|0)}{R(1|1) - R(1|0)}$$

Further, the confusion matrix is also the estimation of population proportion by sample proportion and contains sampling error. Therefore, 95% confidence interval of each element of the confusion matrix can be calculated as follows:

$$\frac{TN}{FP+TN} - 1.96\sqrt{\frac{TN}{FP+TN}\left(1-\frac{TN}{FP+TN}\right)/(FP+TN)} \leq R(0|0)$$

$$\leq \frac{TN}{FP+TN} + 1.96\sqrt{\frac{TN}{FP+TN}\left(1-\frac{TN}{FP+TN}\right)/(FP+TN)}$$

$$\frac{FP}{FP+TN} - 1.96\sqrt{\frac{FP}{FP+TN}\left(1-\frac{FP}{FP+TN}\right)/(FP+TN)} \leq R(1|0)$$

$$\leq \frac{FP}{FP+TN} + 1.96\sqrt{\frac{FP}{FP+TN}\left(1-\frac{FP}{FP+TN}\right)/(FP+TN)}$$

$$\frac{FN}{TP+FN} - 1.96\sqrt{\frac{FN}{TP+FN}\left(1-\frac{FN}{TP+FN}\right)/(TP+FN)} \leq R(0|1)$$

$$\leq \frac{FN}{TP+FN} + 1.96\sqrt{\frac{FN}{TP+FN}\left(1-\frac{FN}{TP+FN}\right)/(TP+FN)}$$

$$\frac{TP}{TP+FN} - 1.96\sqrt{\frac{TP}{TP+FN}\left(1-\frac{TP}{TP+FN}\right)/(TP+FN)} \le R(1|1)$$

$$\le \frac{TP}{TP+FN} + 1.96\sqrt{\frac{TP}{TP+FN}\left(1-\frac{TP}{TP+FN}\right)/(TP+FN)}$$

By the way, it is known that error propagation formulas are given as follows;

- Propagation of errors in addition

$$(a \pm \delta a) + (b \pm \delta b) = (a+b) \pm (\delta a + \delta b)$$

- Propagation of errors in subduction

$$(a \pm \delta a) - (b \pm \delta b) = (a-b) \pm (\delta a + \delta b)$$

- Propagation of errors in multiplication

$$(a \pm \delta a)(b \pm \delta b) = ab\left(1 \pm \left(\frac{\delta a}{a} + \frac{\delta b}{b}\right)\right)$$

- Propagation of errors in division

$$\frac{a \pm \delta a}{b \pm \delta b} = \frac{a}{b}\left(1 \pm \left(\frac{\delta a}{a} + \frac{\delta b}{b}\right)\right)$$

Using these error propagation formulas, we have 95% confidence interval of,

$$p_i = \frac{\mathrm{E}[\hat{g}_i] - R(1|0)}{R(1|1) - R(1|0)}$$

as:

$$\frac{a-b}{c-b}\left(1 - \left(\frac{\delta a+\delta b}{a-b} + \frac{\delta c+\delta b}{c-b}\right)\right) \le p_i \le \frac{a-b}{c-b}\left(1 + \left(\frac{\delta a+\delta b}{a-b} + \frac{\delta c+\delta b}{c-b}\right)\right)$$

where we set

$$a = \mathrm{E}[\hat{p}_i],\ b = R(1|0),\ c = R(1|1)$$

and $\delta a, \delta b,$ and δc are half of 95% confidence interval of $\mathrm{E}[\hat{p}_i]$, $R(1|0)$, and $R(1|1)$, respectively.

5.3 MGCI estimation the JAXA high-resolution land use and land cover map data

5.3.1 JAXA high-resolution land use and land cover map data

MGCIs are calculated at different spatial resolutions for each Kapos mountain class using JAXA high-resolution land use and land cover map (2006-2011, 2014-2016, and 2018-2020) [JAXA] and their 95% confidence intervals are estimated. JAXA land cover data has 10 classification categories for 2006-2011 and 2014-2016 and 12 categories for 2018-2020 as shown in F/T-14.

F/T-14 Classification categories of JAXA high-resolution land use and land cover map (11 and 12 are only for 2018-2020)

Digital Number	Land cover	Green/Non green
1	Water	Non green
2	Urban and built-up	Non green
3	Rice paddy	Green
4	Crops	Green
5	Grassland	Green
6	Deciduous Broad-leaved Forest (DBF)	Green
7	Deciduous Needle-leaved Forest (DNF)	Green
8	Evergreen Broad-leaved Forest (EBF)	Green
9	Evergreen Needle-leaved Forest (ENF)	Green
10	Bare land	Non green
11	Bamboo	Green
12	Solar panel	Non green

5.3.2 Verification of land cover data (Confusion matrix)

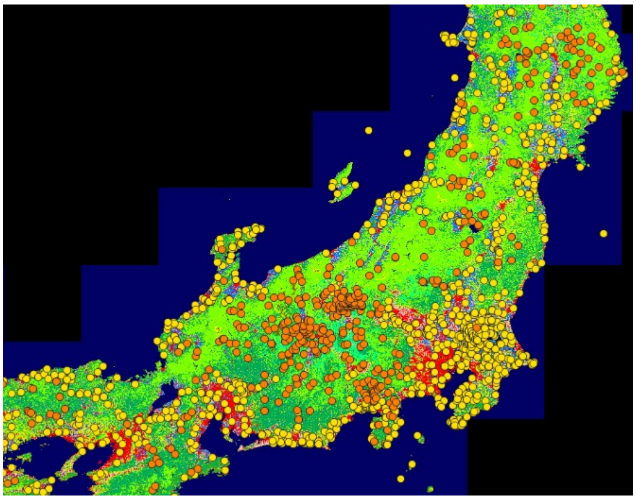
F/T-15 shows 2018-2020 JAXA land cover data (100m resolution) and locations of validation sites. Accuracy verification is achieved by comparing the land cover of the validation site which is confirmed visually with the land cover classification of JAXA land cover map, automatically produced from the satellite image.

JAXA used validation information of approximately 2,700 sites which are independent of the training data, for accuracy assessment of its high-resolution land use and land cover map data (ver21.03, 2018-2020, 10m resolution) and confirmed an overall accuracy of 84.8% [JAXA ALOS ver21.03].

As for the land cover data, ver18.03, 2014-2016, 30m resolution, validation information of approximately 3000 sites were used and overall accuracy was 81.6% [JAXA ALOS ver18.03].

As for the land cover data, ver16.09, 2006-2011, 10m resolution, validation information of approximately 1400 sites were used and overall accuracy was 78.0% [JAXA ALOS ver16.09].

Validation sites in mountain areas were extracted from 2006-2011, 2014-2016, and 2018-2020 JAXA land cover data, and confusion matrices of land cover classification in mountain areas at 250m, 100m, and 50m/30m resolutions were produced. Results are shown in F/T-16 to F/T-18. It is seen that overall classification accuracy in the mountain areas - which is 53-82% for 10 to 12 categories - improved significantly to 90 to 99% for binary green/non-green re-classification and that the classification accuracy also improved as data resolution is higher.



F/T-15 2018-2020 JAXA land cover data (100m resolution) and validation sites (mountain validation sites: orange, non-mountain validation sites: yellow)

F/T-16 2018-2020 JAXA land cover data (100m, mountain area) confusion matrix

		Validation													User's accuracy (%)
		1	2	3	4	5	6	7	8	9	10	11	12	Total	
Classified	1	27	0	0	0	0	0	0	0	0	1	0	0	28	96.4
	2	0	9	0	1	0	0	0	0	0	0	0	6	16	56.3
	3	0	0	4	5	0	0	0	0	0	1	0	1	11	36.4
	4	0	1	0	14	0	0	0	0	0	1	0	1	17	82.4
	5	0	0	0	4	40	1	2	0	0	2	1	1	51	78.4
	6	0	0	1	1	2	118	25	1	6	0	2	4	160	73.8
	7	1	0	0	0	1	2	124	0	0	2	0	0	130	95.4
	8	0	0	0	0	0	0	0	7	1	0	2	0	10	70.0
	9	0	0	0	0	0	11	5	1	98	0	7	1	123	79.7
	10	3	0	0	1	0	0	0	0	0	38	0	0	42	90.5
	11	0	0	0	0	0	0	0	0	1	0	11	0	12	91.7
	12	0	0	0	0	0	0	0	0	0	0	0	11	11	100.0
	Total	31	10	5	26	43	132	156	9	106	45	23	25	611	
Producer's accuracy		87.1	90.0	80.0	53.8	93.0	89.4	79.5	77.8	92.5	84.4	47.8	44.0		82.0

		Validation		
		Non-green	Green	Total
Classified	Non-green	95	2	97
	Green	16	498	514
	Total	111	500	611

		Validation		
		Non-green	Green	Total
Classified	Non-green	0.855856	0.004	
	Green	0.144144	0.996	
	Total	1	1	

(green)	Green
(pink)	Non-green

F/T-17 2014-2016 JAXA land cover data (100m, mountain area) confusion matrix

		Val dation											User's accuracy (%)
		1	2	3	4	5	6	7	8	9	10	Total	
	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Classif ed	1	34	0	0	0	0	0	0	0	0	0	34	100.0
	2	0	7	0	0	0	1	0	0	0	4	12	58.3
	3	1	0	9	4	0	0	0	0	0	2	16	56.3
	4	0	0	0	23	0	1	0	0	0	2	26	88.5
	5	0	0	0	3	63	6	2	0	1	2	77	81.8
	6	1	0	1	0	8	125	38	2	7	1	183	68.3
	7	0	0	0	3	1	35	169	1	7	1	217	77.9
	8	0	0	0	0	0	5	2	15	12	0	34	44.1
	9	0	0	0	0	0	27	11	13	102	2	155	65.8
	10	0	3	0	1	1	0	0	0	0	39	44	88.6
	Total	36	10	10	34	73	200	222	31	129	53	798	
Producer's accuracy		94.4	70.0	90.0	67.6	86.3	62.5	76.1	48.4	79.1	73.6		73.4

		Validat on		
		Non-green	Green	Total
Classified	Non-green	87	3	90
	Green	12	696	708
	Total	99	699	798

		Validation		
		Non-green	Green	Total
Classified	Non-green	0.878788	0.004292	
	Green	0.121212	0.995708	
	Total	1	1	

(green)	Green
(pink)	Non-green

F/T-18 2006-2011 JAXA land cover data (100m, mountain area) confusion matrix

		Val dation											User's accuracy (%)
		1	2	3	4	5	6	7	8	9	10	Total	
Classified	1	55	0	1	1	0	0	0	0	0	0	57	96.5
	2	0	20	0	0	0	0	0	0	0	0	20	100.0
	3	1	0	24	3	0	0	0	0	0	0	28	85.7
	4	0	1	5	6	2	2	0	0	2	0	18	33.3
	5	0	0	3	9	11	1	0	0	2	2	28	39.3
	6	0	1	0	2	0	25	0	0	5	0	33	75.8
	7	0	0	1	1	1	6	7	0	6	0	22	31.8
	8	0	0	0	1	0	0	0	1	1	0	3	33.3
	9	0	0	0	1	0	4	0	5	72	0	82	87.8
	10	0	2	0	0	1	0	0	0	0	5	8	62.5
	Total	56	24	34	24	15	38	7	6	88	7	299	
Producer's accuracy		98.2	83.3	70.6	25.0	73.3	65.8	100.0	16.7	81.8	71.4		75.3

		Validat on		
		Non-green	Green	Total
Classified	Non-green	82	3	85
	Green	5	209	214
	Total	87	212	299

		Val dation		
		Non-green	Green	Total
Classified	Non-green	0.942529	0.014151	
	Green	0.057471	0.985849	
	Total	1	1	

(green)	Green
(pink)	Non-green

F/T-19 Classification accuracy of JAXA land cover data (mountain areas)

Year	Resolution	Number of Verification sites	Classification accuracy (12/10 categories)* (%)	Green/Non-green classification accuracy（%）
2018-2020	100m	611	82.0	99.6
2014-2016	250m	798	66.1	96.1
	100m	798	73.4	98.1
	30m	798	76.9	98.8
2006-2011	250m	299	53.7	90.6
	100m	299	75.3	97.3
	50m	299	79.6	97.7

*12 categories for 2018-2020 and 10 categories for 2014-2016 and 2006-2011

As shown in F/T-19, when MGCIs are calculated at 300m, 250m, 100m, 50m (2014-2016 and 2018-2020) and 30m (2006-2011) resolutions, it was confirmed that the 95% confidence interval became narrower as the spatial resolution increased. As the highest-resolution Kapos mountain classification data, that of 90m resolution was produced and became available [Kawakita], it was found that the highest MGCIs can be obtained when 100m resolution land cover data were used.

Using JAXA high-resolution land use and land cover map data of 100m resolution, the point estimation and the interval estimation of MGCI for each Kapos mountain class were calculated as shown in F/T-20 to F/T-22.

F/T-20 MGCIs calculated using 2006-2011 JAXA land cover data (100m resolution)

Kapos classification	MGCI	MGCI 95% lower limit	MGCI 95% upper limit	FAO estimation 2015(reference)
Kapos 1				0
Kapos 2	0	0	0	0.8667
Kapos 3	0.479932454	0.388758862	0.571106046	0.9976
Kapos 4	0.920235576	0.802742209	1.037728943	0.9969
Kapos 5	1.000198807	0.877558557	1.122837599	0.9971
Kapos 6	1.001861798	0.879194204	1.124529392	0.9931
Overall	0.997114	0.874775	1.119454	0.9938

F/T-21 MGCIs calculated using 2014-2016 JAXA land cover data (100m resolution)

Kapos classification	MGCI	MGCI 95% lower limit	MGCI 95% upper limit	FAO estimation 2010(reference)
Kapos 1				0
Kapos 2	0	0	0	0.8667
Kapos 3	0.324336795	0.219973983	0.428699608	0.9976
Kapos 4	0.964553709	0.814380131	1.114727287	0.9968
Kapos 5	0.99418406	0.84194352	1.146424599	0.9969
Kapos 6	0.991236695	0.839297171	1.143176218	0.9913
Overall	0.989222	0.837443	1.141000	0.9923

F/T-22 MGCIs calculated using 2018-2020 JAXA land cover data (100m resolution)

Kapos classification	MGCI	MGCI 95% lower limit	MGCI 95% upper limit	FAO estimation 2010(reference)
Kapos 1				0
Kapos 2	0	0	0	0.8667
Kapos 3	0.246453693	0.144044964	0.348862423	0.9976
Kapos 4	0.947168659	0.791180728	1.103156589	0.9969
Kapos 5	0.994111550	0.834573777	1.153649323	0.9969
Kapos 6	0.986879668	0.828002972	1.145756364	0.9931
Overall	0.984724	0.826035	1.143413	0.9923

Among the estimated values in F/T-20 to F/T-22, MGCI values estimated by FAO for Kapos 5 and Kapos 6 mountain classes are in very good agreement with the estimation by Japan and calculated values of FAO are within the 95% confidence interval. The estimated values for 2006 to 2011 are 0 in all cases for the Kapos 2 mountain class area. This is because JAXA high-resolution land cover classification data is of bare land (non-green). This value is underestimated when compared with the field monitoring values from the MOE monitoring site 1000 Alpine area survey report [MOE report]. Since the resolution of JAXA land cover data is 100 m (minimum resolution is 30m to 50m), the resolution seems insufficient to identify sparse vegetation which only grows during summer time.

What needs to be discussed is the methodology to calculate MGCI. For this methodology to compute MGCI, in reality, land cover, that has seasonal variability and density changes, is transformed to discrete land cover classification and further into binary green/non-green categories - and then MGCI is calculated. This methodology has inherent discrete errors and when MGCI is small, it is believed that the errors become tangible and cause underestimation.

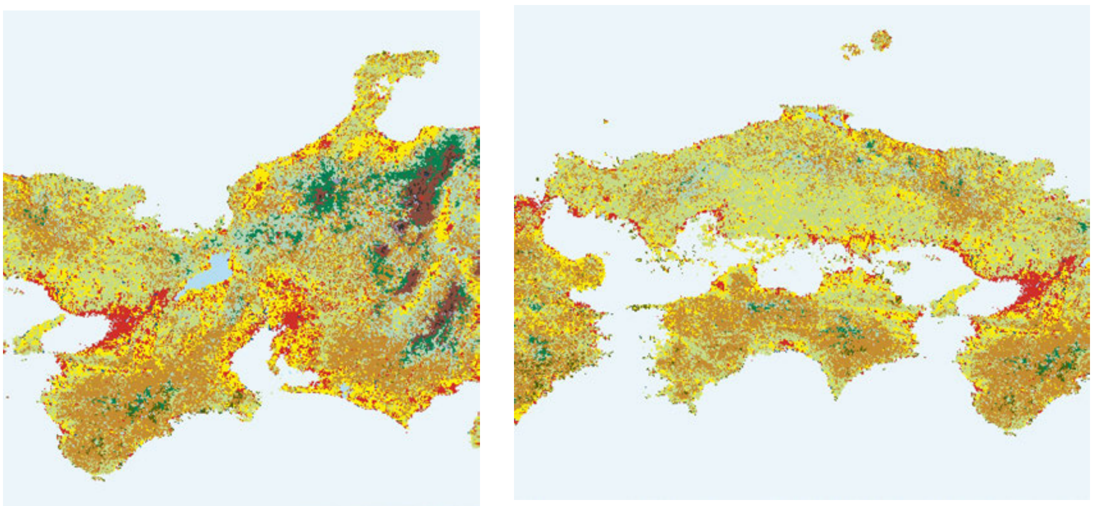
For this, in the current methodology, the vegetation ratio which is continuous is transformed to binary values, when MGCI is small and the sample size is small (corresponding mountain class area is small), the impact of the discrete errors caused by the methodology becomes non-negligible. The impact is not only for Kapos 2 mountain class area, but it should also be considered as an error factor for Kapos 3 and Kapos 4 mountain class zones where Japan has small areas. As a method to decrease the impact of the discrete errors, for example, green/non-green weighting is set for continuous 0 to 1, MGCI can be estimated. The development of such highly accurate MGCI computation methodology which is expanded from the FAO metadata may need to be further studied.

5.4 Reduction of sampling errors of confusion matrix comparing with other data

By comparing the land cover grid data with vegetation map polygons and parcel polygons of farm land, verification of classification accuracy can be made. Particularly by comparing with other data, a sample size of the confusion matrix is increased and thereby improving estimation accuracy of classification errors, it can be shown that the confidence interval of MGCI can be decreased.

Here the vegetation survey (1/25000 scale) prefectural list shape file [MOE vegetation survey polygon data] is used. Vegetation areas are presented as polygon data as a result of the MOE National Survey on the Natural Environment [MOE National Survey on the Natural Environment]. F/T-23 is an example of a vegetation map that the Biodiversity Center of Japan, Natural Environment Bureau, MEO] provides.

F/T-23 Example of vegetation map (source: Biodiversity Center of Japan, Natural Environment Bureau, MOE)



Polygon data of the MOE vegetation map are compared with JAXA land cover grid data and a confusion matrix between green/non-green of JAXA high-resolution land cover data and MOE vegetation map is computed, thereby increasing the sample size of the confusion matrix. For some mountain areas, using vegetation map polygons and 2006-2011 100m resolution land cover data, the sample size of the confusion matrix was increased and the point estimation and 95% confidence interval of conditional probability $R(1|0)$ and $R(1|1)$ were computed. F/T-24 are the confusion matrix and point estimation and 95% confidence interval of the conditional probabilities.

As shown in F/T-24, by increasing the number of validation sites, the conditional probability $R(a|b)$ with decreased estimation errors can be used to calculate the point estimation and 95% confidence interval of MGCI for 2006-2011 100m resolution Kapos mountain classes. The estimations are shown in F/T-25. The 95% confidence interval of MGCI in F/T-25 is smaller than that of F/T-20. This means that by increasing training information to produce the confusion matrix, the confidence of MGCI evaluation value can be enhanced.

Among the 95% confidence interval estimation for 2006-2011 100m resolution JAXA land cover data for Kapos mountain classes, the MGCI estimation by FAO are outside of those calculated by using the specific data owned by Japan. From this, for those Kapos mountain classes (Kapos 2, Kapos 3 and Kapos 4) with small areas in Japan, it can be concluded that FAO estimation for SDG 15.4.2 is being proposed as overestimated.

Although this verification could not be completed for all cases with a schedule of the verification task, personnel and budget, it could demonstrate that by preparing data increasing accurate training information for land cover, it is technically feasible to decrease errors in the estimation, even if certain errors exist in green/non-green classification.

F/T-24 Confusion matrix calculated by comparing the MOE vegetation polygon and JAXA high-resolution land cover data

	Green	Non green
Green	98133	2562
Non green	767	3516

	Mean	Lower limit of 95% confidence interval	Upper limit of 95% confidence interval	Half of 95% confidence interval
$R(1\|0)$	0.42152	0.409105743	0.433934731	0.012414494
$R(1\|1)$	0.992245	0.991697969	0.992791414	0.000546723

F/T-25 MGCI point estimation and 95% confidence interval for 2006-2011, using 100m resolution Kapos mountain classes

	2006-2011 JAXA land cover data			FAO estimation 2010 (reference)
Kapos classification	MGCI	MGCI 95% lower limit	MGCI 95% upper limit	
Kapos 1				0
Kapos 2	0	0	0	0.8667
Kapos 3	0.142818164	0.10970299	0.17593334	0.9976
Kapos 4	0.859043387	0.81684609	0.90124068	0.9969
Kapos 5	0.989115507	0.94467302	1.033558	0.9971
Kapos 6	0.99182182	0.94746112	1.03618252	0.9931
Overall	0.984099	0.939909	1.028290	0.9938

6. Summary

Following the data and methodology defined by the latest metadata, SDG15.4.2 (Mountain Green Cover Index (MGCI)) was calculated in this verification task.

When MGCI was calculated using JAXA high-resolution land cover data, smaller estimations than those estimated by FAO were obtained. Using validation information independent from the training information, a confusion matrix was produced and the accuracy of land cover classification was assessed. As the resolution of used land cover data tends higher, classification accuracy is correspondingly higher and MGCI has a trend to become smaller, suggesting that high-resolution data should be used. It is also the case with the used Kapos mountain classification data.

SDG15.4.2 estimations were calculated considering the accuracy assessment of the land cover data at 100m resolution which Japan has as follows:

・2006-2011　MGCI(overall) 0.984099 (0.939909 or more）

Kapos 2: 0 (it is almost 0 as it is frozen during winter time, but it could be several percent during summer time)

Kapos 3: 0.143 (0.110 or more and 0.176 or less；0 is relevant since the areas are frozen during winter time）

Kapos 4：0.859 (0.817 or more and 0.901 or less)

Kapos 5：0.989 (0.945 or more)

Kapos 6：0.992 (0.947 or more)

・2014-2016　MGCI(overall) 0.989222 (0.837443 or more)

Kapos 2: 0 ((it is almost 0 as it is frozen during winter time, but it could be several percent during summer time)

Kapos 3: 0.324 (0.220 or more and 0.429 or less; 0 is relevant since the areas are frozen during winter time)

Kapos 4 ： 0.965 (0.814 or more)

Kapos 5 ： 0.994 (0.842 or more)

Kapos 6 ： 0.991 (0.839 or more)

・2018-2020　MGCI(overall)　0.984724 (0.826035 and more)

Kapos 2: 0 (it is almost 0 as it is frozen during winter time, but it could be several percent during summer time)

Kapos 3: 0.246 (0.144 or more and 0.349 or less ； 0 is relevant since the areas are frozen during winter time)

Kapos 4: 0.947 (0.791 or more)

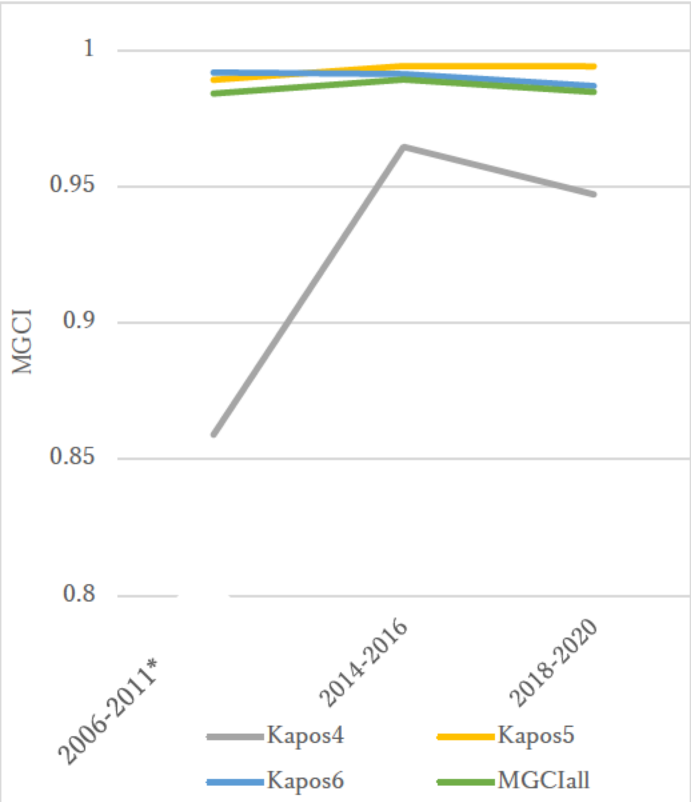
Kapos 5: 0.994 (0.835 or more)

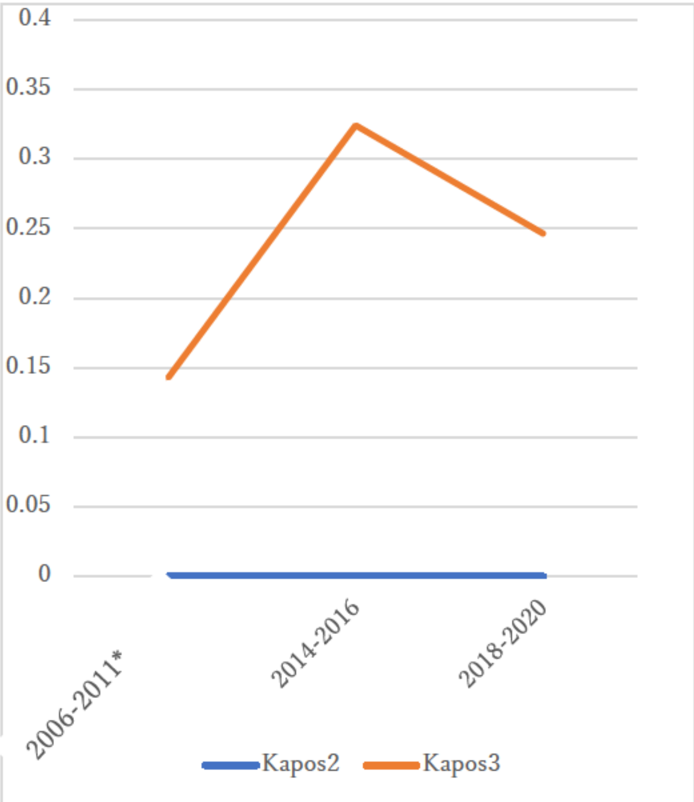
Kapos 6: 0.987 (0.828 or more)

However, for the impact assessment of land cover classification, by comparing with other data which the country has, the accuracy can be improved and it is feasible to make the confidence interval of MGCI narrower and increase the MGCI estimation confidence.

Among the estimates calculated, those point estimation are shown as MGCI annual trend. From this figure, a large increase in MGCI after 2011 is shown.

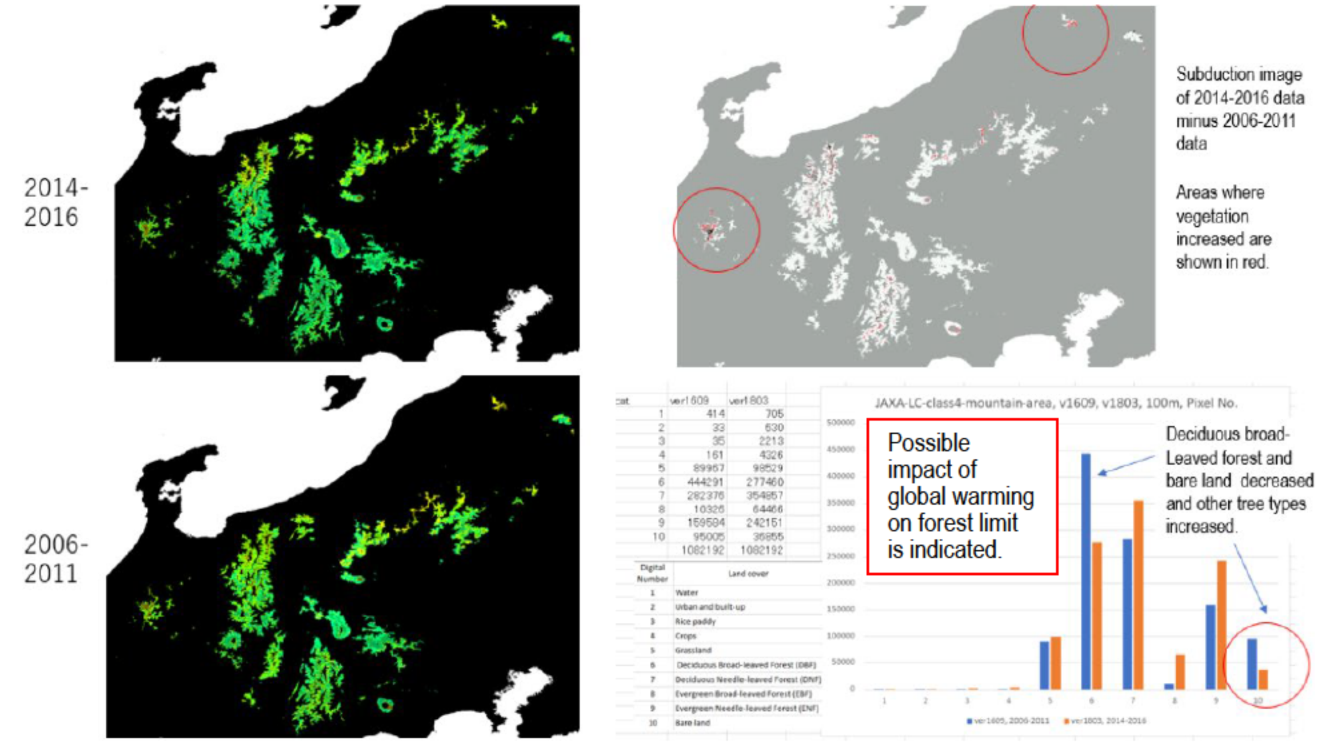
F/T-26 Change of MGCI estimations for Kapos mountain classes calculated using JAXA land cover data (100m resolution)　*2006-2011 data are corrected with MOE vegetation polygon data





In order to investigate the cause, a comparison of vegetation covers in the Kapos 4 mountain class images between 2006-2011 and 2014-2016 using JAXA land cover data (100m resolution) is given in F/T-27. From this figure, by comparing numbers of land cover pixels between the two periods, deciduous broad-leaved forest and bare land decreased and that of other species increased. This may indicate the impact of global warming where the forest limit is moving higher. Also, similar phenomena may be happening for Kapos 3 mountain class areas.

F/T-27 Subtraction image from 2006-2011 and 2014-2016 JAXA high-resolution land cover data and comparison of the histograms of pixels for each land cover.



cat	ver1609	ver1803
1	414	705
2	33	630
3	35	2213
4	161	4326
5	89967	98529
6	444291	277460
7	282376	354857
8	10326	64466
9	159584	242151
10	95005	35855
	1082192	1082192

Digital Number	Land cover
1	Water
2	Urban and built-up
3	Rice paddy
4	Crops
5	Grassland
6	Deciduous Broad-leaved Forest (DBF)
7	Deciduous Needle-leaved Forest (DNF)
8	Evergreen Broad-leaved Forest (EBF)
9	Evergreen Needle-leaved Forest (ENF)
10	Bare land

Assessment of used data and methodology of indicator calculation is made in the following:

- Land cover classification data
  Specific data owned by the country is useful from a view point of accuracy verification and regular update of land cover data together with verification data is also considered as necessary. Particularly for Japan which has small areas and complex topography, high-resolution land cover data is necessary.
  Through the verification task, in comparison with ESA-CCI data (300m resolution), the merits of the JAXA high-resolution land cover data (resolution, accuracy and availability of validation data) and challenges (update frequency, continuity) were identified.

- Kapos mountain classification data
  For mountain classification in Japan, Kapos mountain classification data whose resolution is higher than those provided by FAO and USGS (430m and 250m resolution respectively) is considered necessary. For the verification task, 90m resolution Kapos mountain classification data was produced from SRTM 90m data. The use of further higher-resolution data is advisable such as SRTM 30m data or 10m DEM of GSI.

- Administrative unit data
  GAUL data of FAO does not include Japan's northern island territories and Sakishima islands, Ioh-archipelago of Ogasawara islands and may therefore not be most relevant for use by Japan. High-resolution coast line data was provided by GSI and the data was used to clip the Japanese island data from a global data set. However, the data resolution is very high and requires a long time to process; the Global Map data was used in the following data processing. Effective use of the high-resolution coast line data provided by GSI is recommended.

MGCI estimation based upon areas of mountain areas and green cover and MGCI estimation based upon a number of pixels for mountain area and green cover area were made.

For the methodology based upon area ratio, map projection to estimate the area is necessary and errors at map projection ends and map projection transformation errors can occur

The methodology based upon a number of pixels does not require map projection in the geographic coordinate system, therefore it features fewer errors, simpler data analysis, and shorter processing time, and its use can be recommended.

Annex

F/T-1 List of SDG15.4.2 (Mountain Green Cover Index) estimation cases

Land cover data	Resolution	Calculation method	Map projection	Mountain classification data	Administrative area data	Calculation cases 2000	2010	2015	2018
ESA CCI Data	300m	Area ratio	UTM54	Kapos-FAO (430m)	FAO-GAUL	○	○	○	○
	300m		UTM54/53/52			○		○	
	300m	Number of Pixels	Geographic coordinate			○	○	○	○
JAXA high-resolution land use and land cover map	250m	Area ratio	UTM54		Global Map and Japan coast line data provided by GSI		(2006-2011) ○	(2014-2016) ○	
	100m						○	○	
	50/30m						○ (50m)	○ (30m)	
	250m						○	○	
	100m		UTM54/53/52		National Digital Information Administrative are data		○	○	
	50/30m						○	○	
	250m								
	100m			Kapos-SRTM (90m)			○	○	
	50/30m						○		
	250m	Number of pixels	Geographic coordinate	Kapos-FAO (430m)	Global Map and Japan coast line data provided by GSI		○	○	
	100m						○	○	
	250m			Kapos-USGS (250m)			○	○	(2018-2020) ○
	100m						○	○	○
	100m			Kapos-SRTM (90m)			○	○	○
	50/30m						○	○	

F/T-2 MGCI estimation by FAO(left), MGCI estimation based on the area using ESA-CCI data and Kapos-FAO mountain classification data(center) and MGCI estimation based on number of pixels(right)

	Estmat on by FAO						Calculation based on area (incl. wetland in green)						Calculat on based on number of pixels (incl. wetland in green)					
	Year 2000						Year 2000						Year 2000					
	Kapos mountain class						Kapos mountain class						Kapos mountain class					
IPCC class	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Forest	0.00	20.00	55.30	88.73	94.64	91.15	0.00	17.39	54.19	88.75	94.56	91.01	0.00	28.57	54.57	88.64	94.62	91.16
Cropland	0.00	66.67	35.57	6.17	2.55	5.09	0.00	78.26	44.44	9.39	4.53	8.35	0.00	62.86	44.10	9.45	4.45	8.20
Grassland	0.00	0.00	8.54	4.40	2.15	3.20	0.00	0.00	0.71	1.16	0.30	0.09	0.00	0.00	0.74	1.23	0.25	0.09
Wetland	0.00	0.00	0.35	0.39	0.39	0.07	0.00	0.00	0.33	0.41	0.39	0.07	0.00	0.00	0.34	0.41	0.41	0.07
Settlement	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.13
Other land	0.00	13.33	0.24	0.31	0.27	0.36	0.00	4.34	0.30	0.27	0.19	0.34	0.00	8.57	0.25	0.28	0.26	0.35
MGCI	0.00	86.67	99.76	99.69	99.72	99.52	0.00	95.65	99.67	99.71	99.78	99.52	0.00	91.43	99.75	99.72	99.73	99.52
MGCI all				99.55						99.57						99.56		
	Year 2010						Year 2010						Year 2010					
	Kapos mountain class						Kapos mountain class						Kapos mountain class					
IPCC class	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Forest	0.00	20.00	56.24	89.22	94.49	91.20	0.00	17.39	55.37	89.18	94.43	90.98	0.00	28.57	55.31	89.12	94.51	91.21
Cropland	0.00	66.67	35.28	6.33	2.86	5.06	0.00	78.26	43.22	8.83	4.49	8.14	0.00	62.86	43.37	8.82	4.41	7.91
Grassland	0.00	0.00	7.89	3.72	1.93	2.98	0.00	0.00	0.71	1.22	0.43	0.11	0.00	0.00	0.74	1.31	0.36	0.11
Wetland	0.00	0.00	0.35	0.42	0.44	0.08	0.00	0.00	0.33	0.48	0.44	0.07	0.00	0.00	0.34	0.46	0.45	0.08
Settlement	0.00	0.00	0.00	0.00	0.01	0.33	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.34
Other land	0.00	13.33	0.24	0.31	0.28	0.36	0.00	4.34	0.30	0.26	0.18	0.34	0.00	8.57	0.25	0.28	0.27	0.35
MGCI	0.00	86.67	99.76	99.69	99.71	99.31	0.00	95.65	99.63	99.71	99.79	99.30	0.00	91.43	99.75	99.72	99.72	99.31
MGCI all				99.38						99.40						99.38		
	Year 2015						Year 2015						Year 2015					
	Kapos mountain class						Kapos mountain class						Kapos mountain class					
IPCC class	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Forest	0.00	20.00	58.89	89.37	94.16	91.10	0.00	17.39	57.85	89.28	94.12	90.88	0.00	28.57	57.73	89.27	94.19	91.12
Cropland	0.00	66.67	33.57	6.34	3.01	4.94	0.00	78.26	40.74	8.76	4.74	8.05	0.00	62.86	40.94	8.67	4.66	7.81
Grassland	0.00	0.00	6.95	3.57	2.03	3.01	0.00	0.00	0.79	1.21	0.44	0.11	0.00	0.00	0.74	1.32	0.36	0.11
Wetland	0.00	0.00	0.35	0.40	0.48	0.08	0.00	0.00	0.30	0.47	0.47	0.08	0.00	0.00	0.34	0.44	0.49	0.08
Settlement	0.00	0.00	0.00	0.00	0.02	0.51	0.00	0.00	0.00	0.00	0.02	0.52	0.00	0.00	0.00	0.00	0.02	0.52
Other land	0.00	13.33	0.24	0.32	0.28	0.36	0.00	4.34	0.30	0.26	0.18	0.34	0.00	8.57	0.25	0.29	0.28	0.36
MGCI	0.00	86.67	99.76	99.68	99.69	99.13	0.00	95.65	99.68	99.72	99.77	99.12	0.00	91.43	99.75	99.71	99.71	99.12
MGCI all				99.23						99.23						99.22		
	Year 2018						Year 2018						Year 2018					
	Kapos mountain class						Kapos mountain class						Kapos mountain class					
IPCC class	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Forest	0.00	20.00	59.31	88.97	93.98	90.96	0.00	17.39	57.97	88.96	93.97	90.82	0.00	28.57	58.03	88.90	94.02	90.98
Cropland	0.00	66.67	33.16	6.59	3.14	5.00	0.00	78.26	40.61	8.94	4.80	8.07	0.00	62.86	40.65	8.95	4.73	7.93
Grassland	0.00	0.00	6.95	3.70	2.08	3.09	0.00	0.00	0.79	1.34	0.51	0.12	0.00	0.00	0.74	1.41	0.46	0.12
Wetland	0.00	0.00	0.35	0.41	0.48	0.08	0.00	0.00	0.30	0.04	0.48	0.08	0.00	0.00	0.34	0.45	0.50	0.08
Settlement	0.00	0.00	0.00	0.00	0.02	0.51	0.00	0.00	0.00	0.00	0.01	0.53	0.00	0.00	0.00	0.00	0.02	0.52
Other land	0.00	13.33	0.24	0.32	0.29	0.36	0.00	4.34	0.30	0.27	0.19	0.34	0.00	8.57	0.25	0.29	0.28	0.36
MGCI	0.00	86.67	99.76	99.69	99.69	99.31	0.00	95.65	99.67	99.28	99.76	99.09	0.00	91.43	99.75	99.71	99.70	99.12
MGCI all				99.23						99.22						99.22		

F/T-3 MGCI estimation based on number of pixels using JAXA land cover data (250m, 100m resolutions) and Kapos-USGS mountain classification data (250m resolution)

250m resolution															
	2006-2011					2014-2016					2018-2020				
	Kapos mountain class					Kapos mountain class					Kapos mountain class				
(%)	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
Forest	0	46.06	83.95	92.15	93.17	0	27.67	86.85	93.20	91.00	0.00	31.40	88.95	96.69	93.89
Cropland	0	0.00	0.01	0.32	2.85	0	1.41	0.61	0.82	3.11	0.00	0.00	0.00	0.46	2.21
Grassland	0	3.43	7.69	6.32	2.91	0	12.37	9.01	5.04	4.69	0.00	3.57	6.58	2.09	2.55
Wetland	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Settlement	0	0.00	0.00	0.01	0.38	0	0.04	0.07	0.06	0.44	0.00	0.00	0.00	0.02	0.70
Other land	100	50.51	8.35	1.19	0.69	100	58.51	3.46	0.88	0.76	100.00	65.03	4.47	0.74	0.65
MGCI	0	49.49	91.64	98.79	98.93	0	41.45	96.47	99.06	98.80	0.00	34.97	95.53	99.24	98.65
MGCI all			98.5235					98.6327					98.4819		

100m resolution															
	2006-2011年					2014-2016年					2018-2020年				
	Kapos mountain class					Kapos mountain class					Kapos mountain class				
(%)	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
Forest	0	46.29	82.80	91.39	92.18	0	28.07	86.78	93.18	90.98	0.00	31.44	87.77	95.90	93.01
Cropland	0	0.01	0.02	0.38	3.01	0	1.43	0.60	0.82	3.12	0.00	0.00	0.01	0.51	2.38
Grassland	0	4.89	8.34	6.80	3.56	0	12.74	9.03	5.05	4.69	0.00	4.74	7.29	2.68	3.09
Wetland	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Settlement	0	0.01	0.00	0.03	0.44	0	0.04	0.06	0.06	0.44	0.00	0.00	0.00	0.04	0.80
Other land	100	48.79	8.84	1.39	0.81	100	57.72	3.53	0.88	0.77	100.00	63.81	4.94	0.87	0.72
MGCI	0.00	51.20	91.16	98.58	98.75	0.00	42.24	96.41	99.06	98.79	0.00	36.19	95.06	99.09	98.48
MGCI all			98.3285					98.6269					98.3018		

F/T-4 MGCI estimation based on number of pixels using JAXA land cover data (100m, 50/30m resolutions) and Kapos-SRTM mountain classification data (90m resolution)

100m解像度															
	2006-2011年					2014-2016年					2018-2020年				
	Kapos mountain class					Kapos mountain class					Kapos mountain class				
	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
Forest	0	45.55	82.85	91.43	92.44	0.00	26.22	86.76	93.22	91.31	0.00	30.72	87.83	95.94	93.29
Cropland	0	0.01	0.02	0.37	2.86	0.00	1.43	0.60	0.81	2.94	0.00	0.00	0.01	0.50	2.24
Grassland	0	4.74	8.31	6.80	3.46	0.00	12.83	9.10	5.03	4.55	0.00	4.69	7 27	2.65	2.96
Wetland	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Settlement	0	0.01	0.00	0.03	0.45	0.00	0.02	0.06	0.06	0.44	0.00	0.00	0.00	0.04	0.80
Other land	100	49.69	8.82	1.37	0.80	100.00	59.49	3.47	0.88	0.75	100.00	64.59	4.90	0.86	0.72
MGCI	0	50.30	91.18	98.60	98.76	0.00	40.48	96.47	99.06	98.80	0.00	35.41	95.10	99.10	98.48
MGCI all			98.3170					98.6282					98.2987		

50m解像度						30m解像度					50m解像度				
	2006-2011年					2014-2016年					2018-2020年				
	Kapos mountain class					Kapos mountain class					Kapos mountain class				
	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
Forest	0.00	45.94	82.15	90.93	91.86	0.00	26.92	86.79	93.21	91.31	0.00	31.00	87.16	95.47	92.90
Cropland	0.00	0.02	0.03	0.41	2.87	0.00	1.41	0.60	0.81	2.94	0.00	0.00	0.01	0.52	2 29
Grassland	0.00	5.77	8.81	7.14	3.93	0.00	12.81	9.07	5.04	4.55	0.00	5.41	7.67	3.01	3 20
Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Settlement	0.00	0.02	0.01	0.04	0.47	0.00	0.03	0.06	0.06	0.44	0.00	0.00	0.00	0.06	0.84
Other land	100.00	48.25	9.01	1.48	0.87	100.00	58.83	3.47	0.88	0.75	100.00	63.59	5.15	0.94	0.76
MGCI	0.00	51.73	90.99	98.48	98.66	0.00	41.14	96.47	99.06	98.80	0.00	36.41	94.84	99.00	98.40
MGCI all			98.2183					98.6299					98.2071		

F/T-5 Data used for SDG15.4.2 calculation

Land cover data

Title	Area	Period	Resolution	Category	Used satellite data, etc.
ESA-CCI data	global	Every year 1992 - 2018年	300m	22	AVHRR, SPOT, PROBA-V, MERIS, Sentinel-3
JAXA high-resolution land use and land cover map	Japan	2006 - 2011 (2010 is main)	10, 50, 100, 250, 500m	10	ALOS/AVNIR-2/PRISM, ALOS-2/PALSAR-2
		2014 - 2016 (2015 is main)	30, 100, 250, 500m	10	Landsat-8/OLI, ALOS-2/PALSAR-2
		2018 - 2020 (2020 is main, released on Mar 5, 2021)	10, 50, 100, 250, 500m	12	Sentinel-2, Landsat-8/OLI, ALOS-2/PALSAR-2
MOE vegetation survey polygon data	Japan	6th survey（1999-2005） 7th survey（2005-2012）	Approx. 100m	Vegetation category：10 Major category: 01-58	Areal photo and satellite images usable for vegetation map generation

Kapos mountain classification data, Digital Elevation Model(DEM) data

Title	Area	Resolution	Elevation accuracy	Method
Kapos mountain classification data	global	430、250m	Approx.5m	Shuttle Radar Topography Mission(SRTM) (February 2000)
SRTM90m data	+/-60 lat	90m	Approx.5m	同上

Administrative unit data

Title	Area	Resolution	Method	
FAO Global Administrative Unit Layer（GAUL)	global	1km or higher	Country information and satellite data	
Japan coast line data provided by GSI	Japan	10m or higher	Basic survey	
MLIT National Digital Information Administrative area data	Japan	Approx. 10m	ditto	
Global Map	Global	1km	Country information and satellite data	

F/T-6 Relationship among IPCC/ESA-CCI/JAXA land cover classification

IPCC land cover classificat on		ESA-CCI land cover classification		JAXA high-resolution land cover classificat on	
1. Crop land		10, 11, 12	Rainfed cropland	4	Crops
		20	Irrigated cropland	3	R ce paddy
		30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)		
		40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (< 50%)		
2. Forest		50	Tree cover, broadleaved, evergreen, closed to open (>15%)	8	Evergreen Broad-leaved Forest (EBF)
		60, 61, 62	Tree cover, broadleaved, deciduous, closed to open (> 15%)	6	Deciduous Broad-leaved Forest (DBF)
		70, 71, 72	Tree cover, needleleaved, evergreen, closed to open (> 15%)	9	Evergreen Needle-leaved Forest (ENF)
		80, 81, 82	Tree cover, needleleaved, dec duous, closed to open (> 15%)	7	Deciduous Needle-leaved Forest(DNF)
		90	Tree cover, mixed leaf type (broadleaved and needleleaved)		
		100	Mosaic tree and shrub (>50%) / herbaceous cover (< 50%)		
		160	Tree cover, flooded, fresh or brakish water		
		170	Tree cover, flooded, saline water		
				11＊	Bamboo
3. Grassland		110	Mosaic herbaceous cover (>50%) / tree and shrub ((<50%)		
		130	Grassland	5	Grassland
4. Wetland		180	Shrub or herbaceous cover, flooded, fresh-saline or brakish water		
5. Settlement		190	Urban	2	Urban and built-up
6. Others	Shrubland	120, 121, 122	Shrubland		
	Sparce vegetation	140	L chens and mosses		
		150, 151, 152, 153	Sparse vegetation (tree, shrub, herbaceous cover)		
	Bare area	200, 201, 202	Bare areas	10	Bare land
	Water	210	Water	1	Water
				12＊	Aolar panel
				＊only for ver21.03 (2018-2020)	

Supplement

A.1 Production of Japan’s coast line data

In Japan, the calculation of national land area has as long history as population statistics and the Geospatial Information Authority of Japan (GSI) releases the area survey results of prefectures, cities, towns, and villages every year since 1960. The area survey provides basic data for calculating population densities and local taxes.

The area survey can be accessed at the following URL:

https://www.gsi.go.jp/KOKUJYOHO/MENCHO-title.htm （in Japanese）

In calculating SDG indicators that require land area, such as SDG 15.4.2, it is relevant to use geospatial information which has become the basis for the national land area calculation of Japan. From this point of view, for SDG15.4.2 calculation, GSI coastal line data was produced from the Fundamental Geospatial Data (FGD) and provided to the Office of Statistics Commission, Ministry of Internal Affairs and Communication.

The above mentioned Fundamental Geospatial Data can be accessed at the following link:

https://fgd.gsi.go.jp/download/menu.php

A.2 Production of Kapos mountain classification data (90m resolution)

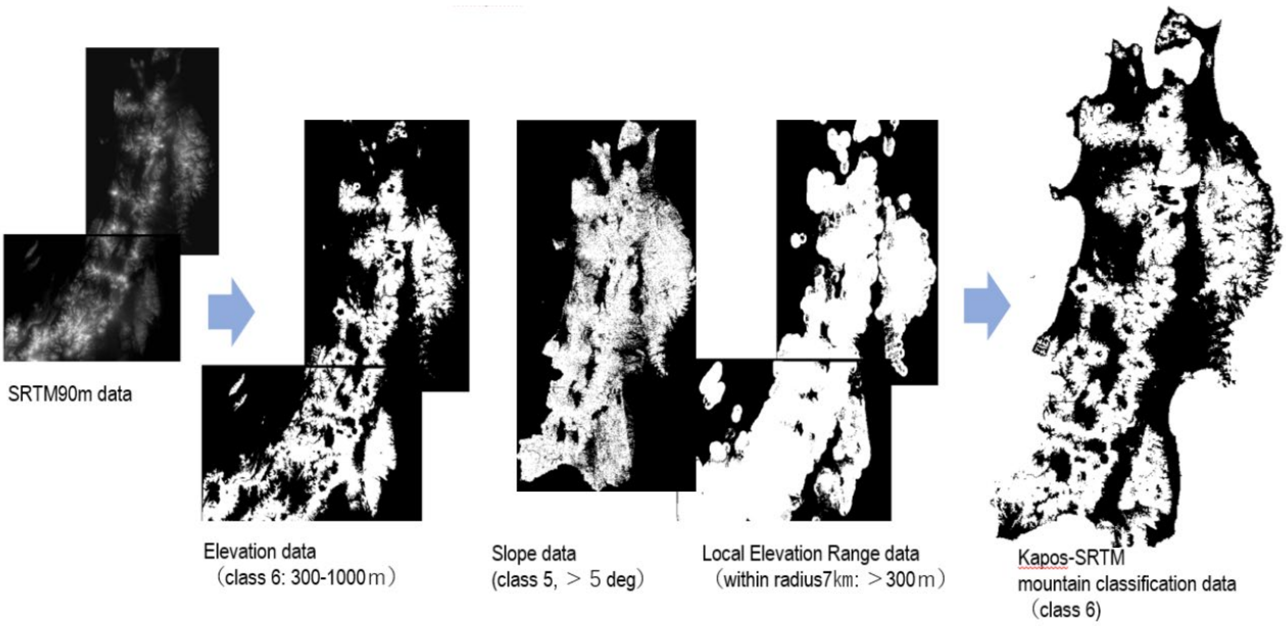
Altitude, slope, and Local Elevation Range (LER) were computed using the SRTM 90m data and with the help of these data, Kapos mountain classification data (Kapos-SRTM, 90m resolution) of Japan was produced.

The production process is shown in the following:

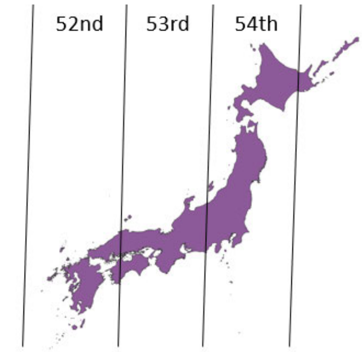
1) Download the 30m SRTM DEM data of Japan.
2) Divide national data to several regional and sub-regional data (three sub-regional data for Hokkaido, regional data for Tohoku, Kanto, Chubu, etc.)
3) Resize the divided DEM data to 90 m data to decrease data volume
4) Analyze if there is 300m altitude difference within 7km around a point (pixel) and if yes, set 1 and if no, set 0. Python and GPU(Graphics Processing Unit) were used.
5) Conduct the processing of 4) for divided DEM data
6) Merge LER maps produced in 5) and produce a national LER map

Altitude and slope can be calculated by QGIS directly from SRTM90m data, but LER requires calculation if 300m altitude difference exists within 7km radii for all the pixels – and this requires significant computing time. For the analysis, a program written in Python was executed using Graphics Processing Unit (GPU) to speed up the computing [Kawakita]. Half a month was necessary to compute LER for the entire area of Japan, Kapos mountain classification data up to 90m resolution was produced. Since the highest resolution of the land cover data is 50m/30m, it is advisable to use 30m resolution Kapos mountain classification data. It can be achieved by using hardware suitable for high-speed computing and improving computation algorithms, etc.

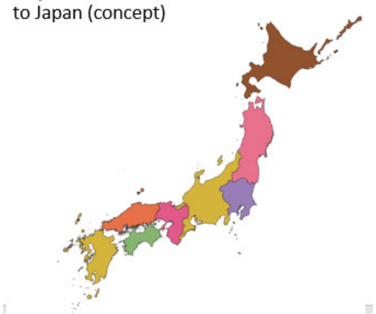
F/T-1 Production of Kapos mountain classification data from SRTM 90m data



A.3 Impact of UTM coordinate applications to MGCI calculation



Application of UTM coordinate systems to Japan (concept)



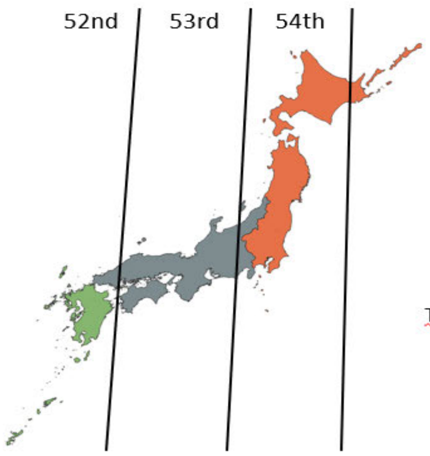
Using the National Digital Information administrative unit (polygon) data (Japan Geodetic Datum 2011), land area calculations applying the UTM coordinate system differently were compared. 0.5% difference in entire national land area estimation appears between when UTM 54th band was applied to entire Japan and when different UTM coordinate systems were applied to regions.

F/T-2 Impact of UTM coordinate system application to land area estimation

Target area	Calculated area when UTM 54th coordinate system is applied(km2)	Calculated area when different coordinate systems are applied(km2)		Difference ratio
		UTM coordinate system	Area (km2)	
Japan	379325			
Hokkaido	83428	54th	83428	1
Tohoku	66900	54th	66900	1
Kanto	32420	54th	32420	1
Chubu	72692	53rd	72638	0.9993
Kinki	27506	53rd	27332	0.9937
Chugoku	32342	53rd	31932	0.9873
Shikoku	19016	53rd	18798	0.9885
Kyushu	43183	52nd	42228	0.9779
Okinawa	1927	52nd	1834	0.9517
Total	379414	52nd	377510	0.9950

Japan was divided into three regions and applications of UTM coordinates to the area estimation of mountain and green cover were studied. 0.02% difference in MGCI estimation was found.

F/T-3 Impact of UTM coordinate system application to MGCI calculation



Application of UTM coordinate systems to Japan (concept)

Table 1 Area and MGCI calculated applying UTM 54th coordinate system to Japan

Region	Kyushu, Okinawa	Chugoku, Shikoku, Kinki, Chubu	Hokkaido, Tohoku, Kanto	Overall
UTM coordinate system	54th	54th	54th	
Mountain area (km2)	15550.41	82336.65	76638.74	174525.80
Vegetation cover area	15470.86	80843.30	75821.33	172135.49
MGCI	0.9949	0.9819	0.9893	0.9863

Table 2 Area and MGCI calculated applying UTM 52th, 53th and 54th coordinate systems

Region	Kyushu, Okinawa	Chugoku, Shikoku, Kinki, Chubu	Hokkaido, Tohoku, Kanto	Overall
UTM coordinate system	52nd	53rd	54th	
Mountain area (km2)	15550.41	81934.23	76638.74	174123.38
Vegetation cover area	15435.49	80443.24	75821.33	171700.06
MGCI	0.9926	0.9818	0.9893	0.9861

A.4 Handling of administrative unit data

FAO used the Global Administrative Unit Layer (GAUL) for country administrative unit data, but it does not include Japan northern territories, Ogasawara islands, and other small islands, and it seems unsuitable to use for Japan.

High-resolution coast line data for Japan was provided by GSI and the data was used to clip Japanese data from the global data set. Because of the high resolution, it took a long processing time and after that, Global Map data (1km resolution) was used. Although the Global Map data does not reflect the latest newly reclaimed land and others, it may not be a big problem to analyze inland mountains. It is recommended to use the high-resolution coast line data provided by GSI more effectively.

F/T-4　Administrative unit data

FAO Global Administrative Layer （GAUL)

Kapos mountain class data overlaid on Global Map

Japan coastline data provided by GSI

Reference

[ESA] ESA (2017) Land Cover CCI Product User Guide Version 2. Tech. Rep. Available at: maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf

[ESA CCI] ESA CCI land cover data （300m resolution, Download CCI LC Products | ESA CCI Land cover website (esa-landcover-cci.org)

[Kapos(2000)] Kapos, V., Rhind, J., Edwards, M., Prince, M., & Ravillous, C. (2000). Developing a map of the world's mountain forests. In M. F. Price , & N. Butt (Eds.), *Forests in Sustainable Mountain Development: A State-of-Knowledge Report for 2000* (pp. 4-9). Wallingford: CAB International.

[FAO HP] Sustainable Development Goals, Food and Agriculture Organization of the United Nations, http://www.fao.org/sustainable-development-goals/indicators/1542/en/

[FAO Kapos] FAO Mountain Partnership HP ： http://www.fao.org/mountain-partnership/our-work/focusareas/foodsecurity/2015-mountain-vulnerability-study/en/

[FAO SDG15.4.2 DATA] SDG15.4.2 estimation disseminated by FAO, http://www.fao.org/sustainable-development-goals/indicators/1542/en/, latest access date: February 28, 2021

[FAO Kapos DATA] Kapos mountain classification areas and percentage disseminated by FAO, http://www.fao.org/fileadmin/templates/mountain_partnership/doc/focusarea/foodsecurity/mountainarea/Mountain_areas_-_light.xlsx, latest access date: February 28, 2021

[FAO Metadata] FAO Metadata, https://unstats.un.org/sdgs/metadata/files/Metadata-15-04-02.pdf

[JAXA] JAXA high-resolution land use and land cover map, https://www.eorc.jaxa.jp/ALOS/a/en/dataset/lulc_e.htm

[JAXA ALOS ver21.03] JAXA ALOS ver21.03, https://www.eorc.jaxa.jp/ALOS/a/en/dataset/lulc/lulc_v2103_e.htm

[JAXA ALOS ver18.03] JAXA ALOS ver18.03, https://www.eorc.jaxa.jp/ALOS/a/en/dataset/lulc/lulc_v1803_e.htm

[JAXA ALOS ver16.09] JAXA ALOS ver16.09, https://www.eorc.jaxa.jp/ALOS/a/en/dataset/lulc/lulc_jpn_e.htm

[SRTM] Space Shuttle Radar Mission
https://srtm.csi.cgiar.org
[USGS Kapos] USGS Mountain Explorer
Global Mountain Explore Home　:
Global Mountain Explorer Home (usgs.gov)

Kapos mountain classification visualization:
https://earthmap.org/?aoi=ar&boundary=level2&layers=%7B%22Kapos%22%3A%7B%22opacity%22%3A1%7D%7D&map=%7B%22center%22%3A%7B%22lat%22%3A-40.43594909816739%2C%22lng%22%3A-63.58954919773806%7D%2C%22zoom%22%3A4%2C%22type%22%3A%22roadmap%22%7D&scripts=%7B%7D

Kapos classification（GME_K1, K2, K3 Datafiles）：https://rmgsc.cr.usgs.gov/outgoing/ecosystems/Global/

[MOE National Survey on the Natural Environment] MOE National Survey on the Natural Environment, Implementation Plan (in Japanese),
http://gis.biodic.go.jp/webgis/files/sc-012_sakusei_youryou_H31.pdf

[MOE National Survey on the Natural Environment] Biodiversity Center of Japan, Natural Environment Bureau, MOE, Vegetation survey list of prefectures (shape file), http://gis.biodic.go.jp/webgis/sc-025.html?kind=vg67

[MOE report] MOE monitoring site 1000 Alpine area survey 2008-2017 report (in Japanese)
（Biodiversity Center of Japan, Natural Environment Bureau, MOE）
http://www.biodic.go.jp/moni1000/findings/reports/pdf/h20-h29_alpin_zone.pdf

[Kawakita]　Local Elevation Range (LER) calculation code for Kapos mountain classification
https://github.com/shirokawakita/Kapos_calculation_example/blob/main/local_elevation_calculation_example.ipynb

[MOFA Japan SDGs Action Platform]
https://www.mofa.go.jp/mofaj/gaiko/oda/sdgs/statistics/goal15.html

[MLIT National Digital Information]
https://nlftp.mlit.go.jp/ksj/index.html

[MLIT GSI land area report] Statistical reports on the land area by prefectures and municipalities in Japan (MLIT GIS), https://www.gsi.go.jp/KOKUJYOHO/MENCHO-title.htm

[GSI Fundamental Geospatial Data] GSI Fundamental Geospatial Data,
https://fgd.gsi.go.jp/download/menu.php

[MIC Big Data meeting] “The industry-government-academia partnership meeting for promotion of use of big data”,
https://www.soumu.go.jp/main_sosiki/kenkyu/big_data/index.html

[Global Map]
https://www.gsi.go.jp/kankyochiri/gm_jpn.html