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本 **Working Paper** は、京都大学寄附講座 農林水産統計デジタルアーカイブ講座のプロジェクト研究として実施された研究成果を公表するためのものである。

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1. Introduction

In recent years, there has been a sharp increase in the harvested area of oil palm in Indonesia, Malaysia, and Thailand, which are major producers of palm oil. According to the statistics of the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT), in 2014, the harvested area reached 8.15 million hectares in Indonesia, 4.69 million hectares in Malaysia, and 644 thousand hectares in Thailand. The harvested area of oil palm in these three countries represents 69.4% of the 19,439 million hectares of the world's harvested area for the crop. These data are used widely across the globe as reliable, official statistical data. However, although these statistics are computed by experts, their accuracy cannot be determined. Therefore, to confirm the reliability of FAOSTAT statistics, we tried to estimate the harvested area in these three countries in November 2017, using the new "dot sampling survey" method on Google Earth, which we developed in 2011. We discovered that the current FAOSTAT statistics (values from 2014) are much smaller than the dot sampling survey estimates of the growing area.

Fig 1 shows the comparisons of FAOSTAT statistics and the dot sampling survey estimates for the three countries in 2014. Fig.2 compares the dot sampling survey estimates with time series statistics of FAOSTAT on the harvested area of oil palm in recent years. As can be seen in the figure, although FAO's statistics show a rapid increase, the estimates are lower than that of the dot sampling survey method, which shows the growing area in real time on Google Earth. Fig.3 shows three types of oil palm areas; the blue bars show growing area based on the dot sampling survey method (2017), green bars are the planted or harvested area (2014) according to each country's website, and orange bars are the harvested area (2014) from the FAOSTAT website by country. According to the figures, the government statistics of each country yield larger estimates than FAOSTAT statistics; however, they are still lower than dot sampling survey estimates. It is unknown why FAOSTAT statistics and the government statistics of each country are so different. We now compare the dot sampling survey value to the statistical value of FAOSTAT.

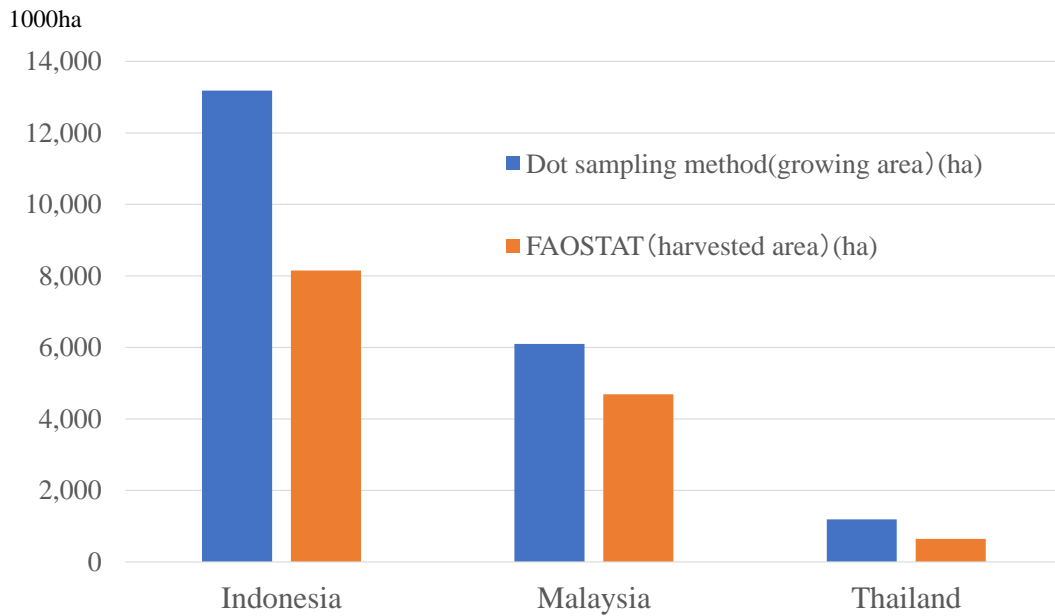


Fig.1: Comparison of the dot sampling survey estimate and FAOSTAT statistics (2014)

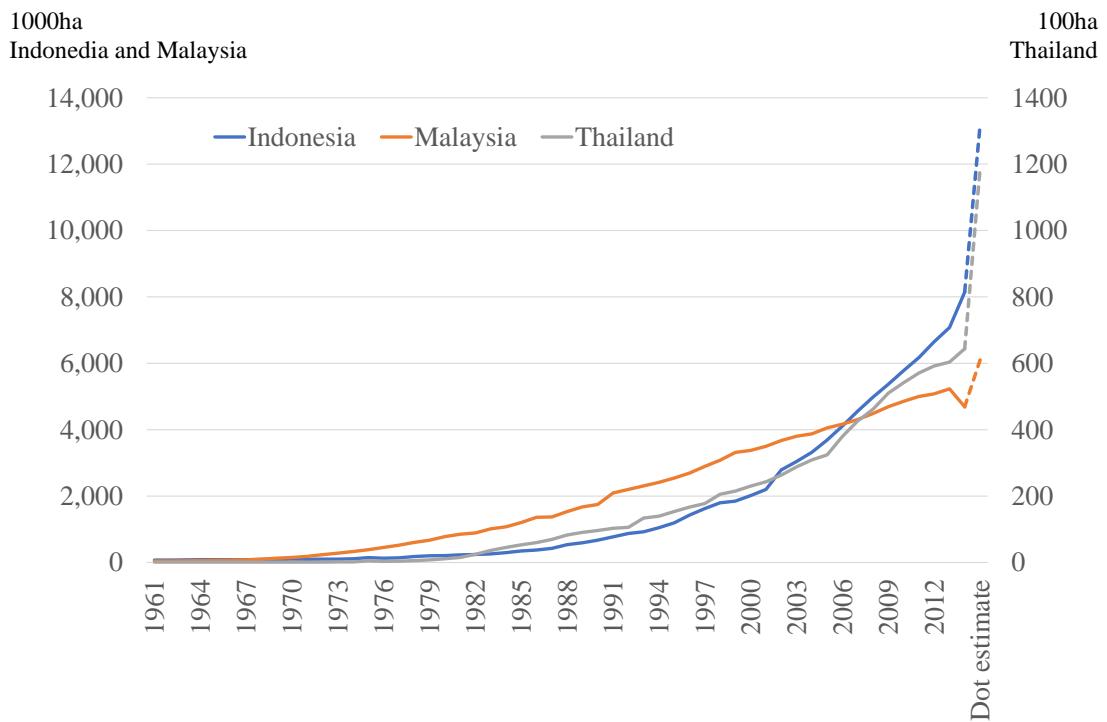


Fig.2: Comparison of the dot sampling survey estimate and long-term statistics of FAOSTAT

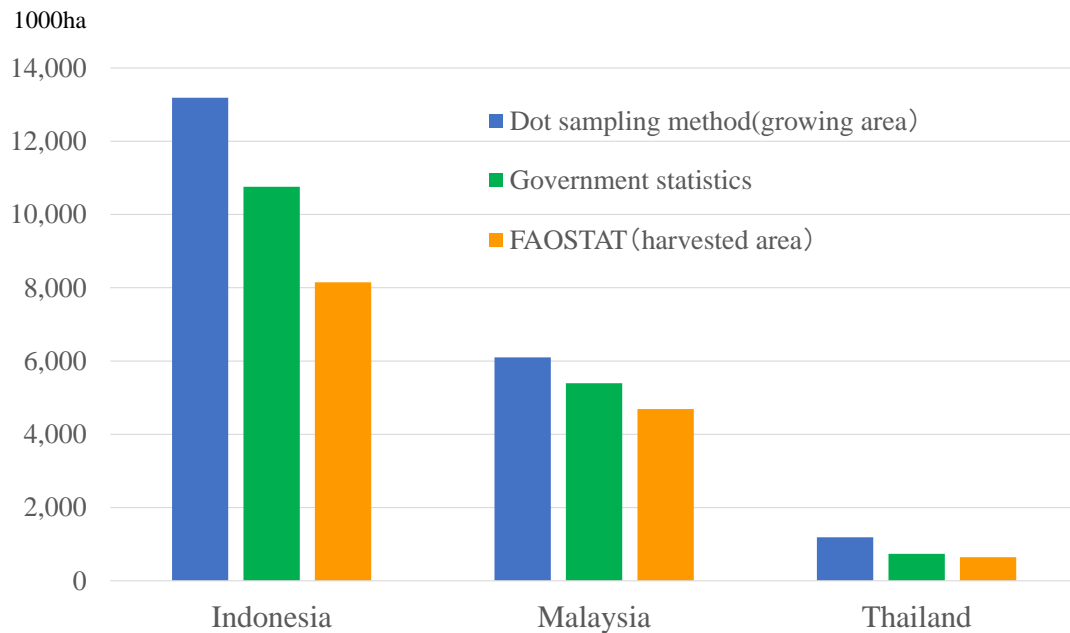


Fig.3: Comparison of the dot sampling survey estimates, each government's estimate and FAOSTAT statistics

Note: The dot sampling survey value in this figure is the growing area and the statistical value of FAOSTAT is the harvested area. The published figures of Malaysia and Thailand are for planted areas, and it is unclear whether the statistical value for Indonesia pertains to planted or harvested areas. The statistics of FAOSTAT and Thailand are for harvested area.

2. Method of the Survey

To estimate oil palm area using the survey, a sampling survey was designed for a sample size of 1,000; however, the sampling survey was designed for a sample size of 200, to be repeated five times independently, while changing the sample spots for convenience in conducting the survey. The results of the five surveys changing sample points (sampling) were summarized in November 2017. This method also follows the practical rule of thumb for calculating a given area three times when using a dot-grid plate or planimeter. Next, we compared the results with the FAOSTAT statistics. The procedure for each survey and sample design with 200 observations was as follows:

Step 1: A given sample of 200 was set on Google Earth, using Excel macro programs for the survey.

Step 2: The land use survey, using the attribute survey method, was applied to the sample dots on Google Earth, as a preparatory survey on the growing area of oil palm. Four categories (arable land, permanent crops, permanent pastures-meadows, and others (non-cultivated)) were set to conduct the survey (Note: It was possible to skip step 2, if we verify directly whether the sample dots are on the growing area of oil palm point. The reason for setting these four categories seems to be extra work; however, its purpose was further verifying the area of arable land, permanent crops, and permanent pasture-meadow, although the results are not shown here).

Step 3: The growing area of oil palm was verified one-by-one with the sample dots, which were identified as permanent crops in the preparatory survey.

Step 4: The sample dots that indicated a growing area of oil palm were counted.

Step 5: The above survey process was repeated five times, changing the locations of sample dots.

Step 6: The total number of sample dots that indicated a growing area of oil palm was computed and divided by the total number of sample dots in the surveys of the country, to estimate the share of the growing area of oil palm.

Step 7: Finally, the growing area of oil palm (\hat{T}) was estimated by multiplying the share of oil palm ($n_{oil\ palm}/n_{total} = \hat{p}$) and country land area (W). The formula is shown below.

$$\hat{T} = \left(n_{oil\ palm} / n_{total} \right) \times W = \hat{p}W$$

Note: For the actual dot sampling survey, growing area should be estimated by conducting the field survey at the dot sample points on the ground. For the results of this study, growing area is estimated using Google Earth, without a field survey.

Fig.4 is an additional reference that shows an example of the sample (size 200) for Indonesia on Google Earth. The sample dots were assigned an identifier and applied systematically. By zooming in at each sample spot, the attribution of land use can be clearly judged. About 14 sample dots on average included an oil palm farm in Indonesia.

3. Results of the survey

3.1 Comparison of the results of the dot sampling survey and the FAOSTAT statistics

To compare the estimated values from the dot sampling survey on oil palm area to the FAOSTAT values by country, we first calculated the respective ratios of the survey results to the country land area and organized them as shown in Table 1.

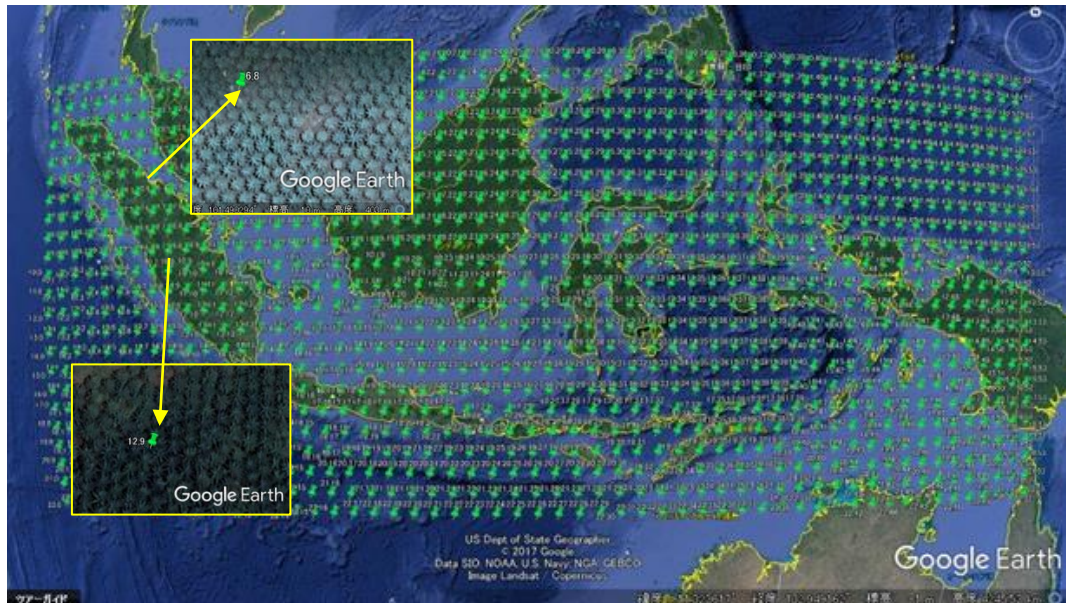


Fig. 4: Sample (sample size 200) applied to Indonesia on Google Earth

The estimated values using the dot sampling survey method are 6.9% in Indonesia, 18.4% in Malaysia, and 2.3% in Thailand; those estimates were higher than the corresponding FAOSTAT harvested area ratio in each country. The statistical values of FAOSTAT are consistently smaller than the actual growing area estimated by the dot sampling survey method in the three countries. The FAOSTAT statistics are 2.6 percentage points smaller in Indonesia, 4.3 points smaller in Malaysia, and 1.1 points smaller in Thailand. These differences greatly exceed the sampling error by the dot sampling survey method, which convinced us that the FAOSTAT statistics are underestimated. The coefficient of variation of estimate (CV) with sample sizes of 1000 is 11.8% in Indonesia, 6.7% in Malaysia, and 20.6% in Thailand. The CV in Thailand is bigger than the other two countries because the share of oil palm in country land is small (only 2.3%).

Table 2 shows the differences between the actual area of the oil palm estimated based on the dot sampling survey and the FAOSTAT statistics. The FAOSTAT statistics is 5.036 million hectares smaller in Indonesia, 1.411 million hectares smaller in Malaysia, and 545 thousand hectares smaller in Thailand. As shown above, the FAOSTAT statistics are lower because there seem to be problems with the statistical survey method in FAOSTAT statistics, but the details of the cause are not determined from these survey results.

Table 1: Comparison of the results of the dot sampling survey and FAOSTAT statistics (ratio)

Comparison of the dot sampling value and FAO value				
	Dot sampling method(growing area)(%)	FAOSTAT (harvested area)(%)	Difference (point)	
Indonesia	6.9	4.3	-2.6	
Malaysia	18.4	14.2	-4.3	
Thailand	2.3	1.3	-1.1	
Sample size				
	Planned sample size	Real sample size	Sampling error (point)	C.V (%)
Indonesia	1,000	973	0.81	11.8
Malaysia	1,000	988	1.23	6.7
Thailand	1,000	993	0.48	20.6

Note: The sampling error was calculated by $\sqrt{pq/n}$.

Table 2: Comparison of the dot sampling survey estimate of oil palm area and FAOSTAT statistics (real number)

	Dot sampling method(growing area) (ha)	FAOSTAT (harvested area) (ha)	Difference(ha)	Dot estimate / FAOSTAT
Indonesia	13,185,621	8,150,000	-5,035,621	1.6
Malaysia	6,099,858	4,689,321	-1,410,537	1.3
Thailand	1,188,495	643,811	-544,684	1.8

3.2 Precautions for comparison of the data

Strictly speaking, a field survey should be conducted to verify the growing area of oil palm at sites indicated by the sample dots. However, it is impossible to visit all sample sites in

those countries from Japan. Fortunately, in this dot sampling survey, it is quite easy to determine from Google Earth that oil palm is growing at a given sample site. As oil palm has a special crown shape, alleviating the need to conduct a field survey. Further precautions that should be considered when comparing the data used here are listed below:

(a) Definition of harvested area and growing area

The FAOSTAT statistics of oil palm area is regarded as the harvested area. On the other hand, the estimated value by the dot sampling survey method is the growing area (planted area). It is impossible to determine the harvested area, based on FAOSTAT's definition of "harvested area," using the dot sampling survey method and Google Earth. Therefore, there is a conceptual difference in definition between both surveys. According to data from the Thai government, the planted area of oil palm is about 1.20 times larger than the harvested area; however, even considering this factor, the difference in the FAOSTAT statistics and the dot sampling survey estimates in each country are still large, especially in Indonesia and Thailand.

(b) How to distinguish oil palm from other crops on Google Earth

In general, it is difficult to strictly conduct agricultural land use surveys (arable land, permanent crops, permanent pastures and permanent meadows and pastures, and others (non-cultivated), etc.) only using Google Earth if the resolution of the maps is low, or if the reading technique of operators is still immature. As such, the results could be unreliable. However, in the three countries targeted here, oil palm trees are often in clear areas. This makes them readily detectable from the Google Earth map images, and the unique shape of the crown ensures they can be distinguished clearly from other trees. Therefore, an area survey of oil palm can easily be performed with precision, and without non-sampling errors such as misreading the attribution. The picture below shows an oil palm farm on Google Earth.

(c) How to deal with farm roads, dykes, etc., in an oil palm farm

It is unknown whether statistical values of FAOSTAT, for example, include the roads and dykes in oil palm farms (such as plantations); however, in the dot sampling survey, it can estimate a pure planted or growing area excluding the area taken up by roads or dykes in the farms.

(d) How to deal with the situation when other permanent crops are growing in the oil palm farm

Other permanent crops are sometimes cultivated in the same lot (such as mixed cultivation) with oil palm; however, in this case, if an area indicated by sample dots does not consist of oil palm, it is not counted as an oil palm growing area.



Fig. 5: Image of oil palm growing farm on Google Earth (Malaysia)

Note: The oil palm is distinctive in its crown shape and can be clearly distinguished from other tree species.

(e) How to deal with the situation when the maps on Google Earth are unclear (low resolution)

If the sample dots area lies in a low-resolution area on Google Earth, it is necessary to refer to the archived image using the Google Earth function, or by examining land use around the sample dots; however, those cases were few.

(f) Time lag issues

Old Google Earth maps cause errors due to time lag. However, in recent years, Google Earth maps have been updated frequently, and maps for most areas surveyed in this study were updated in the 2010s. Therefore, there does not seem to be a serious time lag problem even when comparing the results of the dot sampling survey in this time period (2017) with the FAOSTAT statistics in 2014.

4. Conclusion

We compared the harvested area of oil palm in Indonesia, Malaysia, and Thailand, as per FAOSTAT statistics, with the estimates of the dot sampling trial survey conducted in

November 2017, using Google Earth. The results suggest that the FAOSTAT statistics are underestimated. From the FAOSTAT statistics, the area of Indonesia might be 5.0 million hectares smaller than our dot sampling survey estimate, and that of Malaysia might be 1.4 million hectares smaller than our survey estimate, demonstrating the magnitude of difference. Although the results of this survey were obtained through deskwork using the dot sampling survey method and Google Earth, without field surveys, we believe that our methodology for statistical estimates is adequately reliable. A key factor supporting the accuracy of this survey is the recognizable special shape of the crown of the oil palm, making it readily distinguishable from other tree types on Google Earth maps. The reliability of the survey could be improved with a larger sample size and better map resolution.

Finally, this short report is written with the intent to be shared among stakeholders who are interested in agricultural statistics, especially crop area surveys. We hope this report contributes to improving agricultural statistics. We welcome suggestions on this first dot sampling survey of growing areas of oil palm using the dot sampling method.

Acknowledgements

I deeply appreciate the advice for summarizing this report from associate Professor Tetsuji Senda of Kyoto University and the useful suggestions for improving this report from Mr. Kenji Kamikura, who was a senior statistician at the Ministry of Agriculture, Forestry and Fisheries, Japan (MAFF). Furthermore, we would like to thank Editage (www.editage.jp) for English language editing.

It is a matter of great honor that this small report is to be printed as a paper in the working paper series of the Academic Center for Computing and Media Studies of Kyoto University.

Glossary

Attribute survey

The attribute survey investigates only inclusion in predefined categories, in contrast to the variable survey, which measures the amount in a category. When using this method, it is not necessary to measure the area at sample points, but only identify the category. The dot

sampling method adopts this method; in this survey, we investigated only whether oil palm is growing at sample points on Google Earth.

Dot sampling method

The dot sampling method was developed to estimate the area of land use using Google Earth. The theory comes from the attribute survey. It has long been known as a sampling survey method using maps. The dot sample survey method is able to extract sample points on Google Earth directly at random. Therefore, it is not necessary to organize the population for a sampling survey, and it is also considered an excellent survey method because it is possible to conduct land use surveys on Google Earth. In this system, the sample points are designed to be determined by a combination of latitude and longitude, and arranged in a dot-grid pattern. The following report on the FAO website explains the method:

http://www.fao.org/fileadmin/templates/rap/files/Project/Expert_Meeting_17Feb2014_/P1-1_Dot_sampling_method_for_planted_area_estimation_using_Google_earth_land_use_survey_FAO_RAP_17_Feb_2014.pdf

Dyke

Generally, it is a portion of embankment or similar structure that surrounds paddy fields so that the water used to flow into the paddy does not leak outside, but it can also be used to identify the boundary of the fields (lots). In this report, it is used to refer to the boundary of the growing area.

FAO

FAO (United Nations Food and Agriculture Organization) is a specialized agency of the United Nations, working on the development of the world's agriculture, forestry and fishery industry, and rural development. The FAO consists of 196 member countries (including two sub-member countries) and the EU (European Union), with headquarters in Rome, Italy.

FAOSTAT

FAOSTAT is the largest and most comprehensive online statistical database related to the food and agriculture, forestry and fishery industry operated by the FAO (United Nations Food and Agriculture Organization).

<http://www.fao.org/faostat/en/#data>

Growing area

See “Planted area.”

Google Earth (Pro)

Google Earth is a computer program, provided by Google, which renders a representation of the Earth based on satellite imagery combining satellite images, aerial photography, and GIS data, readily usable by anyone. The dot sampling method uses Google Earth Pro, which integrated with Google Earth in 2017, and added significant functionality for

manipulating GIS data. In this report, we use “Google Earth” referring, actually, to Google Earth Pro.

<https://www.google.com/earth/download/gep/agree.html>

Harvested area

See “Planted area.”

Oil palm

Oil palm is a type of palm that produces palm oil, which is now the most widely used vegetable oil in the world. Of the total 200 million tons of vegetable oils and fats produced, the production of palm oil accounts for 59.2 million tons (2014), nearly 30%.

Planimeter

Planimeter is a measuring instrument used to calculate the area of a figure on a map.

Planted area (Harvested area, Growing area)

Planted area is the crop area intended for harvesting. Harvested area is the crop area that has actually been harvested. In general, harvested area is smaller than planted area owing to disaster, etc. The growing area is where oil palms are grown, regardless of intent to harvest. Areas for permanent crops such as oil palm, which is not harvested for reasons such as abandoned cultivation, could also be considered growing area. It is very difficult to distinguish between harvested area and growing area on Google Earth without an actual field survey. Therefore, conceptually, growing area could be larger than planted area or harvested area in our survey.

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