Dot sampling method for Area Estimation

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ABSTRACT

The purpose of the paper is to introduce a new survey method for area estimation, what we call "the dot sampling method," and show an example of rice planted area survey in developing countries by using this method. This new method has been developed by combining a traditional attribute survey method with two current information technologies, i.e., Excel and Google Earth. These combinations enable us to achieve a more simple, reliable, and cost-effective survey method in comparison with existing methods.

In Section 2 we illustrate how to estimate an actual planted area which is taken up for JICA training course. We show the procedure of the dot sampling method in detail, consisting of four steps: dot sampling, preparatory survey on Google Earth, field survey, and estimation of planted area by crop. This procedure can be easily applied to area survey at the country level.

By way of illustration we conduct rice planted area survey in Sri Lanka and Thailand. In the paper, only the results of preparatory survey on Google Earth are shown. Although the results obtained are found close to official statistics in those countries, we believe that our results are statistically more objective than those obtained by using existing method, even official statistics.

Key Terminology Keywords: Dot sampling Method, Attribute survey, Google Earth, Area survey, Preparatory survey, Field survey.

1. Back Ground

It is very important to develop a reliable and cost-effective survey method for the crop production surveys in the developing countries.

However, we recognize that it is difficult for developing countries to adopt area frame methods based on existing sampling methods, because those methods incur high cost and require considerable labor even in the preparatory stage of sampling survey (necessary to construct area frames). Furthermore, those methods cannot solve the problems cause by non-sampling errors which often occur. In the process of developing the dot sampling method, we learned a point sampling method which is used in European countries, but it seemed to be a complicated method for us because it requires both stratifications and two stage sampling. We do not feel that the procedure itself is effective in any case. Moreover, it uses GIS. In general, such an expensive tool is not easy to learn. The latest remote sensing method incurs high costs and also requires both high techniques and considerable labor.

In contrast, the dot sampling method, which we are going to introduce here, is a new sampling survey method. It tries to estimate planted area by distributing sample dots systematically and directly to a whole target area on the Google Earth and, then, conducting a field survey at the sample dots in the target area. It does not require constructing area frames.

The dot sampling method is developed by combining a traditional statistical theory, which is called attribute survey, with the latest information technologies, namely Excel and

Google Earth. The method is simple, reliable, cost-effective and, what is better, easy to learn. It took two years from 2011 to 2013 to develop this method.

The method also have resolved a lot of issues on crop surveys (e.g. how to construct master sampling frames, how to select survey items, i.e., not only core crops but also rare crops, how to measure dykes, slope, complicated fields, mixed cropping, how to avoid non-sampling errors, how to build human capacities, how to conduct trainings, how to reduce survey costs, etc.) which we had been facing for a long time.

We thank FAORAP for giving us a chance to explain the dot sampling method at the Expert Meeting on Crop Monitoring for Improved Food Security" on 17 February 2014 held as a side event of 25th APCAS[1]. We hope that we will share the dot sampling method and our experience with you.

2. Methodology and Procedure

2.1 Dot sampling method

The dot sampling method originates in the point sampling method which is a traditional sampling method, i.e. attribute survey method. In the process of improving existing methods, we have developed a new method based on the latest information technologies (Excel and Google Earth on the Internet). Therefore we named it "Dot sampling method". Dot sounds like a suitable word reflecting the Internet Age.

As mentioned above, the dot sampling method originates in the point sampling method. Dr. Frank Yates describes the point sampling method as follows[2]:

3.9 Sampling with probabilities proportional to size of units
"If we have areas demarcated on a map, such as fields, and a point is located at random on the map, the probabilities of the point falling within the boundaries of the different fields are clearly proportional to the areas of the field. Consequently, areas can be selected at random with probabilities proportional to their size by the simple procedure of taking random points on the map."(P.35)[3]
"The principle has applications in agricultural surveys designed to determine the acreage and yield of different crops, total cultivated area, etc. All that is required for acreage is to determine the proportion of points which fall in areas of the given type. The method therefore particularly attractive when carrying out surveys of the area crops, etc., by aerial survey, by provided the different crops can be recognized on the photograph, since it avoids all the measurement of area which would be required if an ordinary random sample of areas were taken."(P.35)
4.24 Use of maps as frames in agricultural surveys
"If accurate large-scale maps showing the field boundaries are available, the point method of sampling is very suitable for crop surveys in which contact with farmer is not necessary. The fields will then act as sampling units, and selection will be with probability proportional to size. Provided the whole of a selected field is under a single crop, all that is necessary for acreage estimates is to ascertain the crops, no determination of area being required. If more than one crop is being grown on a selected field, the proportions of area under the different crops must be determined, but eye estimate will usually be adequate for this purpose.
In this type of work two-stage sampling[4] will often be advisable in order to save traveling, and also to avoid having to handle an excessive number of maps". (P.82)

The old traditional sampling method stimulates us to develop the new dot sampling method. The basic idea of the dot sampling method[5] is to simply use a "Dot sheet"[6] for an area survey. It is easy to learn the dot sampling method using the dot sheet.

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[1] Concept Note "Expert Meeting on Crop Monitoring for Improved Food Security" 17 February 2014, Vientiane, Lao PDR.
[2] SAMPLING METHODS for CENSUS AND SURVEYS by FRANK YATES, London, 1949
[3] This is the most important concept in the "Dot sampling method" for area surveys.
[4] We adopt single stage sampling. The two-stage sampling method is not always effective.
[5] It was in May 2011 that the dot sampling method was suggested to us by Mr. Kenji Kamikura who is a senior statistician in MAFF of Japan.

As you can see Figure 1 and Figure 2, the dot sheet has two types. Figure 1 shows a simple random dot sheet, and Figure 2 shows a systematic random dot sheet. The latter sheet is more popular and practical than the former one. The dot sheet has three functions:

① "random sampling without sampling list"
② "a share estimator without measuring"
③ "a special function to be square area frame for variable survey"[7].
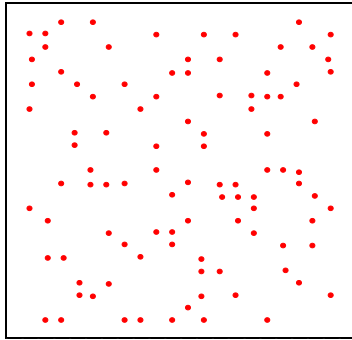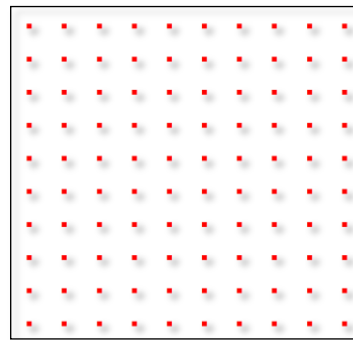

Figure 1: Simple random dot sheet   *Figure 2: Systematic random dot sheet*

Owing to the first function, you can select sample dots without sampling list. It means that you don't have to construct sampling frames, which requires considerable work.

When you use this function for a sampling, you only just overlay the dot sheet on the target area (Figure3). The "overlaying" of the dot sheet on the area realizes the PPS sampling (probabilities proportional to size of fields (units)). To each sample dot selected with systematic random sampling is given the location by the dot sheet. This is the basic idea of the dot sampling using the dot sheet. Each dot can be given the name automatically in actual surveys.
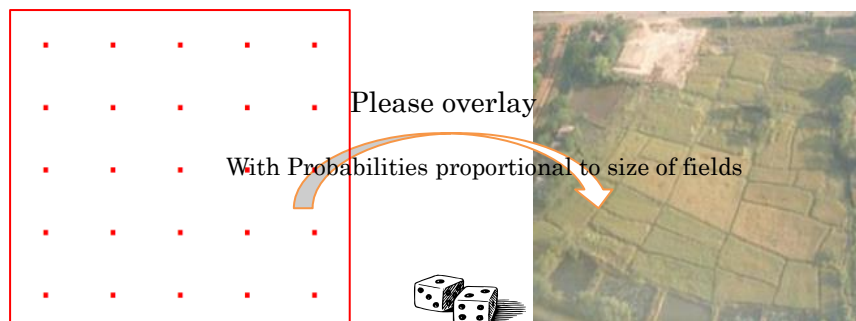

Please overlay

With Probabilities proportional to size of fields

Figure 3:   Dot sheet and target area

The second function suggests that you can conduct an area survey without measuring area at sample fields[8]. This function is shown in Figure 4. Sample dots are already put within a target area.

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[6] We have used the systematic dot sheet to measure area of cultivated lands on maps not only when we were young officers but also when we were primary school children, but we did not have the idea of using it for sampling tool or of using it as a tool to estimate the share of land use category in a large area. Of course, we have learned attribute survey, but we have not regarded it as important.

[7] The third function will be explained later (See. P11).

[8] Before we reached the dot sampling method, we had experienced using list frame method and (both physical and mesh) area frame method. We thought that area sampling surveys should be based on frames, so it must be impossible to estimate reliable area without frames. But we knew those were not always efficient. After giving up using those authoritative methods, we have finally obtained a lot of useful results.
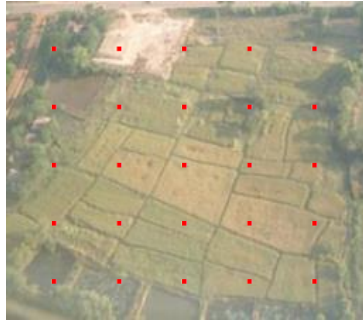
Figure 4: *Dot sheet on the target area*

When you conduct an area survey, you only just identify the category of land use at sample dots, and you count the number of dots by category to estimate the proportion[9]. Therefore, you don't have to measure. Such a survey method is called "attribute survey". As it does not need to measure, and it also suggests that you do not have to get access closely to the sample field.

Furthermore, the number of survey items at a sample dot is only one item. It makes a questionnaire simple. It also makes survey effective.

But, you can estimate land use areas by category based on statistical formula, and calculate reliabilities, namely sampling error.

The formulas which are used here are shown as follows.

Estimate: $\hat{T} = \frac{n_1}{n} W = \hat{p} W$

where,

W : Whole area of target area.

n : Number of sample dots

n_1: Number of sample dots which are identified on the survey item (e.g. rice field)

Standard error (SE)　　SE $= \sqrt{\hat{p}\hat{q}/n}$,

Coefficient of Variance of Standard Error (hereafter abbreviated as CV）is calculated as SE$/\hat{p}$.

where　　　　　　$\hat{p} = \frac{n_1}{n}$,　　　　$\hat{q} = (1 - \hat{p})$

Non sampling errors, such as measuring errors, hardly occur in this method. When you conduct a survey, you don't have to worry about whether a sample dot is composed of a complicated field, a mixed cropping field[10], or slope land, because it is an attribute survey. These merits are due to the properties included in the attribute survey.

2.2 Procedure of the Dot sampling method for a planted area survey

Based on the basic idea mentioned above, we designed the procedure of the dot sampling method for a planted area survey in Figure 5 below. It consists of four steps. The first step is "dot sampling", the second step is "preparatory survey", the third step is "field survey" and the fourth step is "estimation". To realize the idea, especially in the first step, we developed two techniques using Excel VBA. One is to generate the systematic random sampling dots on Excel sheet and the other is to put those sample dots on Google Earth.

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[9] Therefore, it is occasionally called "proportion estimator".

[10] When you find mixed cropping at a sample dot, you have only to give "1" to each crop without considering the weight of planting crop's area. In that case, an increase in the planted area of each crop would come to decrease its yield.
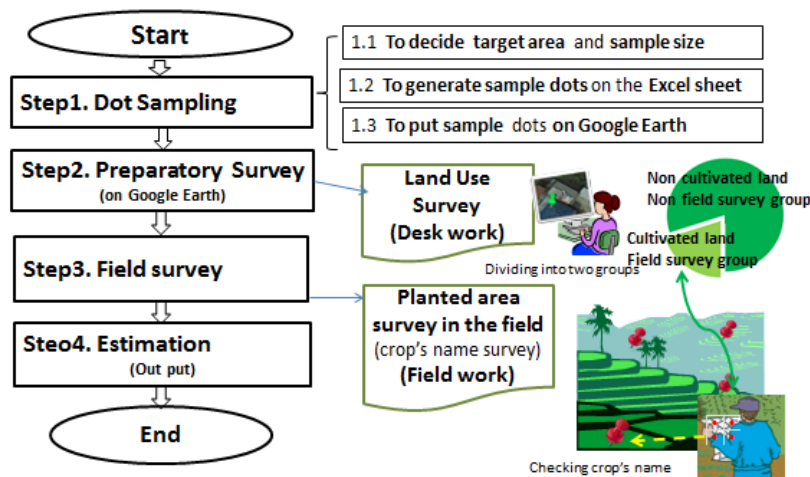
Figure 5: *Procedure of the dot sampling method for a planted area survey*

Next we explain how to apply the method to an actual planted area survey step by step, picking up as a target area the area of JICA training course in Tsukuba city in Japan.

The actual planted area survey method is lectured on in JICA training course[11] every year. The area survey is conducted in a small area. But the procedure can be applied directly to an area survey in a large area, even at the country level.

Step 1 Dot Sampling

The first step, i.e. the dot sampling, consists of three sub-steps. The first sub-step is "to determine target area and sample size", the second sub-step is "to generate sample dots on the Excel sheet", and the third sub-step is "to put sample dots on Google Earth".

Step 1.1 To decide target area and sample size

The target area is shown in Figure 6. This area is located close to JICA Tsukuba International Center. The size of target area is 24ha (400m×600m).[12]

Sample size is determined considering aimed precision, budget, manpower, etc. In the case of JICA training course in 2011, 2012 and 2013, the sample size was 96.

Figure 6: *Target area around JICA Tsukuba International Center*

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[11] "Planning, designing and implementing of sampling survey (crop production survey), from Sep.2 to Sep. 9 2-13" in the "PLANNING AND DESIGNING OF AGRICULTURAL STATISTICS FOR FOOD SECURITY MAKING" by JICA. From AUG.25 to OCT.19, 2013. Until now the training course has been was held in November 2011, in Septembers 2012 and 2013. There are 16 participants from 15 countries in Asia and Africa in 2013.

[12] In this case, the shape of the target area is a rectangle. It might be interesting to draw a figure which has complicated boundaries or physical boundaries.

Step 1.2 To generate sample dots on the Excel sheet

The sampling in a target area is conducted on the Excel sheet using our macro program[13].

First, as shown in Table 1 below, you input data (Name of target area, Size of the target area, Sample size, Starting point and Finishing point[14] with latitude and longitude) which are required in the T-1. Then, based on inputted data, Excel macro program automatically generates sample dots on the T-2.

Table 1: *Dot sampling table combining latitude and longitude*

T-1 Basic data to generate sample dots (Sampling Design)

Target area	Size of the Target area km²	Sample size	Starting point (latitude)	Starting point (longitude)	Finishing point (latitude)	Finishing point (longitude)	Interval in km (depend on (3))	Necessary Number of Lines	Necessary Number of Rows
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=√((2)/(3))	(9)	(10)
JICAshimoyokob	*0.24*	*96*	*36.030751*	*140.12411*	*36.027596*	*140.13022*	*0.05*	*8*	*11*

T-2 Sample dots (Coodinate Values) — Don't change the numbers on yellow cells because the numbers are used for the calculations.

Name of Longitude → Latitude ↓	0	1	2	3	4	5	6	7	8
0,	36.03075098,140.12 41082	36.03075098,140.1 24663606033	36.03075098,140.1 25219012066	36.03075098,140.1 25774418099	36.03075098,140.1 26329824132	36.03075098,140.1 26885230165	36.03075098,140.1 27440636198	36.03075098,140.1 27996042231	36.03075098,140.1 28551448264
1,	36.030300311329,1 40.1241082	36.030300311329, 140.124663602856	36.030300311329, 140.125219005711	36.030300311329, 140.125774408567	36.030300311329, 140.126329811422	36.030300311329, 140.126885214278	36.030300311329, 140.127440617133	36.030300311329, 140.127996019989	36.030300311329, 140.128551422844
2,	36.029849642658,1 40.1241082	36.029849642658, 140.124663599678	36.029849642658, 140.125218999356	36.029849642658, 140.125774399034	36.029849642658, 140.126329798712	36.029849642658, 140.12688519839	36.029849642658, 140.127440598068	36.029849642658, 140.127995997746	36.029849642658, 140.128551397424
3,	36.029398973987,1 40.1241082	36.029398973987, 140.124663596501	36.029398973987, 140.125218993001	36.029398973987, 140.125774389502	36.029398973987, 140.126329786003	36.029398973987, 140.126885182503	36.029398973987, 140.127440579004	36.029398973987, 140.127995975504	36.029398973987, 140.128551372005
4,	36.028948305316,1 40.1241082	36.028948305316, 140.124663593323	36.028948305316, 140.125218986647	36.028948305316, 140.12577437997	36.028948305316, 140.126329773293	36.028948305316, 140.126885166617	36.028948305316, 140.12744055994	36.028948305316, 140.127995953263	36.028948305316, 140.128551346586
5,	36.028497636645,1 40.1241082	36.028497636645, 140.124663590146	36.028497636645, 140.125218980292	36.028497636645, 140.125774370438	36.028497636645, 140.126329760584	36.028497636645, 140.126885150573	36.028497636645, 140.127440540876	36.028497636645, 140.127995931022	36.028497636645, 140.128551321168
6,	36.028046969741, 140.1241082	36.028046969741, 140.1246635886969	36.028046969741, 140.1252189773937	36.028046969741, 140.1257743660907	36.028046969741, 140.1263297747875	36.028046969741, 140.12688513484 4	36.028046969741, 140.1274440522181	36.028046969741, 140.12799590878	36.028046969741, 140.12855129575
7,	36.0275962993031, 140.1241082	36.0275962993031, 140.12466358379 2	36.0275962993031, 140.1252189675883	36.0275962993031, 140.12577435137 5	36.0275962993031, 140.1263297351637	36.0275962993031, 140.1268851189599	36.0275962993031, 140.12744050275	36.0275962993031, 140.1279958865442	36.0275962993031, 140.12855127033 4
8,	36.0271456306321, 140.1241082	36.0271456306321, 140.1246635806615	36.0271456306321, 140.12521896122 9	36.0271456306321, 140.12577434184 4	36.0271456306321, 140.12632972245 9	36.0271456306321, 140.1268851030731	36.0271456306321, 140.12744048368 8	36.0271456306321, 140.12799586430 3	36.0271456306321, 140.12855124491 7

The location of each sample dot is shown with the combination of latitude and longitude. This is the sampling on the Excel sheet. Each sample dot is given the name by numbering rows and columns of the table, and those can be automatically converted on Google Earth (See Figure 7). This procedure makes it easy to check the category of land use at sample dots and to visit there in the field.

Step 1.3 Putting sample dots on Google Earth

Based on the data of the Excel sheet which is shown above, the sample dots with names are displayed in the target area on Google Earth by macro program[15] as you can see Figure 7 below.

Figure 7: *Sample dots which are put in the target area on Google Earth*

This technique makes a survey effective dramatically. Before the development of the macro program, we put sample dots one by one on Google Earth manually. Both Starting point and finishing point are required to generate T-2 table.

Step 2 Preparatory survey for field survey on Google Earth

After the sampling, you conduct "land use survey" on Google Earth, which is called "preparatory survey" for field survey. It is a desk work. The main purpose of the survey is to make the field survey more efficient

Table 2 shows the questionnaire for the preparatory survey, and the questionnaire has been filled with the results of the survey. Category and codes are shown on the left side of the questionnaire.

You will find two rare or uncommon categories in Table 2. One is "Dyke", and the other is "Tentative reserve".

In general, cultivated land consists of two parts, one is field proper and the other is attached dyke. Dyke plays dual roles: one is as a border of field and the other is to keep water in the rice field. In this table, "dyke" includes tree, rock, ant-hill, cottage, parking space, etc. Therefore, "Paddy field" and "Upland" do not include dykes here. These definitions are useful to estimate yield per unit (1ha) based on crop cutting survey, because crop cutting is conducted in the field proper which does not include dyke.

"Tentative reserve" makes your work efficient. For example, when you are conducting a preparatory survey, you may come across some sample dots whose land use categorization cannot be quickly determined. In such cases you can proceed to next sample dots.

Table 2: *Questionnaire of the preparatory survey (Sep. 2012)*

	Category	Code		0	1	2	3	4	5	6	7	8	9	10	11
Cultivated land	Paddy field	1	0	1	1	2	8	8	5	5	1	1	1	4	4
	Dyke	2	1	8	1	1	1	7	1	5	1	1	1	1	6
	Upland	3	2	3	8	5	1	1	1	6	5	1	1	1	1
Non Cultivated land	Residential Land	4	3	4	4	4	4	4	1	1	1	5	1	1	1
	Road (asphalt)	5	4	4	4	4	4	5	3	3	1	2	5	6	1
	Road(soil)	6	5	4	4	4	4	4	3	3	3	5	1	5	6
	Irrigation, river	7	6	4	4	4	5	4	6	3	3	3	8	2	5
	others	8	7	4	4	4	4	8	3	3	3	3	8	3	1
Tentative reserve		9													

Through the preparatory survey, you can obtain information concerning actual sample size of the field which you should survey because you don't have to conduct field survey at sample dots on the non-cultivated land. You should conduct field surveys at "Cultivated land" and "Tentative reserve"[16] individually.

Table 3 shows the result of the preparatory survey. This result is estimated from the preparatory survey on Google Earth. This table suggests that the role of preparatory survey is not only to show the actual sample size of the field you should go to survey, but also to show land use statistics. It is thought that the results are close to real statistics, but have a time lag a little. Furthermore standard errors and CV are calculated by category.

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[16] But, in this training, trainees visited all sample dots including "Non cultivated land". They could learn the method clearly by checking the category at each sample dot.

Those outputs show that you can obtain important information on land use statistics even in the stage of preparatory survey[17].

Table 3:   *Result of the preparatory survey (Sep. 2012)*

	Category	Code	Frequency	Share (%)	Area (ha)	SE	CV
Cultivated land	Paddy field	1	30	31.3	7.5	4.7	15.1
	Dyke	2	3	3.1	0.8	1.8	56.8
	Upland	3	14	14.6	3.5	3.6	24.7
Non Cultivated land	Residential Land	4	24	25.0	6.0	4.4	17.7
	Road (asphalt)	5	12	12.5	3.0	3.4	27.0
	Road(soil)	6	5	5.2	1.3	2.3	43.5
	Irrigation, river	7	1	1.0	0.3	1.0	99.5
	others	8	7	7.3	1.8	2.7	36.4
Tentative reserve		9	0	0.0	0.0	...	...
Total			96	100.0	24.0	0.0	0.0

Step 3 Field survey

When you conduct a field survey, Google Earth guides you to the sample dots on the map. You only identify the land use category of planting crops at sample dots.

The field survey should be conducted in growing seasons of crops. In the field survey, you don't have to survey at sample dots which are located on non-cultivated lands. As mentioned above, this is a reason why you should conduct a preparatory survey before the field survey. It makes the field survey more efficient. The actual sample size will be decreased dramatically (See P13-14).

Figure 8 shows that trainees are seeking for a sample dot with guide maps. At the back of them you can see rice fields.

Figure 8:   *Field survey with maps Google Earth (Sep.2012)*

Table 4 shows the questionnaire of the field survey. It is the same form as the preparatory survey. The category codes are shown at the left side. Yellow color (code 101) shows rice planted area. The results of the preparatory survey are updated by conducting the field survey. This relationship between the preparatory survey and field survey is very important to understand the role of the field survey and the structure of the dot sampling method.

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[17] Google Earth is what is called "Big Data". It has huge data, and we can use them for free. We can produce land use statistics from Google Earth.

Table 4: *Questionnaire of the field survey (Excel sheet) (Sep.2012)*

Category	code
Dyke	3
Residential land, (Include bulding, parking, etc)	4
Road (asphalt)	5
Road (soil)	6
Irigation, River	7
Others	8
Paddy	101
Sweet potato	102
Soybean	103
Vegitable	104
Fruite (Tree)	105
Turf (Lawn)	106
No plant (prepalation)	107

	0	1	2	3	4	5	6	7	8	9	10	11
0	101	3	7	8	6	5	101	101	101	101	8	104
1	106	101	101	101	8	101	5	101	101	101	101	3
2	107	8	4	101	101	101	6	5	106	101	101	3
3	4	6	105	4	5	101	101	101	5	101	101	101
4	4	4	4	4	107	101	107	101	101	5	101	101
5	4	4	4	106	5	107	106	106	3	101	5	101
6	8	8	4	5	107	5	106	5	106	5	101	5
7	8	4	4	4	107	107	104	6	106	106	5	101

Step 4 Estimate of planted area by crop

Table 5 shows the result of estimation based on the field survey. You will find various crops which are growing at the sample dots. It means that you can estimate not only core crops' planted area but also rare crops' planted area. You can also calculate SE and CV by category. They are calculated using simple formulas, as we mentioned (See P.4).

Table 5: *Result of the planted area survey (Sep.2012)*

Category	code	Number of dots	Share (%)	Area (ha)	SE	CV
Dyke	3	4	4.2	1.0	2.0	48.9
Residential land, (Include bulding, garden, parking,	4	14	14.6	3.5	3.6	24.7
Road (asphalt)	5	14	14.6	3.5	3.6	24.7
Road (soil)	6	4	4.2	1.0	2.0	48.9
Irigation, River	7	1	1.0	0.3	1.0	99.5
Others	8	7	7.3	1.8	2.7	36.4
Paddy	101	33	34.4	8.3	4.8	14.1
Sweet potato	102	0	0.0	0.0	0.0	···
Soybean	103	0	0.0	0.0	0.0	···
Vegitable	104	2	2.1	0.5	1.5	70.0
Fruite (Tree)	105	1	1.0	0.3	1.0	99.5
Turf (Lawn)	106	9	9.4	2.3	3.0	31.7
No plant (prepalation)	107	7	7.3	1.8	2.7	36.4
Total		96	100	24.0	0.0	0.0

3. Further discussions

This section introduces some interesting discussions and questions we have faced in the process of developing the dot sampling method. These issues have not been studied and arranged sufficiently yet, but must be interesting future research, especially for practical statisticians. Some of them might be difficult to solve, but we wish you would join us together. We could find out something interesting such as the reliability of statistics, the relationship between the dot sampling method and other area frame survey methods, contrivances on the area survey, etc.

3.1 Random sampling and Systematic sampling

It is interesting to find which is better random sampling or systematic sampling (See P. 3, Figure 1, 2). Concerning this matter, Mr. Nobunori Kuga who is a senior statistician in

the MAFF of Japan conducted an experiment on accuracy and precision of dot sampling method using Monte Carlo method to confirm the superiority in January 2014.

The method and results are shown as follows.

First, please see Figure 9 (This is an image graph, number of dot 100), and suppose that he drew a quarter circle in the square using EViews which is an application software on his PC. Next he put sample dots at random. The sample size is 10,000. Then he counted the number of sample dots which fell within a quarter circle, and calculated frequencies. The experiment was iterated 100,000 times. Then he summarized the results (Figure 10).
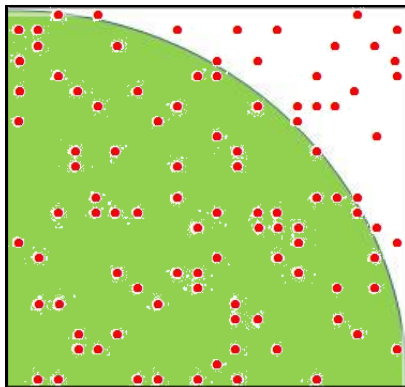
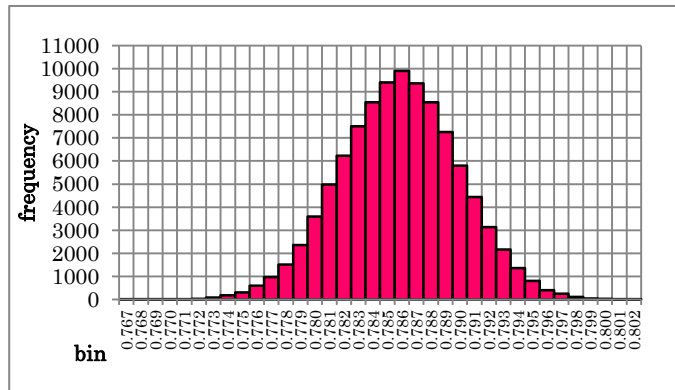*Figure 9: Image of the Random sampling*

Figure 10: Frequency distribution of the random sampling.

Next, in the same way as before, he tried on the experiment of systematic sampling (See Figure 11). In case of systematic sampling, the first sample dot was put at lower left corner (in the range of " 0.01 ×0.01= 1/10,000 square" including the origin) at random, and it was defined as the starting point, then remained sample dots (9,999 sample dots) are put systematically. This experiment was also iterated 100,000 times (Figure 12).
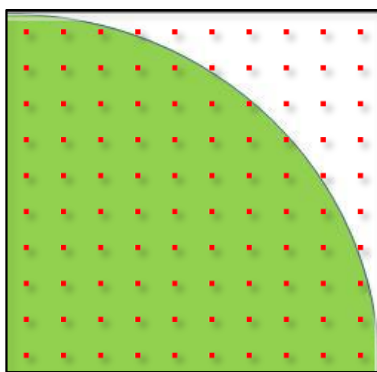
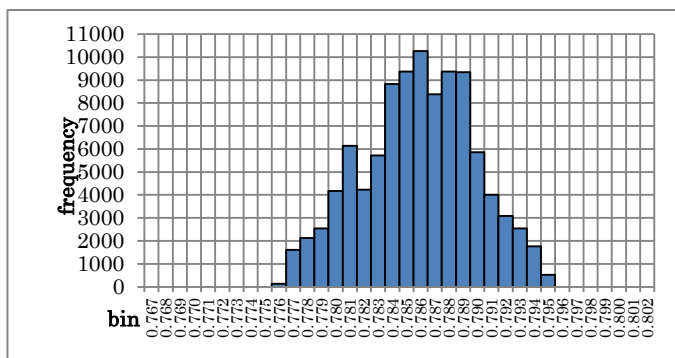*Figure 11: Image of the Systematic sampling*

Figure 12: Frequency distribution of the systematic sampling.

Finally, the comparison between two experiments was shown in the table 6. The results of the experiments show that the shape of the frequency distribution of random sampling is more beautiful than that of systematic sampling. But, min, max and average of systematic sampling are better

Table 6: *Comparison of random and systematic*

	Random	Systematic
min	0.7669	0.7756
max	0.8016	0.7949
average	0.7853906	0.7854058
true value	0.7853982	0.7853982
average/true value	0.9999904	1.0000097
SD	0.0041119	0.0039703

than those of random sampling respectively.

From the practical point of view, systematic sampling is better than random sampling, too. Therefore, we are convinced that it is reasonable to adopt the systematic sampling method for the dot sampling method.

[Note] *Concerning this matter, this simulation method is used to estimate the value of π. The theoretical share is shown as below.*

$$(True)Share\ P = \frac{A_{circle/4}}{A_{square}} = \frac{(\pi r^2/4)}{r^2} = \frac{\pi}{4} = \frac{3.1415926536\ldots}{4} = 0.785398163$$

The formula shows that circumference rate (π) can be estimated using the formula. $\hat{\pi} = 4\hat{p}$. Therefore it suggests that you can estimate the value of π using sampling method. Please try it while changing sample size.

3.2 A test survey on the dot sampling method in Kamakura city

A test survey on the land use was conducted in Kamakura (Area: 39.6km^2) in Japan in December in 2012 in order to learn reliability of the dot sampling method in a small city. The test survey was conducted by using the third function to make square area frames with dots[18].

The idea of the test is basically the same as the Monte Carlo simulation mentioned above, although the scale is small. The outline of the test is shown as follows.

First, we selected a sample by using the dot sampling method with square frames (see Figure 13). The sample size was 994. The square frame was set such that the original sample dot should be the center of the square frame. The size of square frame is 50m×50m[19]. And the distance between each pair of sample dots is about 200m.

***Figure 13:** Dot sampling with square area frame in Kamakura city*

Second, as shown in Figure 14, by using five sample group of the center and the corners of the square frame, we conducted a preparatory survey at the each dot[20] on Google Earth.
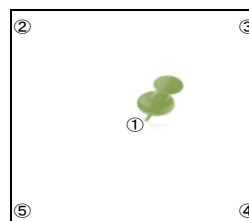

***Figure 14:** Original sample dot and square frame*

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[18] See P3. This function of the dot sampling method suggests that it can make square area frames for valuable survey. This function can be applied to the mesh area frame survey. The length of a side can be used for a transect frame. The transect frame is tried in LUCAS method.

[19] The size of square is changeable.

[20] This function can be a cluster sampling method. LUCAS method in EU used the cluster sampling method.

Third, the results of the test were generated as follows:

Table 7: *Number of sample dots by category/sampling group*

	Sampling group					
	①	②	③	④	⑤	Total
Cultivated land	38	41	28	30	31	168
Wood	372	385	390	381	381	1,909
River, Lake, Beach	10	9	7	10	9	45
Residence, Park, etc	488	468	498	491	478	2,423
Road	86	95	68	80	93	422
Total	994	998	991	992	992	4,967

Table 8: *Share of sample dots by category/sampling group*

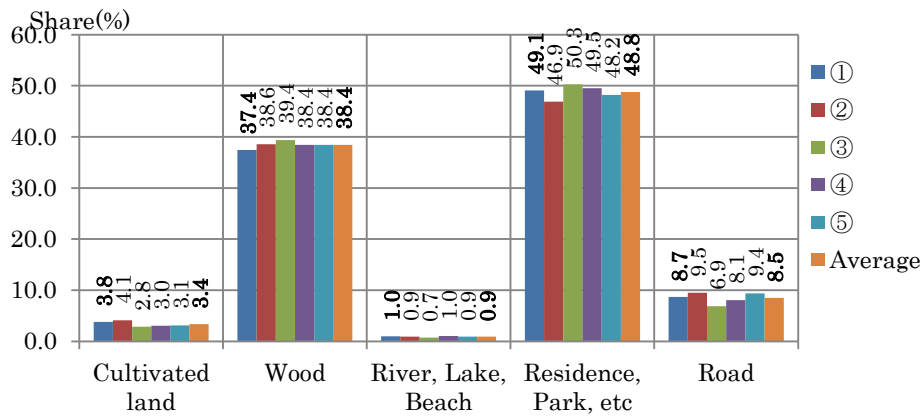|	Sampling group					
	①	②	③	④	⑤	Average
Cultivated land	3.8	4.1	2.8	3.0	3.1	3.4
Wood	37.4	38.6	39.4	38.4	38.4	38.4
River, Lake, Beach	1.0	0.9	0.7	1.0	0.9	0.9
Residence, Park, etc	49.1	46.9	50.3	49.5	48.2	40.3
Road	8.7	9.5	6.9	8.1	9.4	8.5
Total	100.0	100.0	100.0	100.0	100.0	100.0

Figure 15: *Comparison of estimate by category/sampling group*

Table 7 shows the number of sample dots by category/Sampling group. Table 8 shows the share of each group, and Figure 15 is drawn by using the data in Table 8.

As you can see, Figure15 shows that each estimate (①,②,③,④and⑤) [21] is close to the "Average". " ① " which belong to the original sample dot group is also close to each estimate. We think that according to the results, the estimate by the dot sampling method is reliable. Even the estimate of river, lake, and beach which has small share is reliable too. But, the estimates are generated similarly in any case. It is thought that differences among the estimates occur due to "sampling error" caused by the different sample.

If you want more reliable estimates, you need to increase sample size. In addition, it is a good idea to fix sample dots over the several years. If you avoid the sampling errors caused by a change to the sample every year, you will be able to find the tendency of the progress clearly.

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[21] As you can see, total number of sample dots are different each other in Table 7. The reason why sample size of each ②,③, ④ and ⑤ are different from that of original sample ①, because five dots do not always fall together within the boundary of Kamakura city.

3.3 Relations between share (%) of cultivated and CV by sample size

Concerning this matter, Figure 16 shows the relationship between share of cultivated land and CV by sample size. The graph indicates the following:

- The best way to increase reliability is to increase sample size.
- The smaller the sample size and the share make CV larger.
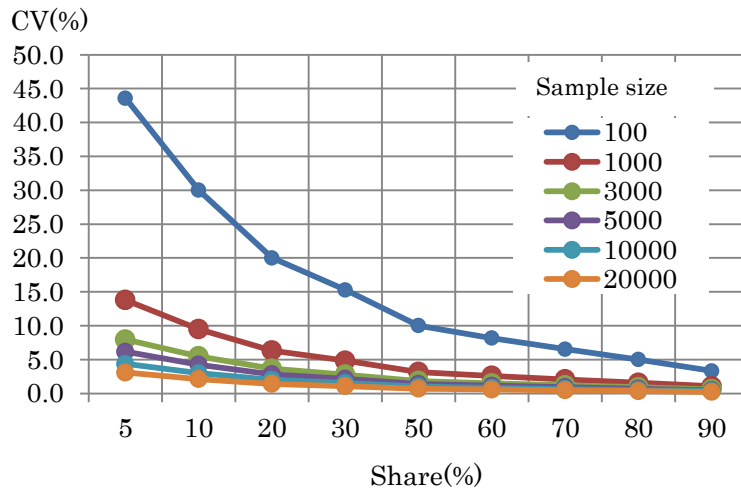- The larger sample size makes CV smaller, whereas the larger share makes CV smaller.

Figure 16: Relations between share (%) of cultivated and CV by sample size

When you conduct a planted area survey, you don't have to survey sample dots which are located at non-cultivated lands. The actual sample size of target area you have to survey depends on the magnitude of the share of cultivated lands.

In addition, this graph is useful not only for the calculation of the sampling error after the survey, but also for the designing of sample size. For example, when you design a sampling survey of rice planted area in your country based on this method, perhaps you have an existing data on the share of rice planted area calculated by the traditional method. If you would determine the approximate share and your aimed CV, this graph could suggest to you the corresponding sample size. For example, when the share is 50% (30%), and aimed CV is 10% (5%) in your country, the necessary sample size (n) is 100 (900) approximately.

Concerning this matter, next discussion will be useful.

3.4 Actual sample size for a field survey

As discussed above, the sample size of preparatory survey is determined by considering precision, i.e., aimed CV. On the other hand, you don't have to conduct field survey at sample dots in non-cultivated land which are categorized in the stage of the preparatory survey. Therefore, the sample size of the field survey is definitely smaller than that of the preparatory survey.

If you make a plan to conduct a field survey in the whole area, you need much budget and manpower. If the purpose of the survey is to estimate planted area, the field survey should be conducted at the sample dots in the cultivated area.

Table 9 shows both the needed sample size and actual sample size determined by aimed CV, respectively.

As you can see, when cultivated land which is a target category has a share of 20% and your aimed CV is ±3% (5%), the needed sample size is 4444(1600), whereas the sample size in the field survey is only 889 (320).You can see that the actual sample size is decreased.

Therefore please don't be afraid that attribute survey requires a big sample size. A large part of sample dots can be surveyed at your desk in the stage of preparatory.

Table 9: *Needed sample size by CV and actual sample size by CV*

Share of Cultivated Land (%)	Share of Non cultivated land (%)	Needed sample size by CV(%) (Preparatory survey)			Actual sample size by CV(%) (Field survey)		
p	q=(100-p)	3	5	10	3	5	10
1	99	110,000	39,600	9,900	1,100	396	99
2	98	54,444	19,600	4,900	1,089	392	98
3	97	35,926	12,933	3,233	1,078	388	97
4	96	26,667	9,600	2,400	1,067	384	96
5	95	21,111	7,600	1,900	1,056	380	95
10	90	10,000	3,600	900	1,000	360	90
15	85	6,296	2,267	567	944	340	85
20	80	4,444	1,600	400	889	320	80
30	70	2,593	933	233	778	280	70
40	60	1,667	600	150	667	240	60
50	50	1,111	400	100	556	200	50
60	40	741	267	67	444	160	40
70	30	476	171	43	333	120	30
80	20	278	100	25	222	80	20

3.5 Category for land use survey

If you would make a plan for land cover/use survey, how to determine the category for land use would be an important issue. The category table is prepared according to purposes of the land use survey. Table 10 shows three kinds of category tables for land use survey.

Table 10: *Category tables for Land use survey*

T1 Standard

Category	Code
Crop land	a
Forest land	b
Grassland	c
Wetland	d
Settlements	e
Otherland	f
Water	g

T2 Preparatory survey for crop survey

Category Name	Code
Non-Cultivated land	1
Cultivated land (Upland)	2
Dyke (Upland)	3
Lowland(paddy)	4
Lowland (Dyke)	5
Tentative	8
Low resolution	9

T3 Field survey

Category	Code
Rice (lowland)	11
Rice (upland)	12
Cassava	13
Meize	14
Soybeen	15
Sugarcane	16
Vegitable	17
...	...

T1 is a standard classification. This is suggested by Word Bank and FAO[22]. T2 is a special category which is used in our preparatory survey for crop production survey. In T2 table, "Dyke" is added for the special purpose of estimating real planted area. "Tentative reserve" plays a special role in making preparatory survey efficient. T3 is a category table for a field survey. It is used when you estimate planted area by crop[23]. The target crops are determined by the designer of the survey. You can put here all the codes of crops which you want to estimate.

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[22] FAO, THE WORLD BANK. (2010) *GLOBAL STRATEGY TO IMPROVE AGRICULTURAL AND RURAL STATICTICS 15*
[23] The results of planted area survey can be used for the crop cutting surveys. These sample dots are selected with PPS, so you can use those sample dots directly for the yield survey.

4. Results obtained ~Application of the method in a country level~

So far we have explained the dot sampling method and how to use it concretely for some specific small area which is taken up in the JICA training course activities. In this section, we would like to introduce the results obtained by applying the method at the country level. The procedure necessary to implement the method for a large area is the same as that for a small area, although the field surveys have not been conducted yet.

4.1 Sri Lanka

First, we would like to show you the case of Sri Lanka where we conducted a land use survey by using the dot sampling method in December 2013.
As you can see, Table 11 shows the dot sampling on Excel sheet. Figure 17 shows sample dots which are put on Google Earth. The sample size is only 100. This sample size is determined tentatively as an example. Based on the theory of probability, the number of sample dots which fall within the border of Sri Lanka is determined as the actual sample size. Therefore, the designed 100 sample dots do not always fall exactly within the border, but the error is small, ±1 or ±2 from our experiences. Those are the results of the first step.

Table 11: Dot sampling table on Excel sheet (Sri Lanka)

1. Fill in blank cell on T-1 Table below
T-1 Basic data to generate sample dots (Sampling Design)

Target area	Size of the Target area km²	Sample size	Starting point (latitude)	Starting point (longitude)	Finishing point (latitude)	Finishing point (longitude)	Interval in km (depend on (3))	Necessary Number of Lines	Necessary Number of Rows	Index of Line on the work sheet.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=√((2)/(3))	(9)	(10)	(11)
Sri Lanka100	65,610.000	100	9.885	79.385	5.886	82.098	25.614449	18	12	34

T-2 Sample dots (Coordinate Values)   **Don't change** the numbers on yellow cells because the numbers are used for the calculations.

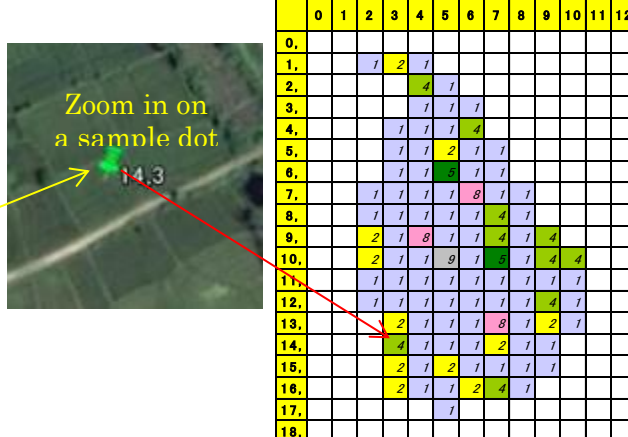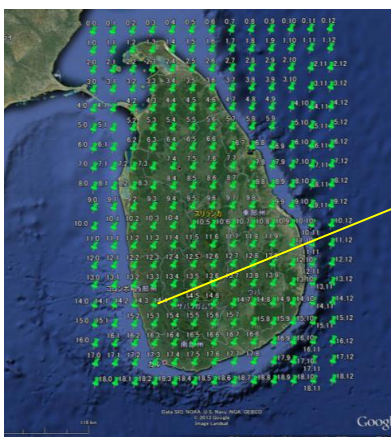| Name of Longitude → Latitude ↓	0	1	2	3	4	5	6	7	8	9
0,	9.885,79.385	9.885,79.618565960175	9.885,79.8521319203499	9.885,80.0856978805249	9.885,80.3192638406999	9.885,80.5528298008748	9.885,80.7863957610498	9.885,81.0199617212248	9.885,81.2535276813998	9.885,81.4870936415747
1,	9.65412740579358,79.385	9.65412740579358,79.6184039659715	9.65412740579358,79.8518079319435	9.65412740579358,80.0852118979155	9.65412740579358,80.3186158638865	9.65412740579358,80.5520198298575	9.65412740579358,80.7854237958295	9.65412740579358,81.0188277618005	9.65412740579358,81.2522317277725	9.65412740579358,81.4856356937435
2,	9.42325481158716,79.385	9.42325481158716,79.6182459808505	9.42325481158716,79.8514919617015	9.42325481158716,80.0847379425525	9.42325481158716,80.3179839234035	9.42325481158716,80.5512299042545	9.42325481158716,80.7844758851055	9.42325481158716,81.0177218659565	9.42325481158716,81.2509678468075	9.42325481158716,81.4842138276585
3,	9.19238221738074,79.385	9.19238221738074,79.6180919915525	9.19238221738074,79.8511839831055	9.19238221738074,80.0842759745657	9.19238221738074,80.3173679662211	9.19238221738074,80.5504599577625	9.19238221738074,80.7835519493155	9.19238221738074,81.0166439408675	9.19238221738074,81.2497359324245	9.19238221738074,81.4828279239725
4,	8.96150962317432,79.385	8.96150962317432,79.6179419851715	8.96150962317432,79.8508839703435	8.96150962317432,80.0838255955145	8.96150962317432,80.3167679406865	8.96150962317432,80.5497099258575	8.96150962317432,80.7826519110295	8.96150962317432,81.0155939862005	8.96150962317432,81.2485358813725	8.96150962317432,81.4814778665435
5,	8.73063702896791,79.385	8.73063702896791,79.6177959499156	8.73063702896791,79.8505918983135	8.73063702896791,80.0833387847475	8.73063702896791,80.3161837966265	8.73063702896791,80.5489797457835	8.73063702896791,80.7817756949475	8.73063702896791,81.0145716440965	8.73063702896791,81.2473675932535	8.73063702896791,81.4801663542415
6,	8.49976443476149,79.385	8.49976443476149,79.6176538713075	8.49976443476149,79.8503077426145	8.49976443476149,80.0829616139215	8.49976443476149,80.3156154852295	8.49976443476149,80.5482693566365	8.49976443476149,80.7809232278435	8.49976443476149,81.0135770991505	8.49976443476149,81.2462309704585	8.49976443476149,81.4788848417655
7,	8.26889184055507,79.385	8.26889184055507,79.6175157157390	8.26889184055507,79.8500314795415	8.26889184055507,80.0825472193127	8.26889184055507,80.3150629590836	8.26889184055507,80.5475786988546	8.26889184055507,80.7800944386255	8.26889184055507,81.0126101783966	8.26889184055507,81.2451259181672	8.26889184055507,81.4776416579382
8,	8.03801924634865,79.385	8.03801924634865,79.6173815430419	8.03801924634865,79.8497630860822	8.03801924634865,80.0821446291239	8.03801924634865,80.3145261721649	8.03801924634865,80.5469077152049	8.03801924634865,80.7792892582459	8.03801924634865,81.0116708012869	8.03801924634865,81.2440523443279	8.03801924634865,81.4764338873689

Figure 17: *Sample dots on Google Earth*

Figure 18: *Questionnaire for preparatory survey*

15

Figure 18 shows the results of the preparatory survey on Google Earth in Sri Lanka, and land use (whose codes are shown in Table 12) at each sample dot is categorized one by one. Table 12 shows the land use statistics obtained by the preparatory survey. Figure 19 shows the pie graph of Table 12. In addition Figure 20 shows the comparison of the official statistics of harvested area and the dot sampling estimate of paddy field. According to the graph, the estimate of paddy field is close to the official statistics. Although this is only a demonstration to learn the dot sampling method at the country level, our result is surprisingly very close to the official statistics. Those are the outputs of the second step.

Table 12:   *Land Use Statistics*

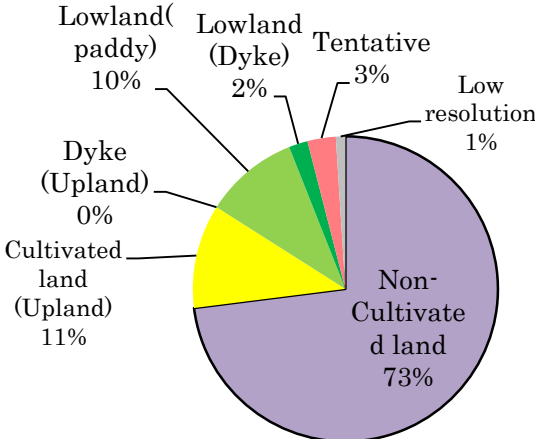| Category Name	Code	Number of Sample	Rate	SE	CV	Estimate (1,000ha)
Non−Cultivated land	1	73	0.73	0.04	6.1	4,790
Cultivated land (Upland)	2	11	0.11	0.03	28.4	722
Dyke (Upland)	3	0	0.00	0.00		0
Lowland(paddy)	4	10	0.10	0.03	30.0	656
Lowland (Dyke)	5	2	0.02	0.01	70.0	131
Tentative	8	3	0.03	0.02	56.9	197
Low resolution	9	1	0.01	0.01	99.5	66
Total		100	1.00	0.00	0.0	6,561

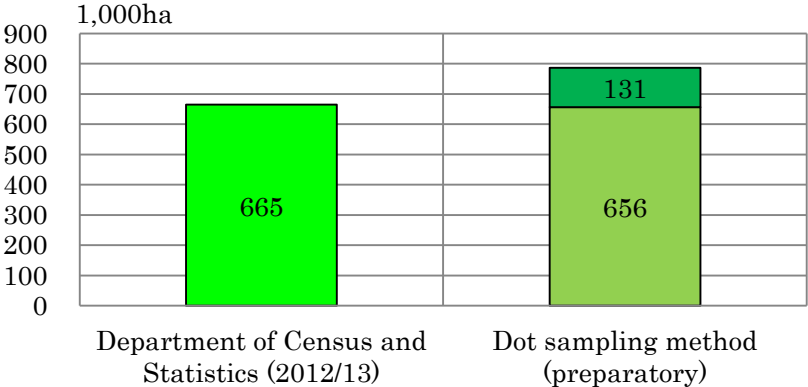*Figure 19:*   *Land use in Sri Lanka*

Figure 20:   *Comparison (Harvested area/Lowland)*

As mentioned above, the purpose of this paper is to show the procedure of the dot sampling method. If you conduct the survey according to the procedure, you can quickly

obtain the results of land use survey on Google Earth like this. It took only one hour from beginning to end partly because the sample size was only 100.

But, if you want to estimate crops planted area actually in a crop growing season, you should visit sample dots which are put on cultivated lands (at least, upland + lowland + Dyke + Tentative[24]) in the crop growing season. In the above case, the number of sample dots you should visit is only 26, and you can estimate not only crop planted area but also the share of dyke objectively.

Actual planted area survey is conducted like this. But we would like to suggest that you can estimate approximately the area of rice growing even using the preparatory survey on the Internet. You can also check the area of rice field, including the share of dyke area, in Asian countries quickly.

4.2 Thailand

Next, we would like to show you land use statistics in Thailand which were obtained from the preparatory survey. The survey was conducted by us as a test survey in August 2013 and, however, the field survey has not been conducted yet, because we live in Japan.

Table 13: *Land use statistics*

Category		Code	Number of dots	Rate(%)	Area(ha)	SE	CV
Cultivated land		···	517	51.8	26,554,859	1.581	3.1
Cultivated land/Breakdown	Cultivated land(upland)	1	246	24.6	12,635,387	1.363	5.5
	Cultivated land Paddy (Major rice)	11	184	18.4	9,450,859	1.226	6.7
	Cultivated land in mountain	2	5	0.5	256,817	0.223	44.6
	Dyke, Trees,etc	3	43	4.3	2,208,625	0.642	14.9
	Maybe orchard	7	32	3.2	1,643,628	0.557	17.4
	Aqua farm	8	7	0.7	359,544	0.264	37.7
Forest, River, Lake, etc		4	451	45.1	23,164,877	1.574	3.5
Residence, Factory, Road		5	27	2.7	1,386,811	0.513	19.0
Cloud		6	4	0.4	205,453	0.2	49.9
Total			999	100.0	51,312,000	···	···

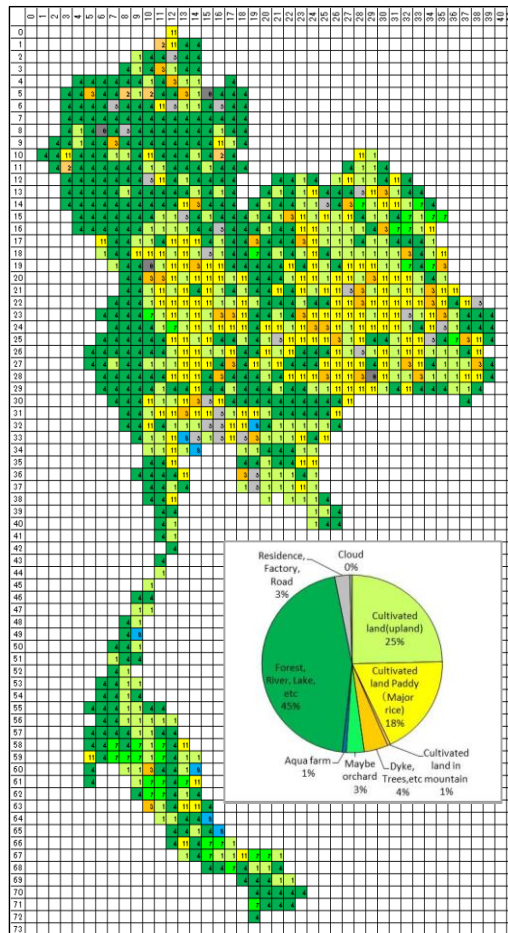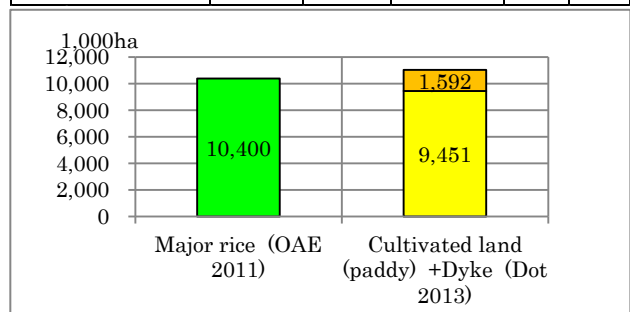| Category		Number of dots	Rate(%)	Area(ha)	SE	CV
Paddy field	Pure planted area （Major rice）	184	18.4	9,450,859	1.2	6.7
	Dyke, Trees,	31	3.1	1,592,264	0.5	17.7
	Total	215	21.5	11,043,123	1.3	6.0

Figure 21: *Land use map*

Figure 22: *Comparison of the official and dot*

As you can see, those outputs show that even if the outputs are obtained from the preparatory surveys on Google Earth, the results/analysis might be useful. The sample size was

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[24] Tentative: Category to reserve deciding sample dot's category on the operation of the preparatory survey on a tentative basis. It is one of the measurements to go along smoothly.

only 1,000. The actual sample size was 999. It implies that all the sample dots fell within the border of Thailand. The difference might occur due to either probability or boundary lines on Google Earth.

Figure 21 shows a land use map in Thailand. Table 13 shows the results of preparatory survey in Thailand. Figure 22 shows the comparison of the official statistics (Major rice) and the estimates by the dot sampling method (planted area +dyke). Both the values are close each other. The data shows that official statistics on the planted area of major rice in Thailand are reliable. It is said, however, that the planted area includes dykes in Thailand. The share of dyke by the dot sampling method is 14.4%. We think it is a reasonable estimate.

[Note] *Concerning the matter of the dyke, how to handling of dyke in yield survey and area survey is a significant issue, since the definitions are usually unclear. In case of Thailand, it is said that the dyke is included in the planted area. Therefore, although the yield is estimated by using crop cutting method, the original crop cutting yield is adjusted to the official yield which includes dykes.*

In any event, when the production is calculated on the basis of "yield multiplied by area", yield must be defined with including dyke in case area includes dyke, but in many cases in many countries there are no definitions made on how to handle this issue[25]. The dot sampling method is useful to estimate the area of dykes and the pure (proper) planted area. Please don't forget this dot sampling method can be applied to the sampling for crop cutting surveys without making list.

Rice production (t) = Yield per ha (t) $\times$ planted area

5. Conclusion

So far we have explained what the dot sampling method is and how to use it. This method has been developed by combining traditional attribute survey method with Excel and Google Earth, and we are still in the process of improving the method.

As mentioned earlier, the dot sampling method is quite simple and reliable. It has also succeeded in resolving various issues, which have been left unresolved so far. Best of all, it can produce a lot of results in a short time. In fact, these advantages of the dot sampling method originate in traditional attribute survey method. In our research process, we have re-realized that combining this method with Excel and Google Earth enables us to make the most of the merits which are included in attribute survey method.

Table 14: Advantages and achieved techniques

	Items	Advantages/Achieved techniques	
Attribute method Excel Google Earth		Simple statistical methodology. No measuring (Category survey), Non sampling errors hardly occur.	Simple
		Sampling without list.	Easy
		Accurate Web maps. (Location, Category)	Reliable
Procedure	Sampling	on Excel Sheet, Google Earth.	Cost effective
	Preparatory	on Google Earth. Survey item: One (category).	
	Field survey	on the Field, No-contact with farmers. Resolved complicated land, rare crops, etc.	
Results (Estimates)		Simple Manual/Questionnaire. Speedy, reliable outputs.	

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[25] Kenji Kamikura. Senior Statistician, Statistics Department Ministry of Agriculture, Forestry and Fisheries of Japan (AfricaRice, Cotonue, Benein, March 2013). *Package of Agricultural Production Survey*

The dot sampling method is a newly born method. Unfortunately, it is not well-known. Its application at the country level has not been conducted yet. We hope that the method will be tested and used, especially in some Asia-Pacific countries in the near future.

6. Success achieved and issues for further research

As mentioned above, the dot sampling method can resolve a lot of issues, which have remained unresolved so far, e.g. simplicity, efficiency, reliability, etc. At this stage, we do not find any issues necessary for further research from the technical point of view.

However, we recognize that it is very difficult to use this method in developing countries from our experience. There are two reasons at least. First, the infrastructure for the Internet is needed no matter what. As mentioned repeatedly, we owe the dot sampling method mostly to Google Earth. Therefore, it is most important to improve the infrastructure for Internet necessary in order to use Google Earth comfortably. Second, it is very difficult for some government to shift from the traditional survey method to a new survey method, e.g., the dot sampling method. It seems that nothing is more important than to maintain the status quo, e.g., the reporting method, which is based on the reports from the village or prefecture level.

Accordingly, it might be the first step that we recommend that such a government should use the dot sampling method to support the reporting method, or to check the results obtained with the reporting method. The method, especially the preparatory survey on Google Earth necessary in order to estimate cultivated land area, does not need to cost so much. There is no risk of losing a lot of money through this method.

It might also be a good idea to continue further research on crop survey methods not only from the methodological and technical point of view but also from the sociological point of view.

Now some countries in Africa are conducting the pilot surveys using the dot sampling method[26]. We expect that they will show us good results and make any suggestions for further research.

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[26] Improving Food Security Information in Africa. Africa Rice Center, Ministry of Agriculture , Forestry and Fisheries, Japan.(July 2013), *Rice Production Survey using the Dot Sampling Method and Google Earth.*

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