SAMPLING DESIGN FOR GLOBAL SCALE MAPPING AND MONITORING OF AGRICULTURE

Shashikant A. Sharma and Jai Singh Parihar

Space Applications Centre, Indian Space Research Organisation, Ahmedabad, India, sasharma@sac.isro.gov.in

KEYWORDS: Global Agriculture, Sampling, Stratification, Crop Monitoring, MERIS.

ABSTRACT:

In the changing global environment there is a need for an operational system for monitoring of world food crop production using satellite observations. It is useful in two primary missions – food security in developing countries, and forecasting production available for global market of agricultural crops. In the present study, grids of size (i) 5ºX5º (ii) 1ºX1º (iii) 30'X30' (iv) 15'X15' (v) 7.5'X7.5' and (vi) 5'X5' were generated and percent crop area was calculated for each grid of all sizes using MERIS landuse/landcover data of 300 m resolution. The grid size of 15'X15' was found to be optimum for global monitoring, as there is not much change in the distribution of the grids after reducing the sample size. Using the 'cumulative square-root of frequency method five stratas was defined, which reduces the variance of the population estimate by sampling.

1. INTRODUCTION

To address the massive area to be covered, it is essential to develop a sampling strategy for analysis of satellite data. The study was conducted to evolve a effective sampling plan for estimation of global agriculture and monitoring its condition at various scales. The stratification objectives are twofold: (i) reducing the variance of estimate and (ii) allowing a regional tuning of the classification parameters to take into account the regional characteristics.

In 1974, the Large Area Crop Inventory Experiment (LACIE) – a joint effort of NASA, USDA and NOAA attempted forecasting harvests in important wheat producing areas of the world. The sampling unit size was 5 X 6 nautical miles and stratified random sampling approach was used to get about 2.2 percent sampling error and the production estimation to satisfy 90/90 criterion (LACIE, 1978). It was later on followed by the project - Agriculture and Resource Inventory Survey through Aerospace Remote Sensing (AgRISTARS). The goal of AgRISTARS was to determine the usefulness, cost and extent to which aerospace remote sensing data can be integrated into existing and future system.
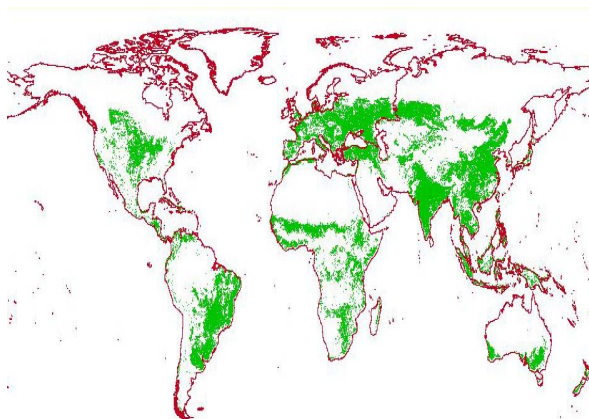

Figure 1: Agriculture Regions Over the Globe

2. METHODOLOGY

As shown in figure 1 and figure 2, the distribution of crop varies a lot together with its concentration and vigor. In the present study, grids of size (i) 5ºX5º (ii) 1ºX1º (iii) 30'X30' (iv) 15'X15' (v) 7.5'X7.5' and (vi) 5'X5' were generated with proper codes for the whole world. The grids were generated over the land area excluding the Antarctica region. Percent crop area was calculated for each grid of all sizes using MERIS land use / land cover data. It is 300 m resolution raster data of the Globecover global land cover map for the period from December 2004 to June 2006. The data is in geographic coordinates in a Plate-Carrée projection (WGS84 ellipsoid) with image size as 129595 X 64800 pixels.. This global Land Cover map is derived by an automatic and regionally-tuned classification of a MERIS FR time series. Its 22 land cover classes are defined with the UN Land Cover Classification System (LCCS) (Bicheron et al., 2008).

Grid Size	Number of Grids	Agriculture Grids	Per cent
5º X 5º	1116	597	53.5
1º X 1º	18714	9846	52.6
30' X 30'	69012	31526	45.7
15' X 15'	263002	115545	43.9
7.5'X 7.5'	1022523	426902	41.8
5' X 5'	2276188	915582	40.2

Table 1: Global Grid statistics for crop monitoring

Total number of grids and the grids having agriculture, obtained using various grid sizes are shown in the table-1. Number of grids having agriculture in different ranges over various continents are shown in table-3.
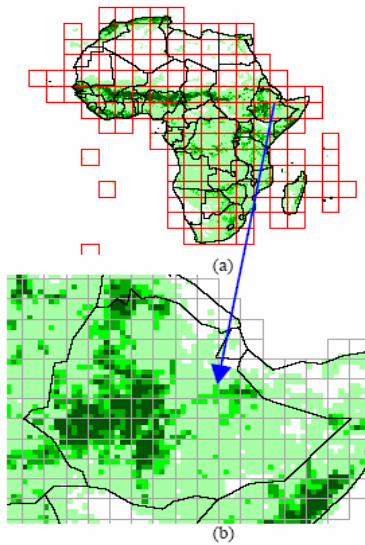
Figure 2. Grids of size 15'X15' for (a) Africa Continent and (b) Ethiopia Country Shown in Five Equal Ranges of Percent Crop Cover

3. RESULTS AND DISCUSSION

There is wide range of variability in agriculture area over the whole world..Table-2 shows the distribution of grids with respect to percent agriculture in each grid. More than 50 percent of grids are non-agriculture grids. Distribution of the grids in intervals of 5 percents shows a skew distribution of the agriculture grids.

Range of crop(%)	30'X30'	15'X15'	7.5'X7.5'	5'X5'
	Percent of grids in each range			
0	54.32	61.41	64.4	59.8
0-5	10.38	8.17	7.0	7.5
5-10	4.60	3.63	3.2	3.5
10-15	3.40	2.76	2.4	2.6
15-20	2.96	2.28	2.0	2.2
20-25	2.53	2.04	1.8	1.9
25-30	2.30	1.84	1.6	1.7
30-35	2.05	1.59	1.4	1.6
35-40	1.79	1.51	1.3	1.5
40-45	1.64	1.41	1.3	1.4
45-50	1.57	1.32	1.2	1.3
50-55	1.38	1.23	1.1	1.3
55-60	1.33	1.15	1.1	1.2
60-65	1.21	1.13	1.0	1.2
65-70	1.25	1.07	1.0	1.2
70-75	1.23	1.08	1.0	1.2
75-80	1.23	1.08	1.1	1.2
80-85	1.21	1.12	1.1	1.3
85-90	1.15	1.18	1.2	1.4
90-95	1.25	1.35	1.4	1.7
95-100	1.23	1.66	2.3	3.3

Table 2 : Comparative Statistics of Crop Proportion in Different Sizes of Grids

Table 2 and 3 shows that the grid size of 15'X15' was found to be optimum for global monitoring. There is not much change in the distribution of the grids after reducing the size from15'X15'. The distribution of grids in different continents is seen in table-3. Due to large variability in the crop proportion in grids, simple random sampling gives high variance in the estimation. The average of all grids is 35.8 with a standard deviation and coeff. of variation (CV) as 31.3 and 87.5 % respectively. Stratified random sampling approach was used for dividing the population into different stratas. Based on clustering algorithm, the total number of 15'X15' girds was divided in to six stratas including non- agriculture grids. The stratas were defined based on percent agriculture in each grid as shown in table-4. They were (i) A : 70-100 % (ii) B : 40-70 % (iii) C : 20-40 % (iv) D : 5-20 % (v) E : 0-5 %(vi) X : 0 % (Non-agriculture). The global data in 15'X15' grids stratified into six stratas is shown in figure 3.
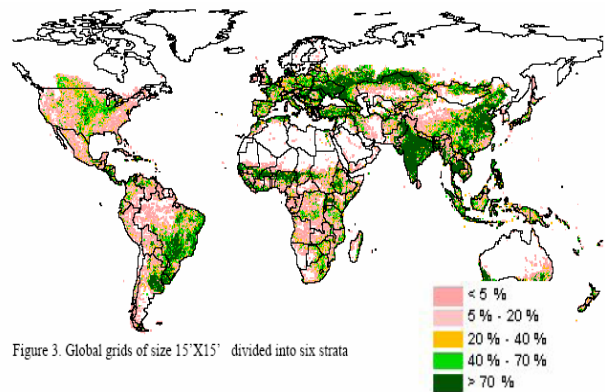

Figure 3. Global grids of size 15'X15' divided into six strata

Using the 'cumulative square-root of frequency' method developed by Dalenius & Hodges(1959) the stratas were defined as shown in table-5. They are (i) A : 75-100 % (ii) B : 50-75 % (iii) C : 30-50 % (iv) D : 10-30 % (v) E : 0-10 %(vi) X : 0 % (Non-agriculture). There is a reduction in CVs of all stratas except E type.

As shown in figure-4, weekly NDVI composites from MODIS data over the crop growth period was generated for monitoring crop condition at all grid levels. Any anomaly in NDVI may be scrutinized further at lower grid level and crop condition can be assessed. This will help in drought monitoring and crop condition assessment on the global scale.
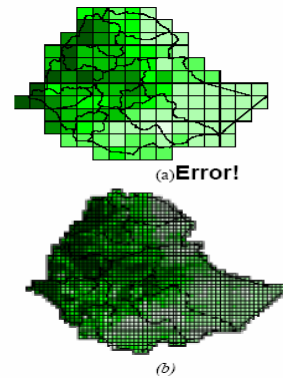

Figure 4. (a) 1ºX1º and (b) 15'X15' Grids of Ethiopia Showing NDVI for the Week July 27-Aug 4, 2008

CONCLUSION

The study shows an effective sampling plan for estimation of global agriculture and monitoring its condition at various scales. The grid size of 15'X15' was found to be optimum for global monitoring. There is not much change in the distribution of the grids after reducing the size from 15'X15'. Using the 'cumulative square-root of frequency method five stratas was defined. This reduces the variance of the population estimate by sampling. Weekly NDVI composites from MODIS data can be effectively used for monitoring crop condition at all grid levels. This will help in drought monitoring and crop condition assessment on the global scale.

5º X 5º	0	0-20	20-40	40-60	60-80	80-100
Asia	39.3	37.8	9.9	7.1	4.0	1.9
Africa	24.8	56.1	14.0	5.1	0.0	0.0
Australia	45.8	43.8	4.2	6.3	0.0	0.0
N America	67.8	26.0	5.4	0.8	0.0	0.0
S America	16.2	58.1	14.3	6.7	4.8	0.0
Europe	53.8	18.5	11.8	7.6	8.4	0.0
Oceania	70.8	29.2	0.0	0.0	0.0	0.0
World	46.5	36.9	8.9	4.7	2.5	0.5
1º X 1º	0.0	0-20	20-40	40-60	60-80	80-100
Asia	16.7	39.4	14.0	10.5	9.2	10.1
Africa	17.7	51.4	15.5	8.8	4.1	2.6
Australia	35.9	40.4	7.4	6.5	5.4	4.5
N America	13.6	60.9	15.9	7.3	2.2	0.1
S America	7.6	57.6	12.2	9.8	8.2	4.7
Europe	9.2	29.9	21.4	18.1	12.9	8.5
Oceania	10.4	75.4	9.0	4.3	0.9	0.0
World	53.1	23.8	8.9	6.2	4.4	3.5
30' X 30'	0	0-20	20-40	40-60	60-80	80-100
Asia	53.0	17.7	8.5	6.3	6.1	8.5
Africa	43.4	31.7	11.4	6.4	3.9	3.2
Australia	74.2	13.2	3.2	2.6	3.2	3.7
N America	73.8	16.4	5.9	2.8	0.9	0.2
S America	26.2	39.1	11.5	8.4	9.1	5.7
Europe	46.4	14.8	11.9	10.8	9.5	6.6
Oceania	42.4	41.8	8.3	4.5	2.2	0.8
World	54.3	21.3	8.7	5.9	4.9	4.8
15'X15'	0	0-20	20-40	40-60	60-80	80-100
Asia	55.2	15.2	7.5	6.0	6.0	10.1
Africa	47.3	28.2	10.0	6.2	4.1	4.1
Australia	76.6	10.4	3.0	2.3	3.0	4.6
N America	74.5	15.1	5.8	3.1	1.1	0.3
S America	29.8	35.7	10.1	8.4	8.7	7.3
Europe	45.9	13.9	11.5	10.4	9.7	8.7
Oceania	28.2	43.3	12.3	8.0	5.3	2.9
World	61.4	16.8	7.0	5.1	4.4	5.3
7.5'X7.5'	0	0-20	20-40	40-60	60-80	80-100
Asia	57.5	13.3	6.5	5.5	5.6	11.6
Africa	51.8	24.4	8.7	5.9	4.2	5.0
Australia	78.7	8.5	2.6	2.1	2.7	5.4
N America	75.6	13.9	5.6	3.2	1.3	0.5
S America	34.4	31.2	9.5	8.1	8.3	8.5
Europe	45.8	13.9	10.6	9.6	9.7	10.5
Oceania	20.3	38.9	15.0	10.7	8.6	6.5
World	64.4	14.6	6.1	4.7	4.1	6.1
5'X5'	0	0-20	20-40	40-60	60-80	80-100
Asia	58.9	12.2	6.0	5.1	5.4	12.3
Africa	54.1	22.5	8.0	5.6	4.2	5.6
Australia	79.8	7.5	2.5	1.9	2.4	5.8
N America	76.3	13.1	5.3	3.2	1.4	0.7
S America	37.2	28.8	9.0	7.7	8.1	9.3
Europe	46.0	13.9	10.0	9.0	9.4	11.7
Oceania	16.6	36.6	14.9	11.3	10.5	10.1
World	59.8	15.8	6.7	5.2	4.8	7.7

Table 3: Grid Statistics Showing Distribution of Cropped Region for Continents and the World

15'X15' Stratas	Range (%)	No. of grids	Percent of grid	Avg	Std. Dev	Coff. of Var.
X	0	183879	61.4	0	0	
E	0-5	24465	8.2	2.4	1.4	58.6
D	5-20	25949	8.7	12.1	4.3	35.9
C	20-40	20908	7.0	29.8	5.8	19.3
B	40-70	21860	7.3	54.7	8.7	15.9
A	70-100	22363	7.5	86.8	8.9	10.2

Table 4: Stratification of 15' X 15' Grids for Global Crop Monitoring Using Clustering

15'X15' Stratas	Range (%)	No. of grids	Percent of grid	Avg	Std. Dev	Coff. of Var.
X	0	183879	61.4	0	0	
E	0-10	35344	11.8	4.1	2.9	70.73
D	10-30	26685	8.9	19.6	5.8	29.59
C	30-50	17466	5.8	40.1	5.8	14.46
B	50-75	16926	5.7	62.7	7.3	11.64
A	75-100	19124	6.4	89.1	7.3	8.19

Table 5: Stratification of 15' X 15' Grids for Global Crop Monitoring Using Square-Root Method

REFERENCES

Bicheron P.,Defourny P, Brockmann C, Schouten L, Vancutsem C, Huc M, Bontemps S, Leroy M., Achard F, Herold M, Ranera F, Arino O. GLOBCOVER: Products Description and Validation Report. 2008.

Dalenius & Hodges JL (Jr) (1959), Minimum variance stratification, Journal of the American Statistical Association, Vol-54, pp:88-101.

LACIE Symposium: Proceedings of Technical Sessions (Volume –I) (1978), NASA

ESA Globcover Project led by MEDIAS France/POSTEL