The Indonesian Journal of Geography. Vol. 18. No. 55.
June 1988. pp. 11-28

MONTHLY PROBABILITIES FOR ACQUIRING REMOTE SENSED DATA OF INDONESIA WITH CLOUD COVER LESS THAN 10 , 20 AND 30 PERCENT

by
J.P. GASTELLU-ETCHEGORRY*

ABSTRACT

The Indonesian spatiotemporal cloud cover distribution was quantified with the aid of GMS, Landsat and SPOT data. Iterative interactive factorial analyses grouped pixels with similar profiles into 18 classes for all land areas. For each class, statistics of Landsat and SPOT images, grouped by class, were used to verify, calibrate and improve class profiles. This led to quantified temporal profiles of probability of acquiring remotely sensed data with 10 , 20 and 30 percent cloud cover, for any Indonesian land area.

INTRODUCTION

The analysis of the first SPOT images of Indonesia verified the importance of high resolution remotely sensed data for many applications. An objective assesment of the opportunities for use of remotely sensed data in Indonesia requires the consideration of the chain of natural and technical constraints which influence the acquisition and processing of remotely sensed data. It is well known that cloud cover is the major constraint for remotely sensed visible data acquisition in Indonesia, but until now there has been no quantitative information about its effect on data acquisition. This paper provides the main spatiotemporal characteristics of cloud cover in Indonesia. They were defined with a methodology (Gastellu-Etchegorry, 1988) which combined the use of GMS, Landsat and SPOT data. After a brief review of the main steps of this methodology (Figure 1), all probabilities of acquiring remote sensing data with less than 10, 20 and 30 percent are given for all Indonesia land areas.

THE DATA

Landsat and SPOT Data

All catalogs of Indonesian Landsat and SPOT acquisitions (Table 1) were ordered:

* Dr. Gastellu-Etchegorry is a visiting lecturer at PUSPICS (Remote Sensing Centre), Gadjah Mada University, Yogyakarta Indonesia.

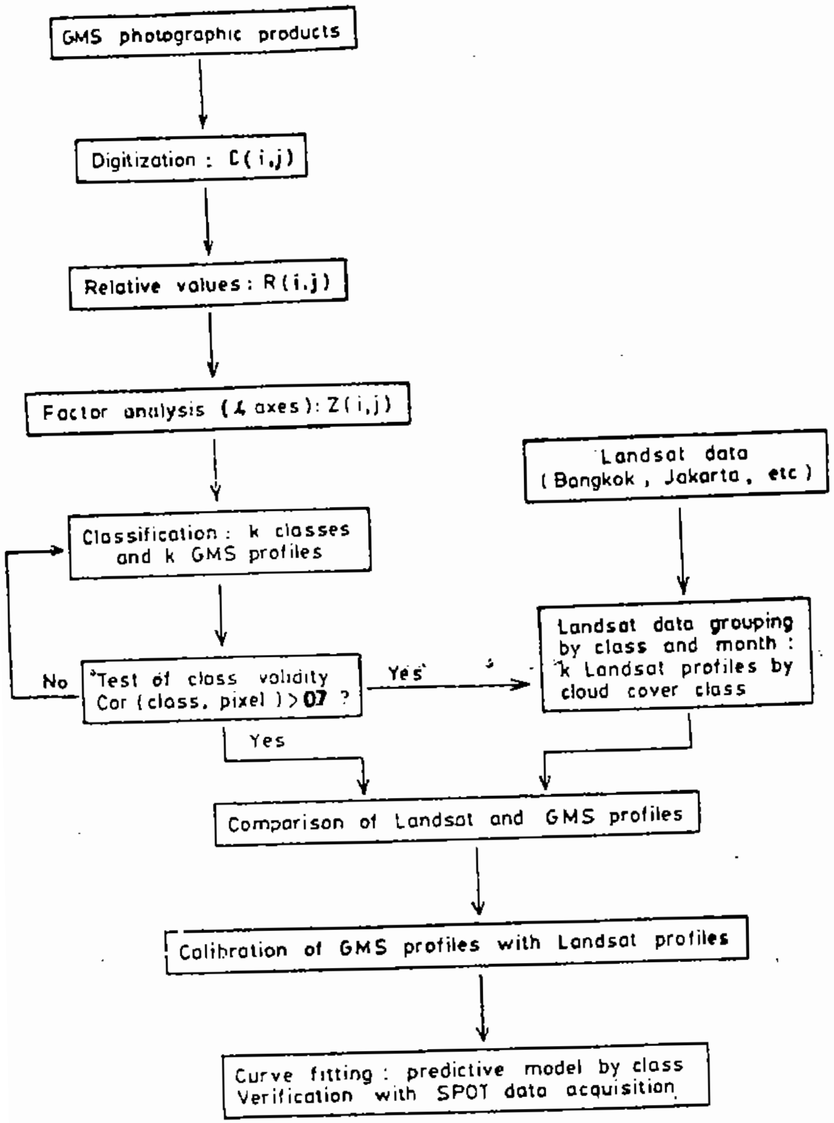

Figure 1. Flow Chart of the Main Steps of the Study

1. Jakarta ground station (Indonesia): 2150 MSS Landsat images from May 1984 to February 1987; maluku and Irian jaya images are not acquired.
2. Bangkok ground station (Thailand): 5578 MSS Landsat images from March 1982 to October 1986; Irian Jaya and Maluku images are not acquired.
3. Alice Spring ground station (Australia): 1484 MSS Landsat images from January 1980 to February 1982; kalimantan and Sumatra images are not acquired.
4. EROS (U.S.A.): 1445 landsat MSS images from Jully 1972 to January 1987.
5. SPOT Image (France): 1713 SPOT images from March 1986 to March 1987; Maluku and Nusa Tenggara were not surveyed.

By analysing the spatiotemporal distribution of the images it appeared that for any given area the number of Landsat and SPOT acquisitions was too small for accurate determination of yearly cloud cover profile, so other sources of cloud cover information were considered.

TABLE 1: PERCENTAGES OF LANDSAT (JAKARTA, BANGKOK, AUSTRALIA AND EROS STATIONS) AND SPOT DATA WITH CLOUD COVER LESS THAN 70/50/30/20/10 AND 25/10 PERCENT

	Jakarta	Bangkok	Australia	EROS	SPOT
Java	34/29/24/14/8 (426)	46/36/25/13/2 (3479)	52/44/18/00/0 (549)	51/43/33/20/9 (292)	30/4 (312)
N T T	41/33/26/19/9 (198)	Station out of range	57/43/25/10/2 (229)	61/59/51/30/12 (178)	(0)
Suma-tra	29/22/19/14/8 (661)	24/13/5/4/0.9 (2414)	Station out of range	Not purchased	22/4.8 (462)
Kali-mantan	21/15/13/09/5 (496)	20/11/5/3/0.8 (2736)	Station out of range	27/15/8/3/0.3 (564)	12/0.7 (543)
Irian	Station out of range	tation out of range	15/6/2/0.6/.3 (974)	41/27/16/4/1.6 (159)	17/2 (264)
Sula-wesi	19/12/10/04/1 (265)	51/40/27/16/8 (82)	34/22/04/0/0 (76)	44/29/11/3/1.5 (229)	31/6 (132)

Note: Numbers of acquisitions are between brackets. Variability between stations is due to their different periods of acquisition and to a lesser extent to the operators who estimate the cloud cover.

GMS Data

Locally availabe visible data between 1981 and 1985 from Geostationary Meteorological Satellite (GMS) were used (Gastellu- Etchegorry, 1986). Since 1981 the Indonesian Institute of Aeronautics and Space (LAPAN) has acquired and stored GMS data on computer compatible tapes (CCT) between 3 and 5 GMT every day. Due to the large spatial extent of Indonesia, this acquisition time corresponds to different local times: 0900 to 1100 local time in Sumatera, and 1200 to 1400 local time in Irian Jaya. Thus, a calibration of GMS data is necessary in order to provide valid observations for analysis dependet on the geographic position of the study area considered.

As digital processing of large numbers of CCT magnetic tapes was not practical, all visual displays of GMS visible digital data acquired between 1981 and 1985 were considered. In order to limit the volume of data to four dates per month, these visual displays were randomly sampled. Because some GMS data were missing, the four year period between 1981 and 1985 was represented with 176 dates. Missing data were interpolated and 192 dates were used for analysis.

Digitization

GMS images were manually digitized to permit automated data handling. The geometric digitization was processed as a convenient $1^0 15$ gridded system, 18 lines x 38 columns, which defined 684 pixels. Simple visual digitization allowed quick and easy compensation for the significant variability in the quality of photographic products. Cloud cover digitization consisted of attributing to each pixel a number from one to five representing the equal ranges of cloud cover percentage, from 0 to 100 percent. Thus, any pixel of the Indonesian Archipelago is represented by a vector, or data file, with 192 temporal components. The cloud cover index C(i,j) of pixel "i" at the time "j" is an element of a 192 x 684 contigency matrix. All the 684 cloud cover data files were stored on a floppy disk for use by microcomputer.

THE CLOUD COVER SPATIAL DISTRIBUTION

Data Handling

The determination of the main spatiotemporal characteristics of the cloud cover was performed by a factorial analysis of correspondences (Benzecri, 1984) of the 192 x 684 contingency table C(i,j). In order to emphasize information about the similarity between pixels, relative values, not absolute values, of the original data are considered. The distance between the points representing the variables is the Chi-square distance (Benzecri, 1984). It is a usual Euclidian distance for which the relative data are individually centred relative to the square root of C(j) and weighted with the inverse of C(j). The Chi- square distance between two pixels provides a quantitaive measure of the similarity between these pixels express similar cloud cover temporal profiles. Due to the special characteristics of the Chi-square distance, the grouping of very close variables does not modify the distances

between the other variables; therefore no information is lost when grouping of variables takes place, and no additional information is gained if homogeneous groups of variables are indefinitely partitioned (Lagarde, 1983).

Large Scale Cloud Cover Pattern

By analyzing the information provided by the first four factorial axes, a "parallelepiped" classifier (Gambart-Ducros, 1983) grouped all pixels into classes with similar characteristic profiles such that each class was represented by a unique cloud cover profile. This approach roughly outlined the main homogeneuos classes of Indonesian land areas. Due to the strong negative correlation between the value of the Chi-square distance and the value of the inter-pixel similarity of the cloud cover, the groups of pixels correspond to neighbouring pixels, and thus to geographical areas.

With a large value of the correlation "class-pixel" (Gastellu- Etchegorry, 1987), such as 0.9, the total number of classes was 67, too large for good representation of information. A trade-off was made using a threshold of 0.70 with the total number of classes being 18 (Figure 2). Schematic yearly information was computed by averaging the monthly data over the four-year period for all Indonesia's 18 classes. In order to be useful, these profiles must be quantified with respect to the probability of acquiring remotely sensed data with a given cloud cover percentage. Because GMS acquisition times differ from those of Landsat and SPOT, and because the resolution of GMS is different from data segments of these other systems, the original levels of radiometric digitization do not allow a straightforward solution. In this context, the cloud cover temporal profiles of all classes must be calibrated with the aid of statistics from Landsat and SPOT data acquisitions. This approach permitted verification and improvement of the GMS cloud cover profiles.

CLOUD COVER PROFILES

Landsat and SPOT Data Analysis

In a first step all Landsat and SPOT data were grouped by group station, by homogeneous zone, and by month of acquisition, from 1972 to 1987. Cloud cover percentages were grouped as: less than 10, 20, 30, 50 and 70 percent for landsat images, and less than 10 and 25 percent for SPOT images. Landsat and SPOT images have different sizes and SPOT data are acquired half an hour after Landsat data. Due to these different characteristics and to different cloud cover thresholding levels, SPOT and Landsat data were not grouped together. SPOT data were used to verify the final results. Probabilities of data acquisition according to the cloud cover and confidence intervals were computed. In the homogeneous zones within Maluku and Nusa Tenggara, the available number of Landsat and SPOT images was too small to derive significant results; in this case remotely sensed data from neighbouring homogeneous zones were grouped. Data analysis stressed yearly patterns per class, i.e. a maximum of probability occurs in July-August for class 5 (Java) and February-March for class 1 (North Sumatera). The period of Landsat and

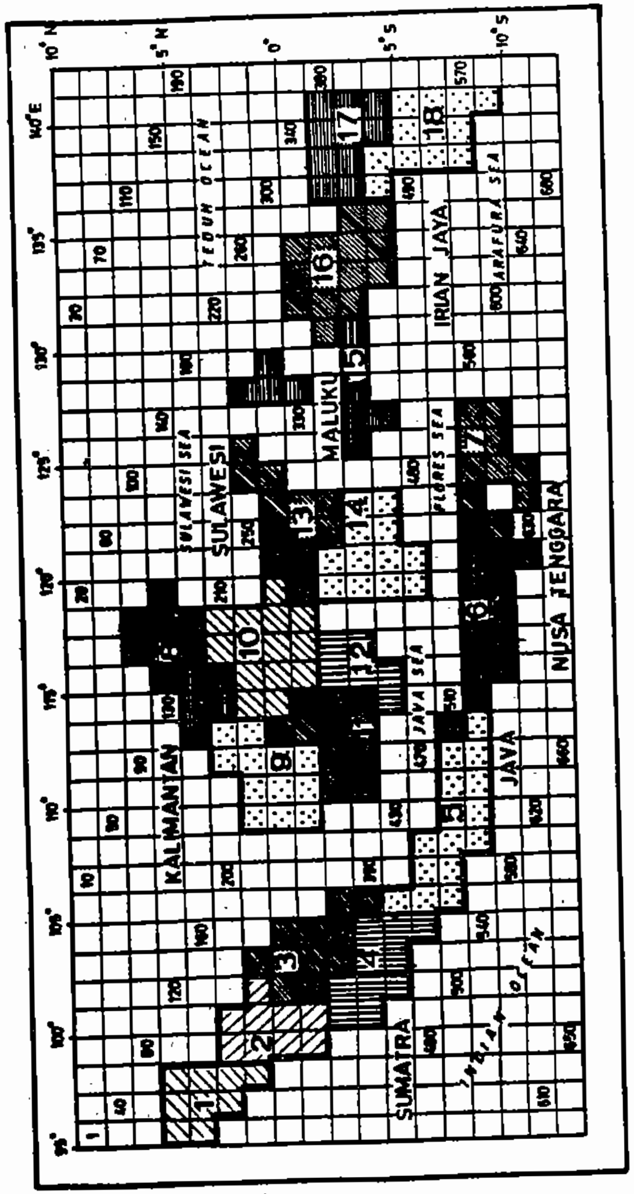

Figure 2 The 18 Cloud Cover Zones of the Indonesian Archipelago.
(Note : Pixels are labelled 1 to 684.)

SPOT acquisitions ranges from 1972 to 1987 whereas the analysed GMS data were acquired from 1981 to 1985. These different ranges of data acquisitions are not incompatible because the Landsat derived yearly cloud cover profiles supported the hypothesis of a small inter-annual variability of the cloud cover profiles compared to the annual variability.

In order to quantify the yearly patterns of all the homogeneous zones all data were grouped by month and by homogeneous zone or set of neighbouring homogeneous zones, independently of the year of acquisition (Appendix 1). These data were analysed with their confidence intervals; for some months the number of Landsat acquisitions was not large enough to provide accurate results. Each homogeneous zone was characterized with its mean, minimal and maximal monthly probability of having a given cloud cover. Table 2 displays the 95 percent confidence intervals of the mean probabilities of having less than 10, 20,30, 50 and 70 percent cloud cover for all homogeneous areas.

Table 2: MEAN MONTHLY PROBABILITIES PER CLASS TO ACQUIRE IMAGES WITH A GIVEN CLOUD COVER AS DERIVED FROM LANDSAT ACQUISITIONS.

CLAAS	<70%			<50%			<30%			<20%			<10%		
	-	Mean	+	-	Mean	+	-	Mean	+	-	Mean	+	-	Mean	+
1	24	28	32	15	18	22	8	11	14	4.8	6.3	8.9	1.2	2.3	3.9
2	21	25	29	11	14	17	5	7	10	3.8	5.2	7.8	1.5	2.2	3.5
3	15	18	22	7	9	12	3	5	8	1.4	2.6	4.1	0.4	1.4	2.9
4	22	26	30	12	16	19	6	9	12	3.6	4.9	7.51	13	2.4	4
5	38	41	44	31	34	37	23	26	29	12	16	14	4.5	5.6	76
6&7	50	55	60	40	45	50	28	33	38	14	18	22	5	7.1	10
8	25	29	33	15	18	21	7	10	13	3.5	5	7.8	0.6	1.6	3.3
9	17	20	23	9	12	15	5	7	9	3	4.4	6.3	0.3	1.3	2.8
10	11	14	17	5	7	10	2	4	5	0.6	1.6	3.2	0	0.8	2.1
11	15	13	22	8	10	13	4	6	9	1.9	3.3	5.1	0.7	1.7	3.5
12	17	22	28	6	9	13	3	6	9	0.8	1.8	4.6	0.3	1.3	4.1
13&14	27	32	37	16	20	25	9	12	16	3.4	4.9	7.8	1	2.1	4
15	29	37	45	18	25	33	4	8	14	0	0.6	3	0	0	3
16	16	21	26	6	9	13	1.1	2.6	5.2	0	0.8	3	0	0.5	2.2
17	7	10	16	1	4	8	0	1	4.4	0	0.1	2	0	0	2
18	7	12	16	2	5	8	1	2	4.6	0	0.5	2.2	0	0.3	1.7

Note The "-" and "+" display the 95 percent confindence intervals.

The Probability Temporal Profiles

A linear interative process led to the calibration of the GMS cloud cover profiles. For each homogeneous zone the mean, minimum and maximum of each GMS profile was set equal respectively to the previously defined mean, maximal and minimal monthly probabilities from Landsat. The calibrated GMS curves were expressed as mathematical functions. These curves were fitted with a seventh order polynomial using the method of least squares, giving correlations greater than 0.90.

All coefficients and 95 percent confidence intervals were computed for each homogeneous area with the 30 , 20 and 10 percent cloud cover classes (Table 3). This approach led to three predictive models per homogeneous area (Appendix 2).

TABLE 3. COEFFICIENTS OF 7TH ORDER EQUATIONS WHICH FIT THE 10, 20, AND 30 PERCENT CLOUD COVER PROFILES OF EACH ZONE.

CLASS	AO	A1x10	A2x10	A3x10	A4x104	A5x106	A6x108	A7x109	C.I.
10%	1.35	14.64	-28.33	26.56	-13.36	36.10	-49.42	2.696	2
1 20%	6.57	12.27	-27.11	29.12	-16.18	46.61	-66.50	3.730	3
30%	10.42	23.80	-50.06	51.66	-28.02	79.70	-11.30	6.316	4
10%	0.19	11.68	-33.20	37.04	-18.28	43.73	-49.65	2.120	2
2 20%	2.04	18.95	-47.47	50.05	-23.92	55.81	-61.84	2.572	3
30%	3.82	19.92	-55.77	61.85	-30.42	72.60	-82.23	3.499	4
10%	0.82	5.22	- 8.42	4.61	- 0.44	- 3.55	10.45	-0.823	2
3 20%	1.00	12.74	-24.88	18.45	- 5.55	4.63	6.79	-1.001	2
30%	2.91	20.35	-39.28	28.75	- 8.45	6.22	12.38	-1.676	3
10%	1.29	35.02	- 6.12	5.69	- 2.60	6.08	- 7.04	0.324	2
4 20%	.12	13.10	-28.74	30.09	-14.63	35.30	-41.43	1.887	3
30%	1.56	25.15	-48.51	47.73	-22.51	53.44	-62.31	2.851	3
10%	0.88	2.45	8.46	-10.29	5.30	-13.96	17.79	-0.858	2
5 20%	2.67	11.67	- 7.41	6.69	- 1.38	- 4.85	18.37	-1.534	3
30%	8.34	14.15	4.57	- 7.34	5.79	-23.71	42.49	-2.700	4
10%	3.74	- 5.83	3.11	9.83	- 9.43	33.79	- 55.36	3.459	3
6 20%	11.16	-33.58	56.74	-18.01	- 7.74	59.44	-127.8	9.263	5
30%	19.36	-58.36	88.97	-12.78	-25.03	137.06	-270.10	18.794	6
10%	3.91	- 3.48	2.59	10.77	-11.52	45.47	- 80.23	5.290	3
7 20%	8.39	-16.28	43.19	-15.76	- 6.92	56.94	-127.40	9.484	5
30%	14.29	-29.18	73.27	-19.97	-18.09	120.48	-257.20	18.753	6
10%	1.32	- 5.16	10.76	- 6.65	1.64	- 1.37	- 0.49	0.083	2
8 20%	3.38	- 6.66	7.09	10.71	-12.61	46.52	- 73.33	4.247	3
30%	8.34	-15.49	29.06	-10.01	- 2.84	21.70	- 40.66	2.497	4
10%	- 0.54	6.38	-18.33	23.35	-13.48	38.60	- 53.89	2.931	2
9 20%	- 0.70	18.78	-55.63	70.65	-40.41	114.5	-158.10	8.504	2
30%	- 1.54	28.07	-73.56	92.99	-54.65	160.30	-229.50	12.796	3
10%	0.80	- 2.37	1.26	3.65	- 3.72	13.52	- 21.85	1.323	2

TABLE 3 (Continued)

10 20%	1.73	- 6.07	7.48	0.47	- 3.44	15.77	- 28.36	1.841	2
30%	3.50	- 6.94	6.91	3.97	- 6.29	25.35	- 43.14	2.706	2
10%	0.85	4.19	-18.69	25.25	-14.08	37.81	- 48.82	2.439	2
11 20%	1.54	6.73	-32.03	44.45	-25.04	67.53	- 87.49	4.387	2
30%	4.18	3.58	-23.14	35.55	-20.83	57.49	- 76.00	3.897	3
10%	0.71	- 3.75	8.25	- 5.70	1.79	- 2.39	0.33	0.132	3
12 20%	0.84	- 3.70	7.08	- 3.29	0.40	0.10	- 3.36	0.276	3
30%	3.18	- 2.92	1.70	5.70	- 4.53	12.90	- 16.33	0.784	4
10%	1.44	- 6.73	6.44	5.17	- 7.60	31.56	- 55.80	3.626	2
13 20%	3.15	- 14.73	12.02	15.87	-19.99	80.41	-140.00	9.037	3
30%	9.44	-29.19	32.14	13.09	-26.02	113.20	-204.20	13.408	4
10%	1.38	- 4.81	1.91	70.27	- 6.67	23.88	- 38.74	2.380	2
14 20%	3.03	- 9.75	13.76	21.26	-18.18	62.92	-100.30	6.093	3
30%	9.21	-22.53	16.45	18.74	-21.86	82.56	-137.50	8.588	4
10%	1.63	- 7.07	3.82	11.67	-12.78	50.02	- 86.32	5.536	3
15 20%	3.50	-14.83	3.36	34.35	-34.14	129.70	-220.50	14.009	4
30%	0.03	-30.13	21.30	38.81	-46.33	185.60	-323.80	20.907	6
10%	0.44	- 1.45	- 0.54	4.23	- 3.38	11.06	- 16.52	0.933	2
16 20%	0.74	- 2.69	0.78	4.45	- 4.03	13.72	- 20.90	1.195	3
30%	2.88	- 9.13	9.35	2.25	- 5.19	20.79	- 33.88	2.008	3
10%	0.14	- 0.78	- 0.54	3.12	- 2.54	8.52	- 13.07	0.757	2
17 20%	0.16	- 1.06	- 0.44	3.84	- 3.28	11.35	- 17.84	1.057	2
30%	1.05	- 2.41	- 0.47	7.62	- 6.71	23.52	- 37.27	2.221	4
10%	0.00	1.61	- 7.08	9.46	- 5.32	14.58	- 19.44	1.010	2
18 20%	0.05	1.93	- 9.24	12.68	- 7.21	19.97	- 26.86	1.410	2
30%	97.00	3.21	-18.00	25.71	-14.89	41.71	- 56.71	3.008	3

Note : C.I. displays the mean 95% confidence intervals. "W" being the week (1 for 1st week of January and 48 for last week of December), probabilities are: $A0 + A1.W + A2.W^2 + A3.W^3 + A4.W^4 + A5.W^5 + A6.W^6 + A7.W^7$.

To compare the previous results with statistics of SPOT data acquisitions, two opposite effects must be noted. Being compared to Landsat images, combined with a cloud cover spatial distribution which is not exactly homogeneous, induces larger probabilities of acquiring images with very small cloud covers. On the other hand, the SPOT, which crosses the equator half an hour after Landsat meets larger cloud covers. The combination of these two effects was negligible compared to the accuracy of the predictive models. Indeed, all statistics of SPOT data acquisitions were within the limits defined by their corresponding predictive models.

Predictive models are very useful in order to plan the survey of a region with remotely sensed data. An example of application is given. In 1986, SPOT Image was required to acquire, during the dry season, images of the four scenes of the province of Yogyakarta (Java) with less than 10 percent cloud cover and with an incidence angle smaller than 16. From July 27th to October 13th, 56 images were acquired and two scenes were ecquied with less than 10 percent cloud cover; five images had less than 10 percent cloud cover and 21 images had less than 25 percent. This result matches with the prediction that the cumulative probability of acquiring a scene with less than 10 percent cloud cover is around 70 percent; the cumulative probability of acquiring four scenes with less than 10 percent cloud cover is around 24 percent.

CONCLUSION

Most Indonesian land areas can be characterized by a distinct yearly cloud cover pattern with a relatively small inter-annual variability. For example, Java has a well defined clouded season in December-January, but the most clouded season of North Sumatra occurs in September-October. With the aid of GMS profiles and all available statistics from Landsat and SPOT data acquisitions, the study area was partitioned into 18 homogeneous zones, each one being characterized by a distinct cloud cover temporal profile. Thus, the cloud cover temporal behaviour of all Indonesian land areas was summarized as 18 temporal profiles. The curve fitting of these profiles resulted in predictive models of the 10 , 20 and 30 percent cloud cover constraint of any land area.

These models constitute an easily and quickly readable product, and are particularly useful in estimating the time necessary in order to survey an area with a given cloud cover within a defined period of acquisition. They can also be used to forecast the feasability of a multi-date study. Due to the absence of local ground stations capable of acquiring Landsat TM and SPOT data of Indonesia and to the limited capacity of recorders on board current satellite systems, predictive models provide statistical information for determining the priority areas to survey. They can also be very valuable for solving problems due to conflicting requirements of SPOT data the acquisitions with different shooting angles.

It must be noted that results obtained for land areas can be extrapollated to marine areas by calibrating their respective GMS profiles in the same way as their respective neighbouring land areas.

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APPENDIX 1. PROBABILITIES OF LANDSAT ACQUISITIONS OF ZONES 1 TO 18, BY MONTH "M" AND CLOUD COVER CLASS.

	ZONE 1						ZONE 2					
M	N	<70%	<50%	<30%	<20%	<10%	N	<70%	<50%	<30%	<20%	<10%
JAN	56	29	21	14	10.7	7	73	15	1	0	0	0
FEB	44	41	23	14	9.1	4.5	65	28	20	18.5	12.3	3.1
MAR	58	29	16	12	8.6	5	61	26	10	6.6	0	0
APR	63	29	14	4.8	1.6	0	87	21	13	2.3	1.1	0
MAY	96	27	19	8 3	6.3	1	111	27	10	3.6	0.9	0
JUN	87	28	21	16	9	1	121	37	30	22.3	19	10.7
JUL	61	39	30	23	8	1 6	79	37	23	10	6	5.1
AUG	23	(17)	(13)	(4)	(0)	(0)	24	38	13	4.2	4.2	4.2
SEP	32	(22)	(9)	(9)	(9)	(3)	34	26	21	5.9	5.9	0
OCT	69	32	22	14	6	1	72	18	4	2.8	1.4	1.4
NOV	56	16	9	0	0	0	85	9	6	2.4	0	0
DEC	51	27	18	9.8	7.8	2	69	22	12	9	2.9	1.4

	ZONE 3						ZONE 4					
M	N	<70%	<50%	<30%	<20%	<10%	N	<70%	<50%	<30%	<20%	<10%
JAN	59	3	0	0	0	0	50	2	0	0	0	0
FEB	59	17	10	3 4	3 4	0	57	21	14	7	5	3.5
MAR	64	25	8	4.7	1.6	0	69	25	15	10	4.3	0
APR	69	25	10	2.9	1.4	1.4	80	31	16	5	2.5	2.5
MAY	112	25	10	3.7	0 9	0	108	39	22	14	7.4	2.8
JUN	111	29	16	9 2	7.2	3.6	113	32	21	13	10.6	4.4
JUL	74	23	18	10.8	5.4	1.4	74	32	23	16	5.4	0
AUG	42	10	7	7.4	2.5	0	26	38	35	15	3.8	3.8
SEP	24	17	8	4 2	4.2	0	24	13	8	0	0	0
OCT	58	21	12	6.9	1.7	1.7	63	25	16	11	6.3	3.2
NOV	71	15	6	5.6	2 8	2.8	64	19	14	12.5	10.9	3.1
DEC	51	6	6	5.6	0	0	39	31	5	5	2.6	2.6

	ZONE 5						ZONE 6 & 7					
M	N	<70%	<50%	<30%	<20%	<10%	N	<70%	<50%	<30%	<20%	<10%
JAN	60	13	7	1.7	0	0	37	19	14	3	3	0
FEB	47	28	26	21	4	0	12	58	50	30	(20)	(10)
MAR	81	41	27	22	12	6	38	63	61	42	13	8
APR	97	43	32	21	10	0	28	57	54	39	14	4
MAY	114	42	35	31	12	4.4	38	63	47	39	26	8
JUN	137	43	38	38	31	15	69	51	46	36	20	9
JUL	97	52	47	39	21	6 2	76	53	42	30	16	7
AUG	80	56	48	38	19	9	51	80	59	59	31	8
SEP	85	59	49	38	20	8	59	61	54	46	22	10
OCT	111	53	40	27	17	8	85	60	51	41	29	14
NOV	129	33	29	21	16	5	69	56	43	29	16	7
DEC	91	32	26	15	11	5	43	40	19	9	7	2

Note : For all zones, the 95 percent confindence intervals are particularly large with small acquisitions "N". Maxima occur at different periods : January for Zone 1 and June for Zone 5.

ZONE 8

M	N	<70%	<50%	<30%	<20%	<10%
JAN	17	12	6	0	0	0
FEB	48	40	23	14.6	6.3	4.2
MAR	62	27	24	17.7	8.1	1.6
APR	68	31	16	11.8	2.9	0
MAY	92	36	21	3.3	1.1	0
JUN	92	30	15	5.4	2.2	1.1
JUL	62	19	13	6.5	3.2	0
AUG	46	41	28	23.9	19.6	2.2
SEP	59	29	15	8.5	3.4	3.4
OCT	56	34	18	7.1	3.6	3.6
NOV	72	21	15	4.2	0	0
DEC	43	28	19	14	9.3	2.3

ZONE 9

N	<70%	<50%	<30%	<20%	<10%
45	16	2	0	0	0
65	8	8	0	0	0
67	15	8	1.5	0	0
80	15	9	3.8	3.8	0
96	23	9	5.2	4.2	2.1
107	28	18	13	7.5	1.9
67	28	22	13.4	4.5	0
40	20	18	10	5	5
36	36	25	16.7	13.9	2.8
74	23	12	9.5	9.5	4.1
80	18	9	3.8	1.3	0
55	7	2	1.8	0	0

ZONE 10

M	N	<70%	<50%	<30%	<20%	<10%
JAN	40	10	5	2.5	0	0
FEB	63	8	5	3.2	0	0
MAR	72	15	11	6.9	1.4	0
APR	69	19	10	5.8	2.9	0
MAY	90	17	9	5.6	4.4	4.4
JUN	95	13	7	1.1	1.1	0
JUL	74	11	1	0	0	0
AUG	43	28	12	4.7	4.7	2.3
SEP	50	14	10	2	0	0
OCT	55	11	7	3.6	1.8	0
NOV	75	13	5	4	2.7	2.7
DEC	48	10	4	3.5	1.7	0.9

ZONE 11

N	<70%	<50%	<30%	<20%	<10%
37	5	3	0	0	0
55	16	9	5.5	1.8	1.8
62	11	8	8.1	4.8	3.2
67	10	7	4.5	3	0
89	16	7	2.2	0	0
85	15	7	5.9	2.4	0
61	28	11	3.3	0	0
35	34	29	16.7	16.7	8.6
34	21	12	8.8	2.9	2.9
61	13	3	3.3	3.3	1.6
67	22	10	7.5	3	0
43	23	14	7	2.3	2.3

ZONE 12

M	N	<70%	<50%	30%	<20%	<10%
JAN	11	9	0	0	0	0
FEB	28	18	7	7.1	3.6	3.6
MAR	23	22	13	4.3	0	0
APR	27	30	19	14.8	3.7	3.7
MAY	42	21	10	4.8	2.4	0
JUN	40	8	0	0	0	0
JUL	34	18	6	2.9	0	0
AUG	20	25	10	5	0	0
SEP	21	33	10	4.8	0	0
OCT	25	24	20	12	4	4
NOV	31	16	6	3.2	3.2	0
DEC	28	18	11	7.1	3.6	3.6

ZONE 13 & 14

N	<70%	<50%	<30%	<20%	<10%
39	21	5	0	0	0
13	31	15	7.7	0	0
35	40	11	3	0	0
37	30	19	13.5	0	0
22	27	23	18.2	9.1	0
62	24	21	10	4.8	1.6
67	22	12	4.5	0	0
59	49	34	16.9	6.8	3.4
64	42	31	20.3	14.1	6.3
134	45	34	30.6	14.9	5.2
77	32	19	9.1	3.9	0
40	15	10	5	0	0

ZONE 16

M	N	<70%	<50%	<30%	<20%	<10%
JAN	45	24	13	4.4	2.2	2.2
FEB	53	19	8	0	0	0
MAR	33	21	15	3	0	0
APR	15	0	0	0	0	0
MAY	24	25	8	4.2	4.2	0
JUN	34	24	12	8.8	0	0
JUL	18	11	11	0	0	0
AUG	36	50	8	5.6	0	0
SEP	25	16	8	4	4	0
OCT	30	23	3	0	0	0
NOV	36	25	8	0	0	0
DEC	36	19	6	0	0	0

ZONE 17

N	<70%	<50%	<30%	<20%	<10%
22	14	5	0	0	0
20	5	0	0	0	0
20	15	0	0	0	0
9	0	0	0	0	0
9	44	33	11.1	0	0
17	6	0	0	0	0
13	8	0	0	0	0
18	17	17	5.6	0	0
17	6	0	0	0	0
17	0	0	0	0	0
14	14	0	0	0	0
21	5	5	0	0	0

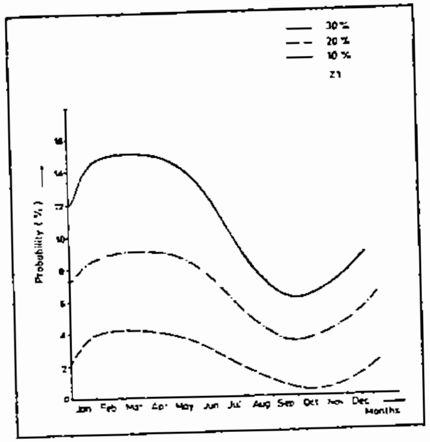
ZONE 18

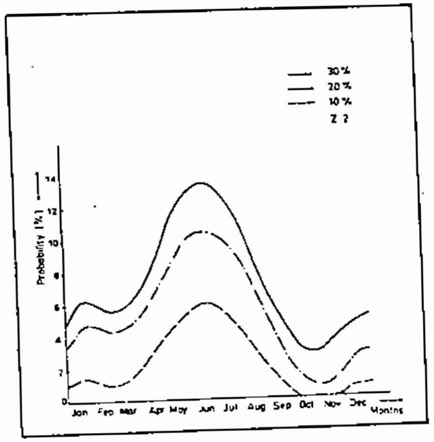
M	N	<70%	<50%	<30%	<20%	<10%
JAN	52	2	0	0	0	0
FEB	34	19	8	0	0	0
MAR	33	21	15	3	0	0
APR	15	0	0	0	0	0
MAY	24	25	8	4.2	4.2	0
JUN	34	24	12	8.8	0	0
JUL	18	11	11	0	0	0
AUG	36	50	8	5.6	0	0
SEP	25	16	8	4	4	0
OCT	30	23	3	0	0	0
NOV	36	25	8	0	0	0
DEC	36	19	6	0	0	0

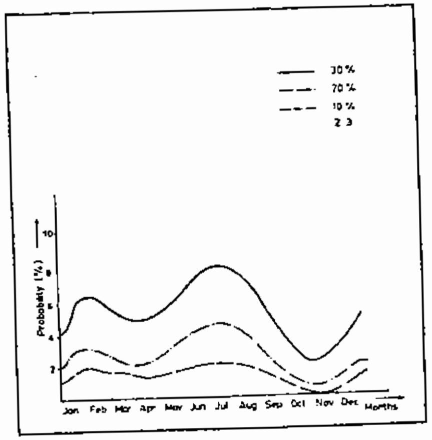
ZONE 15

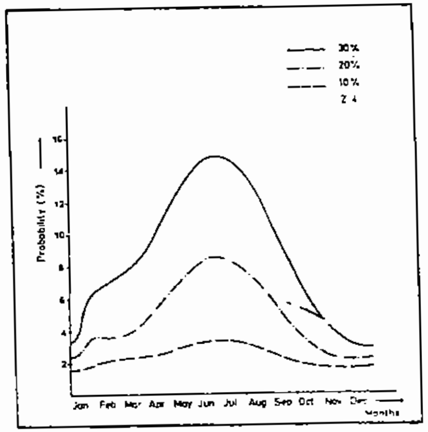
N	<70%	<50%	<30%	<20%	<10%
174	37	25	8	0.6	0

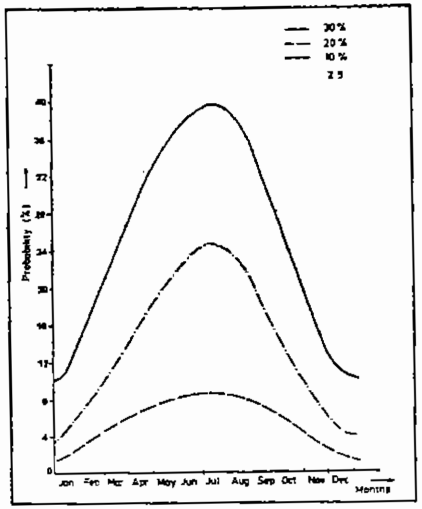
APPENDIX 2. PREDICTIVE MODELS OF THE 10%, 20%, AND 30% CLOUD COVER PROFILES OF ZONES 1 (Z1) TO 18 (Z18).

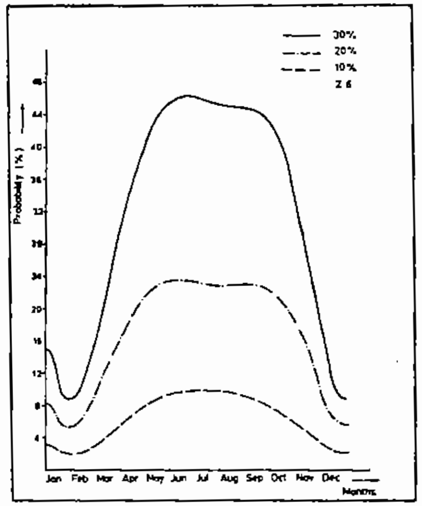


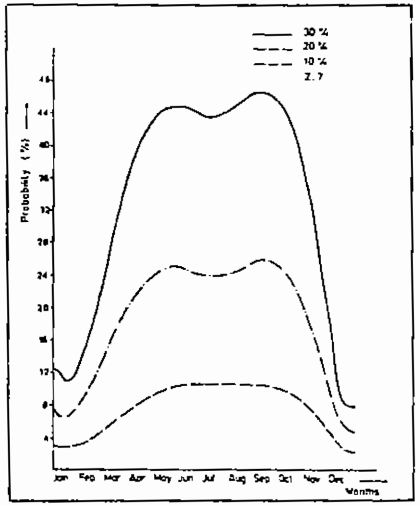


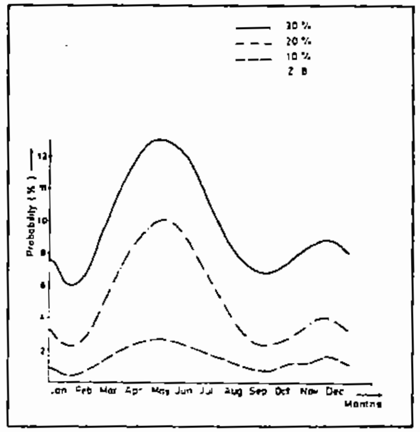


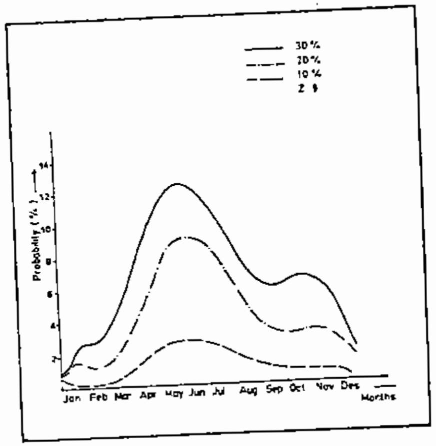


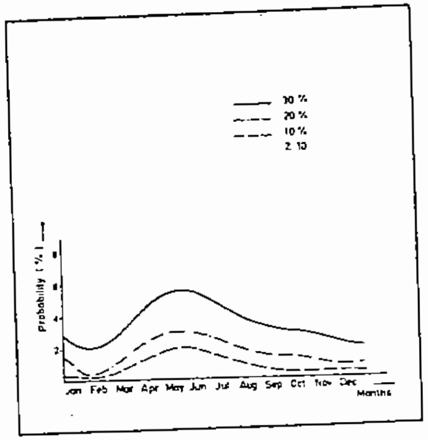


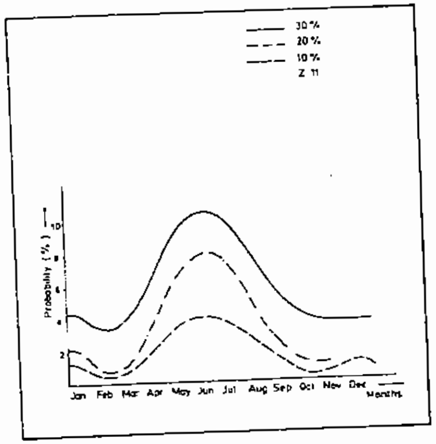


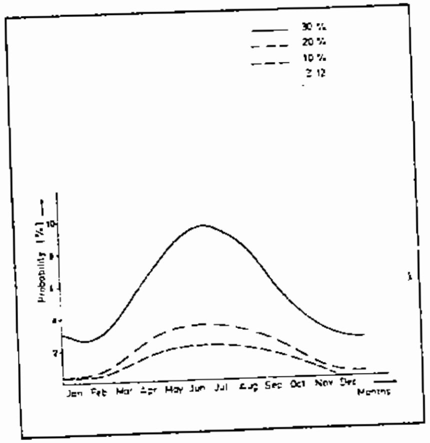


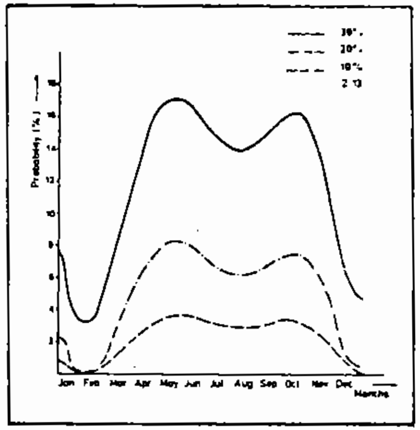


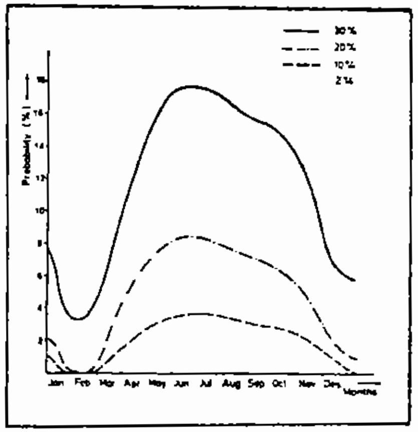

30 %
20 %
10 %
Z 9
Probability (%)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Des
Months

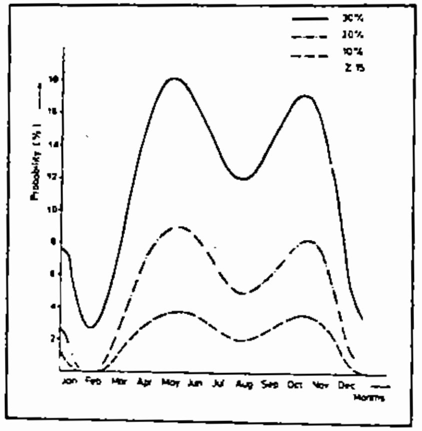

30 %
20 %
10 %
Z 10
Probability (%)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months

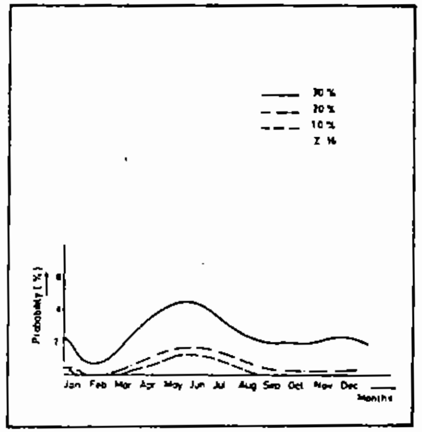

30 %
20 %
10 %
Z 11
Probability (%)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months

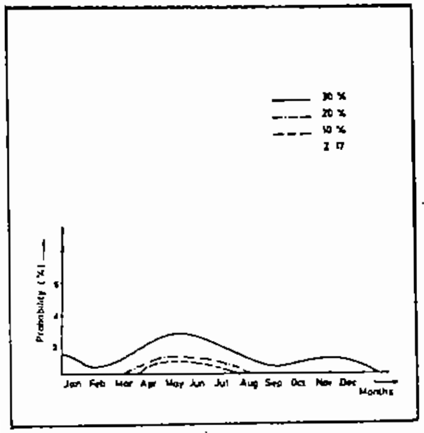

30 %
20 %
10 %
Z 12
Probability (%)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months

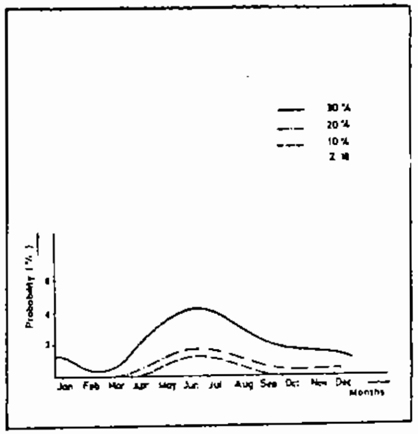

Z 13
Probability (%)
Months


Z 14
Months


Z 15
Probability (%)
Months


Z 16
Probability (%)
Months





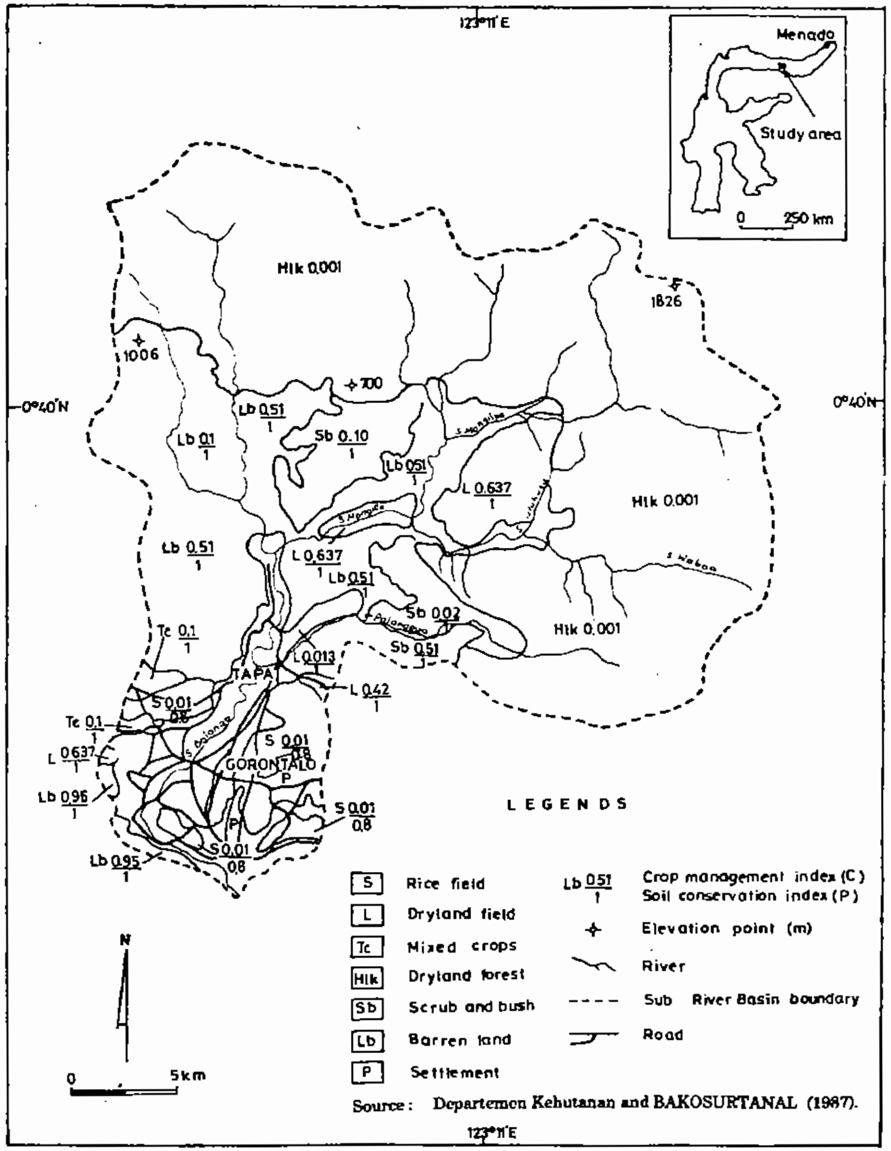


Figure 1. Land Cover/Land Use Map of Bolango Sub-River Basin

mapping procedures, is final, and is ready for reproduction and publication. Figure 1 shows the map of the land cover types in the study area. The land cover types map should be combined with other information, i.e. the C and P factors (the cropping management and erosion control practice factors) as shown in Figure 1 to compose a land use map (Departemen Kehutanan dan BAKOSURTANAL, 1987).

LAND COVER / LAND USE IN THE BOLANGO SUB RIVER BASIN

In what follows, land cover types in the Bolango Sub River Basin (Table 1) are described.

1. Mixed garden (Tc). Mixed garden in this sub river basin covers 249 ha, distributed partly in a dissected hill area (0.3 percent) and on alluvial plains (0.15 percent) of the total area of the existing land cover. The area is located on a slope of 15 to 25 degrees,and has a C index of 0.1 but without conservation effort in that area (P index = 1).
2. Rice field (S). Rice field covers 2.599 ha, and is entirely located in alluvial plain areas. Except in a small area with the slope of 15 - 25 degrees, all areas of rice field are on a slope of 0 to 3 degrees.
3. Barren land (Lb). Barren land covers an area of 12.349 ha or 23.8 percent of the total sub river basin. Barren land has vegetation or is only partly vegetated other than bush or scrub. Grasses sometimes cover these areas. Such areas are frequently in eroded/dissected hills, sometimes in alluvial plain.
4. Dry field (L). Ladang covers 1.749 ha (or 3.39 percent of the whole area of land cover) distributed partly in footslope areas, alluvial plains and also in dissected hills.
5. Scrub and Bush (SB). Scrub and bush, on an area of 3.145 ha (6.08 percent of total land cover), is located in dissected mountains, dissected hills, and a fault block, having 15 to 25 degrees of slope.
6. Settlement (P). Settlement in the study area is the city of Gorontalo (capital of Gorontalo municipality) a total population of 102.123 (local statistical data, 1986). The sub-urban area is also included. Settlement covers the houses, roads, garden, mixed garden etc. It covers 3,236 ha. (6.25 percent) located in alluvial plains having slopes less than 3 degrees.
7. Dryland forest (Hlk). This cover type covers 28,391 ha (54.9 percent), partly distributed in dissected hills and a fault block. The index of P is accounted as 1, because forest naturally protects against the erosion hazard, the C index is 0.001.

CONCLUSION

From this study, the following conclusions can be drawn. Remote sensing techniques, using either Landsat images or airphotos, can be helpful to support land cover and land use mapping. They can also be an important tool for examining the interpretation work and for plotting the C and P index in the field.

Table 1. LAND COVER IN THE BOLANGO SUB RIVER BASIN

Land Cover	Landform	Slope (degrees)	P	C	Area (ha)	Area (%)
1. Mixed garden	dissected hills	15 - 25	1	0.1	249	0.49
	alluvial plain	15 - 25				
2. Rice field	alluvial plain	15 - 25				
			0.8	0.01	2.599	5.02
		0 - 3				
3. Barren land	dissected hills	15 - 25	1	0.1		
		25				
	alluvial plain	0 - 3	1	0.51	12.349	23.87
	fault block	3 - 8	1	0.95		
4. Dry field	dissected hills	15 - 25	1	0.637		
	(Ladang) foot slopes	3 - 8	1	0.013	1.749	3.39
		15 - 25	1	0.42		
	alluvial plain	0 - 3				
	floot plain	15 - 25				
5. Scrub and bus	dissected mountains	15 - 25	1	0.02	3.143	6.08
	dissected hills	15 - 25	1	.10		
6. Settlement	alluvial plain	0 - 3			3.236	
7. Dry land	dissected	15 - 25	1	0.001	28.391	54.90
	forest	25				
Total					51.716	100%

Note: C and P factors are derived from Direktorat Jenderal Reboisasi dan Rehabilitasi Lahan (RRL), 1986 dan Abdurachman et al., 1984.

Forest cover resource is of vital importance to the safety of river basins. For protection against flood, erosion and other natural hazards, the forest area in a region or in a river basin, should be at least 30 to 40 percent of the total area (Fakultas Kehutanan Institut Pertanian Bogor, 1985). The existing forest area in Bolango Sub River Basin is more than the recommended forest cover, extending an area of 28.391 ha (54,9 percent). Therefore, this sub river basin still has an ideal forest cover to protect it against erosion.

Thus, eventhough the forest cover is still adequate for protection, special attention should be given to barren or critical lands which cover almost one fourth of the total area.

ACKNOWLEDGEMENTS

The writers are very grateful to Drs. F.B. Soetarto, Deputy Chairman and Drs. Al. Susanto, Chief of Geography Division of BAKOSURTANAL, Dr. Bruce Foster and Dr. Colin Pain, Land Resources Evaluation and Planning Project (LREP) consultants. Thanks also goes to Ir. Suhardjo, Chief of Sub Balai RTL-RLKT Sub DAS Bolango, and Ir. Pramono Dwi Susetyo, Project Leader of RTL-RLKT for their assistance during the field work.

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The Indonesian Journal of Geography. Vol. 18. No. 55.
June 1988, pp. 35-46

WATER RESOURCES OF THE CHAD BASIN REGION

by
Franklyn R. Kaloko *

ABSTRACT

River basin development is seen as a very effective means of improving agricultural productivity. In the Chad Basin area of the Sahelian Zone of the West African Sub-Region, the water resources have been harnessed to ensure viable agricultural programmes for Nigeria. However, the resultant successes have met by many problems that range from physical to socio-economic and of which water losses have been the most threatening. The study has called for the use of Hexadeconal ($C_{16}OH$) film on the water surface of the Chad as a means of reducing evaporation.

INTRODUCTION

A theory of river basin development involves a set of rules in the form of programme that takes special account of a particular region and itemizes aims and objectives for improving the levels of living of the people in that area. Olayide (1980) attempted to enumerate those aspects of river basin theory which in view of a programme for national, economic and social development, strive at a close integration with the structures, features and variables of the development process in Nigeria. These include: (i) ".... the regional population in relation to the area of land available and land water relationship; (ii) the demographic situation in relation to water demand and job opportunities as well as the growth of Franklyn R.Kaloko,Ph.D. is Senior Lecture in Geography at the Departement of Geography, Fourah Bay College, University of Sierra Leone Freetown, Sierra Leone-West Africa. Productive enterprises now and in the future; (iii) the structure of government in relation to the administrative and political processes in the region. This is more relevant in a federalised political system that is backed up by growing administrative decentralization; (iv) the structure of the agrarian and industrial enterprise in growth terms and patterns of spatial distribution ...." (Faniran, 1972: 131).

* Franklyn R. Kaloko, Ph.D. is Senior Lecture in Geography at the Department of Geography, Fourah Bay College, University of Sierra Leone Freetown, Sierra Leone-West Africa.