REMOTE SENSING TECHNIQUES FOR GRASSLAND MANAGEMENT AND ASSESSMENT OF AGRICULTURAL DEVELOPMENT

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ABSTRACT

Remote sensing deals with the acquisition and interpretation of spectral measurements made at distant locations to obtain information about the earth's surface.

With the development of sensors combined with powerful information systems brought about by the advancement of computer technology in recent years, new opportunities have been opened up for the application of remote sensing techniques in agriculture.

Experiments consisting of spectral reflectance measurements using gound-based sensors have provided a large amount of information relating to vegetation identification, estimation of plant biomass and crop yield, crop condition assessment including water and fertilizer deficiency. On the basis of the results obtained, data from airborne and satellite sensors have been applied to agricultural use including crop forecasting, or resources and environment management and evaluation over wide areas with computer-aided analysis techniques.

1 Grassland management: The author analyzed land cover types using Landsat multispectral scanner data in northern Tochigi Prefecture. Four grassland classes reflecting grassland conditions were identified among the fourteen classes of land cover types described. Furthermore, by combining Landsat spectral data with records of first cutting yield, multiple regression model was created to estimate grassland yield of the district.

2 Assessment of agricultural development: In most of the developing countries which are endowed with vast expanses of land, there are still areas which have remained comparatively unexplored. As a result, in these regions, there is a lack of precise soil surveys which are most important for selecting suitable land for agricultural development in a short time. The author developed an evaluation system using Landsat data for agricultural development in North Sumatra, Indonesia. The characteristics of the system are as follows: 1) each thematic map including data on elevation and land-use was integrated as a grid cell data file of 500 meter by 500 meter in size, 2) according to the quality and quantity of available thematic maps, a three-step evaluation system was designed for carrying out evaluations at each step, and 3) vegetation type was used as a source of information for land evaluation.

Introduction

Food supply in recent years has become an increasingly serious problem due to the large increase in population in the developing countries, while food production in the developed countries tends to be unstable owing to the frequent occurrence of abnormal weather conditions. Therefore it is of paramount importance to develop methods for forecasting and estimating crop production both in the developing and developed countries.

Remote sensing is not a new concept. From time immemorial, man has been using flying machines to observe the earth from a distance. Image interpretation with aerial photography has been used extensively for this purpose and over the years a sophisticated technology has evolved using photographic sensors for remote sensing.

Also in grassland science, aerial photography has been used in the planning of grassland development and evaluation of pasture conditions. These results have been summarized by the National Grassland Research Institute (1977).

On the other hand, with the recent development of computer systems, numerical analysis of satellite-acquired spectral data on agriculture has become one of the most promising

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applications because it gives the opportunity of acquiring data timely over large areas. However, in Japan, research relating to grassland management by this type of remote sensing is in its early stage.

Concept and application

1 Electromagnetic spectrum and bio-information

Remote sensing deals with the acquisition and interpretation of spectral measurements made at a distant location with non-destructive methods based on remote control. The physical basis for remote sensing is the distinctive characteristic of electromagnetic radiance, in which, usually the region from 300 nm (0.3 μm) to 100 cm of spectrum is used for remote sensing measurements (Fig. 1, Landgrebe, 1978).

Experiments consisting of spectral reflectance measurements using ground-based sensors have provided a large amount of bio-information relating to vegetation identification, estimation of plant biomass and crop condition assessment including water and fertilizer deficiency. On the basis of the results obtained, data from airborne and satellite sensors have been applied to agricultural use including crop forecasting or resources and environment management and evaluation over wide areas with computer-aided analysis techniques.

The Remote Sensing Laboratory of the National Institute of Agro-Environmental Sciences is developing new sensors to acquire plant bio-information. Most of these sensors have been used in medicine or engineering and have been adaptated for applications to agriculture. Fig. 2 shows the capabilities for detecting plant qualitative and quantitative characteristics, such as chlorophyll and water contents, dry matter, protein and carbohydrate yields, canopy structure and plant temperature. However, the techniques are still in an early stage, and the system to acquire and process data for bio-information requires a higher degree of sophistication.

2 Platforms and sensors

Fig. 3 illustrates the kind of platforms and sensors used, and the elevation at which remote sensing research is conducted. Sensors mounted on ground-based platforms such as hand-held radiometer on tripod or truck-mounted boom are suitable to acquire basic information about the reflectance characteristics of crop leaves. Camera on captive balloon or sensors on low-altitude airplane may enable to detect differences in the conditions of crop growing in farmers' fields. Also multispectral scanner (MSS) or thematic mapper (TM) mounted on high-altitude airplane or satellite can be used for yield forecast of a region, and environmental assessment of a district.

Ground-based spectral measurements

Fig. 4 shows an example of spectral reflectance patterns of two grass species (tall fescue and orchard grass) and two legumes (white clover and alfalfa). Some of the differences in the spectral pattern which are observed, are related to differences in species or in canopy parameters such as dry weight (DW), fresh weight (FW) and leaf area index (LAI). Fig. 5 shows the relationships between such parameters and reflectance at 1,040 nm of wavelength among six pasture species, each comprising three levels of biomass. A high correlation was observed for the plant water amount (FW-DW, g/m^2). The correlation coefficients increased when several wavelengths were combined, as shown in Table 1.

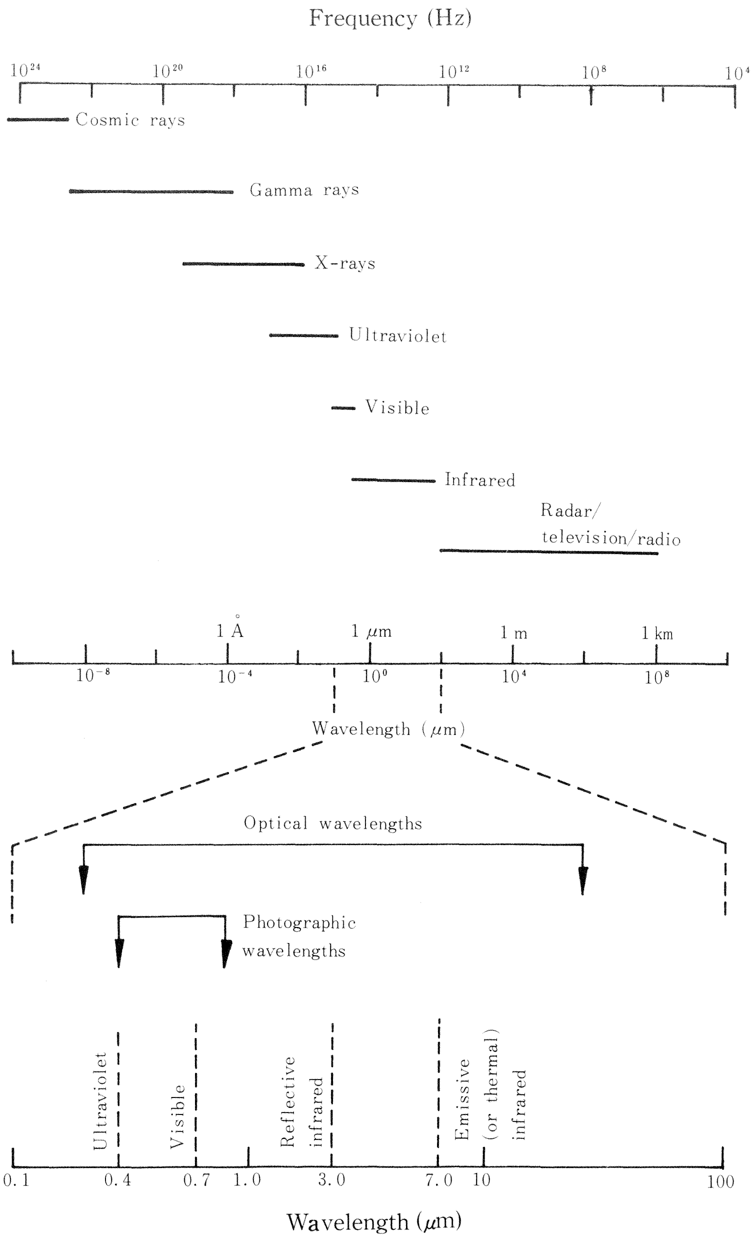

Fig. 1 Electromagnetic spectrum.
The lower part depicts the regions of primary importance in remote multispectral sensing.

Wavelengths	Electromagnetic spectra	Bio-information obtained	Sensors
100 nm – 400 nm	Ultraviolet		Photomultiplier
400 nm – 700 nm	Visible	- Stereo-structure of plant community - Chlorophyll content	Spectroradiometer Camera with film
700 nm – 3,000 nm	Reflective infrared	- Biomass and yield - Proteins, fats and carbohydrates - Water content	Spectroradiometer Camera with IR film
3,000 nm – 0.1 mm	Infrared	- Plant temperature	IR radiometer
0.1 mm – 1 m	Microwave	- Water content - Stereo-structure of plant community - Soil surface condition	Microwave radar
1 m –	Ultrasonic waves	- Stereo-structure of plant community	Ultrasonic waves radar

Fig. 2 Bio-information obtained from electromagnetic spectra.

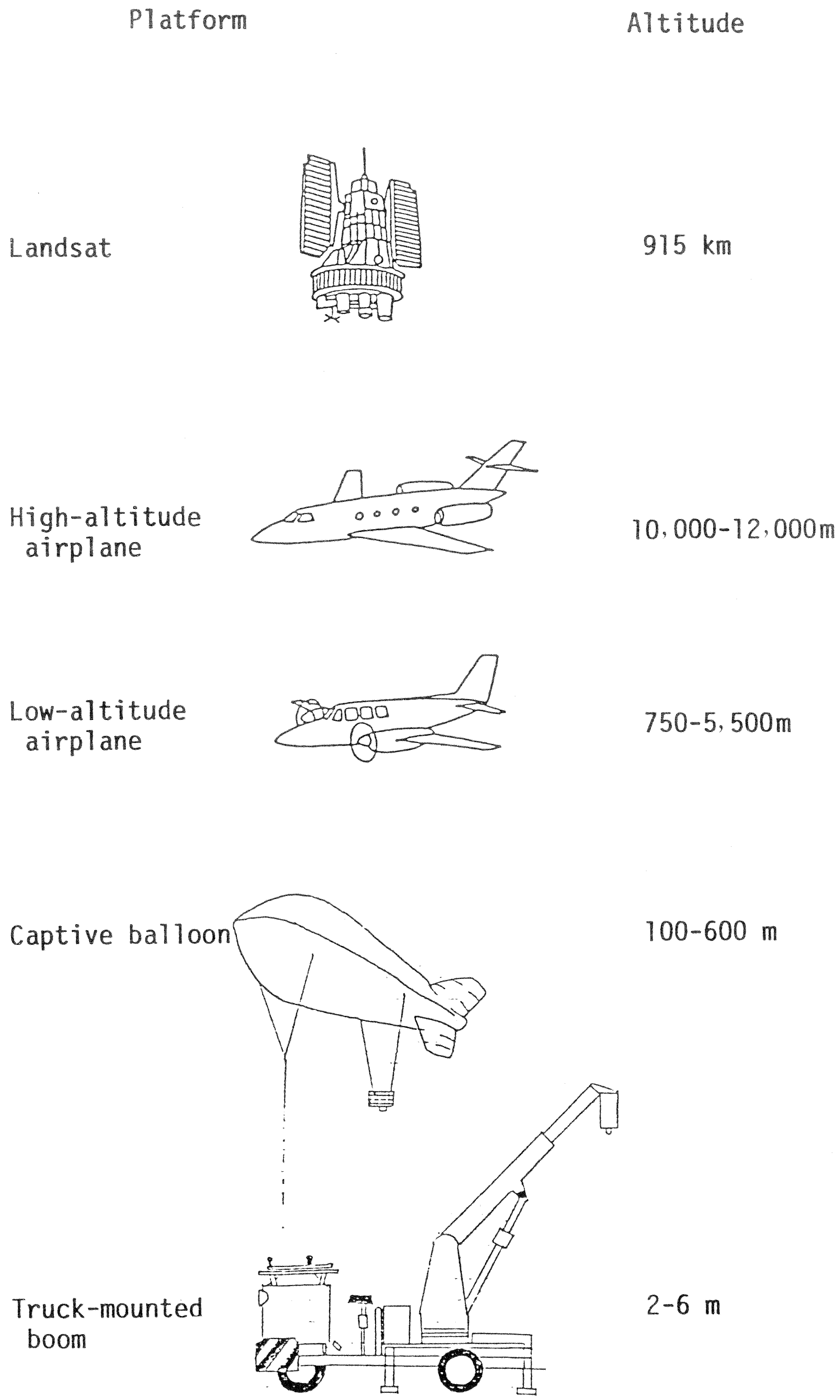

Fig. 3 Kinds of platform and the altitude.

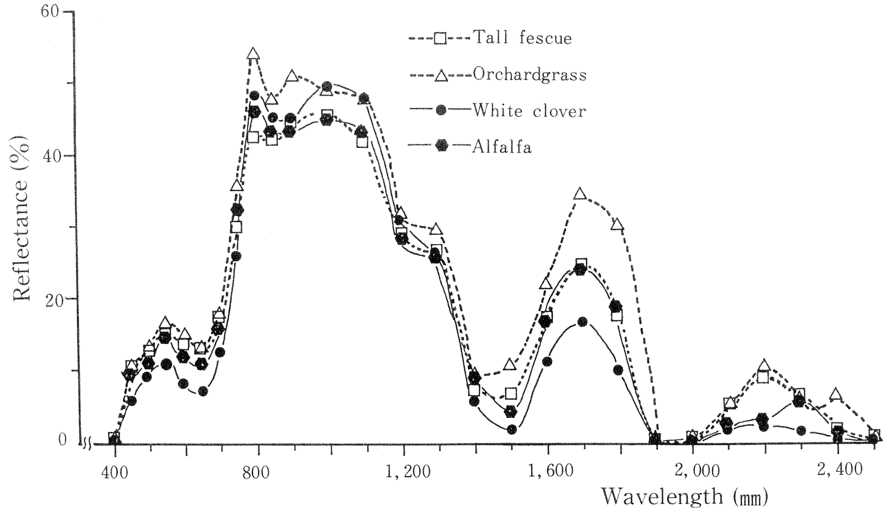

Fig. 4 Spectral reflectance patterns of four pasture species.

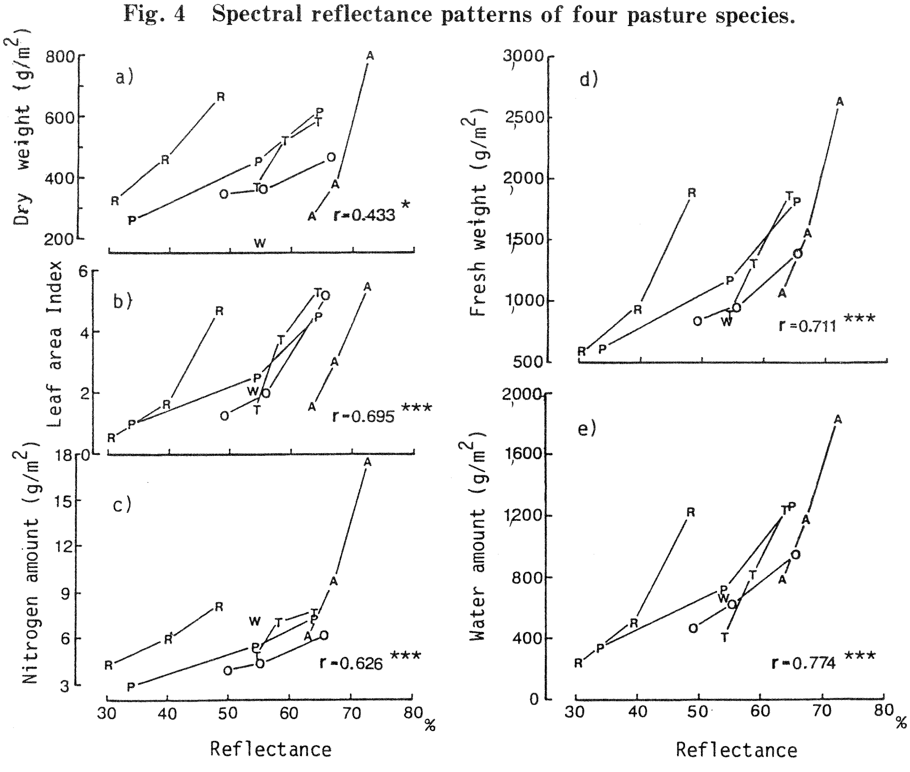

Fig. 5 Relationship between five canopy variables and reflectance at 1,040 nm of wavelength in six pasture species.

Canopy variables : a) dry weight ; b) leaf area index ; c) plant nitrogen amount ; d) fresh weight ; e) plant water amount.

Pasture species : R red top ; P perennial ryegrass ; O orchard grass ; T tall fescue ; A alfalfa ; W white clover.

Each species except white clover, contains three different levels of biomass.

Table 1 Linear correlations of reflectances with canopy variables

Wavelength band	(nm)	Fresh weight	Dry weight	Plant water amount	Leaf area index	Plant nitrogen amount
Single band	650	−0.604**	−0.430*	−0.634***	−0.259	−0.553*
	850	0.763***	0.701***	0.768***	0.894***	0.538*
	1040	0.711***	0.433*	0.774***	0.695***	0.626***
Two bands	1040/650	0.864***	0.660***	0.899***	0.680***	0.852***
	850/650	0.850***	0.738***	0.842***	0.707***	0.754***
Three bands	1040·850/650	0.914***	0.745***	0.924***	0.756***	0.870***

* Significant at 5% level.
** Significant at 1% level.
*** Significant at 0.5% level.
Underlined coefficients indicate the maximum values.

Estimation of first cutting yield of pasture using Landsat MSS

1 Identification of land cover types in Northern Tochigi Prefecture

Pasture yields often fluctuate with differences in management, because pasture is usually cultivated for a number of years under the pressure of cattle grazing or harvest by cutting several times a year. Consequently, pasture shows wide areas of non-uniform growth distribution in contrast to row crops such as rice or wheat. Therefore an understanding of pasture productivity is difficult to acquire at present which makes it difficult to design plans for the improvement of pasture and/or the purchase of supplemental forage on a farm.

A study was undertaken for estimating pasture yields using Landsat multispectral scanner (MSS) data collected on May 25, 1979. A flow chart of the basic steps taken to perform the analysis is shown in Fig. 6 (Akiyama *et al.*, in press, a). A performance of more than 90% was attained in every group, with an average of 94% on the whole (Table 2). Land-use maps including six groups represented by different symbols covering Nishinasuno Town were produced (Fig. 7).

2 Yield estimation by multiple regression model

Multiple regression models for pasture yield estimation were designed (Akiyama *et al.*, in press, b) using actual first cutting yield data collected from 26 pasture plots in Nishinasuno, and combining this information with Landsat spectral reflectance data recorded on computer compatible tape (CCT) from the four channels. The equation used (R=0.923***) is expressed as,

$$Y\ est.\ (kg/ha) = 177X_1 + 132.5X_3 + 99.4X_4 - 216.2X_6 + 10642.5$$

Here,estimated yield (Y est.) expressed as a function of X_i, and X_1 to X_6 in the equation corresponds to the CCT counts from Channels 1 to 6. In CCT, counts from Channels 1, 3 and 4 of the Landsat original data, covering the wavelengths 500–600, 700–800 and 800–1,100 nm are included, respectively. Channel 6 represents the logistic ratio of Channels 4 and 2, log (Ch 4/Ch 2), which was used to increase the amount of information on vegetation.

Yield estimation by multiple regression model using four channels was applied to our study area, and the magnified Shiobara-Nishinasuno area appeared in a yield map shown in Fig. 8. In this map, four yield classes for the first cutting were indicated by grading: 1 for a yield of less than 1.9 ton, 2 for a yield ranging from 1.9 to 4.1 ton, 3 for 4.1 to 5.7 ton and 4 for a yield exceeding 5.7 ton per hectare.

Table 2 Classification performance of training fields into nine land-use groups in northern Tochigi Prefecture

Land-use group (abbreviation)	Performance	Number of points classified as :										Total sample points
		1 For	2 Pas	3 NG	4 GC	5 DF	6 BS	7 UA	8 PF	9 Wat	Unclassified	
1 Forest (For)	90.7	288	26	0	0	3	0	0	0	0	0	317
2 Pasture (Pas)	92.5	9	197	0	6	1	0	0	0	0	0	213
3 Semi-natural grassland(NG)	95.0	0	2	57	1	0	0	0	0	0	0	60
4 Golf course, etc (GD)	96.6	0	3	0	84	0	0	0	0	0	0	87
5 Dry field (DF)	93.0	1	1	0	1	53	1	0	0	0	0	57
6 Bare soil (BS)	90.5	1	4	0	0	9	201	7	0	0	0	222
7 Urban area (US)	93.7	0	0	0	0	0	27	449	1	2	0	479
8 Paddy field (PF)	94.5	0	4	0	0	5	7	7	550	9	0	582
9 Water (Wat)	97.5	0	0	0	0	0	1	1	4	428	3	437
Total	94.0	299	237	57	92	71	237	464	555	439	3	2454

Underlined figures indicate correct classification.

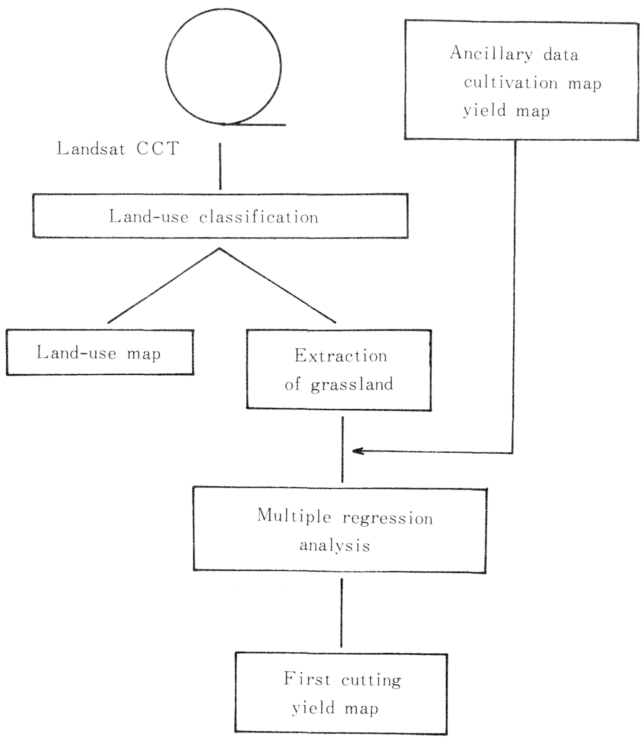

Fig. 6 Flow chart of the basic steps taken to perform analysis of pasture yield estimate.

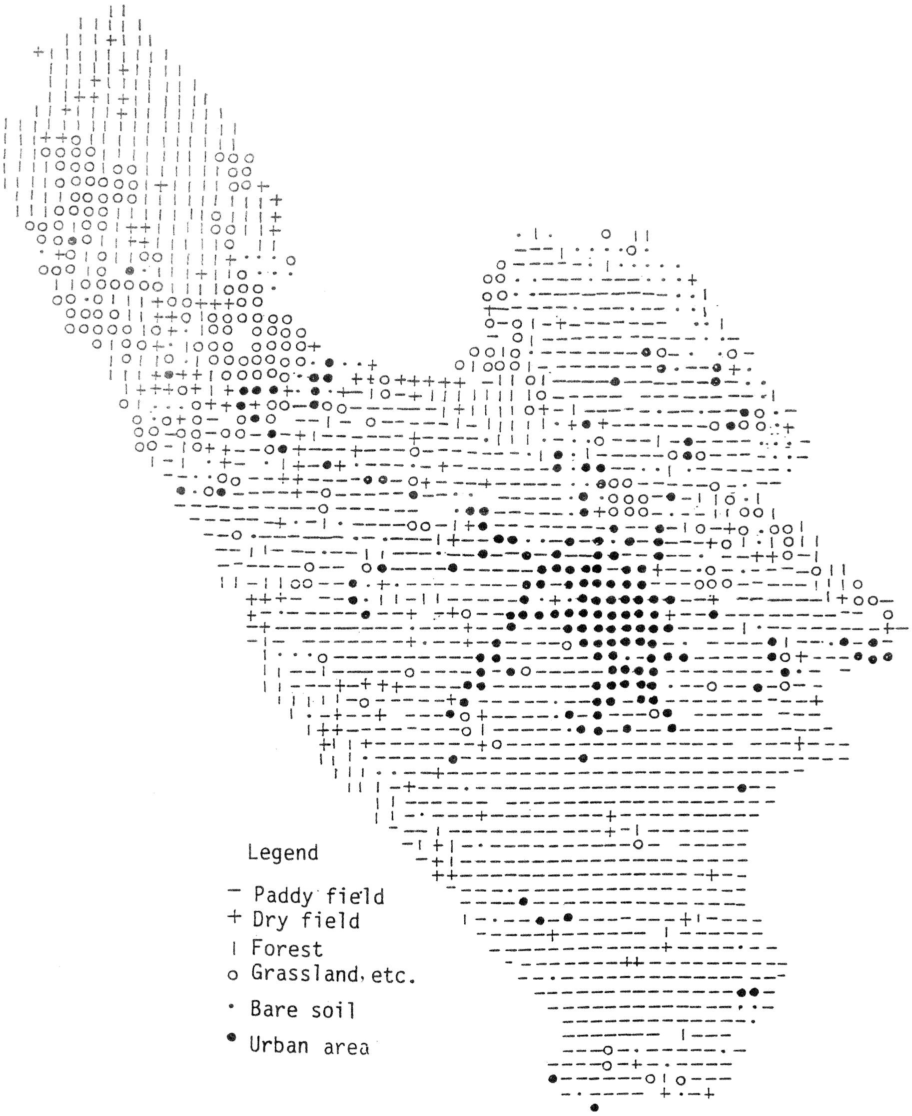

Fig. 7 Land-use classification map using Landsat MSS for Nishinasuno Town in Tochigi Prefecture.
Each symbol represents 171 m×171 m of area.

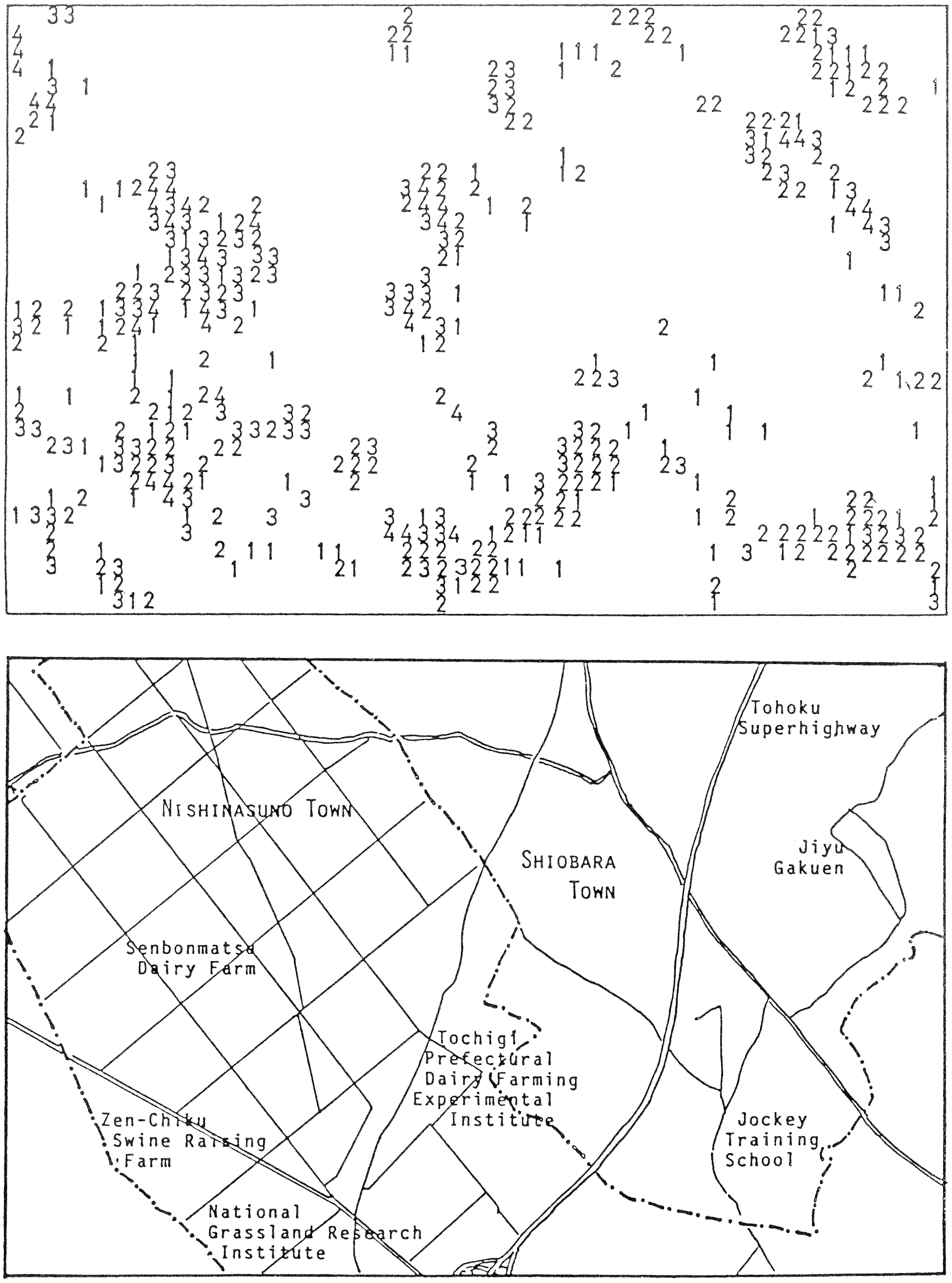

Fig. 8 First cutting yield estimation map for Shiobara-Nishinasuno area.
In the multiple regression model, the best four channels (Ch 1, 3, 4 and 6) were used. Four yield classes for the first cutting of pasture were expressed with numbers from 1 to 4, such as 1 : 0-1.9 ton ; 2 : 1.9-4.1 ton ; 3 : 4.1-5.7 ton ; 4 : over 5.7 ton per hectare.

Land evaluation for agricultural development based on Landsat data

1 Assessment of agricultural development in the tropical area

In most of the developing countries which are endowed with vast expanses of land, there are still areas which have remained comparatively unexplored. As a result, in these regions, there is a lack of precise soil surveys which are most important for selecting suitable land for agricultural development is a short time.

It would be useful if remote sensing technology could be coupled with a computer information system, and if this new technology could be applied to agricultural development programs. In order to fulfil this objective, it would be desirable to conduct detailed analyses covering large areas along with designing evaluation systems for land development using integrated remote sensing data, such as those relating to land-use, vegetation type, drainage system, etc., along with the data already available such as those on geological, topographical, climatic and soil conditions.

However, since the land surface of tropical areas is covered by vegetation all the year round due to the abundant precipitation and high temperature, it is difficult to study soil conditions from space. If vegetation types could be identified on the basis of remote sensing data in which a total assessment of site factors were to be made, appropriate plans for agricultural development could be drawn. Indeed the current status of vegetation can be considered to have resulted from interrelations with the environment, resulting in the creation of vegetation units, hence the assumption that environmental factors may be reflected in the vegetation types.

2 Land evaluation in North Sumatra

Japan International Cooperation Agency is sponsoring a project in remote sensing applications for the development of agricultural infrastructure in the Republic of Indonesia for a 5-year period. In this project, Akiyama and Miyama (1984) designed an evaluation system for agricultural development in North Sumatra, Indonesia. The target area lies between 02°00′-03°30′ North latitude and 99°15′-100°15′ East longitude, including four provinces and one municipality.

Topographically, the land area will be divided into three parts, southern mountainous area, northern plain and eastern vast swamp area facing the Malacca Straits.

On the basis of the vegetation types, Sumatra Island is included in the tropical evergreen rain forest zone. In this type of vegetation, plants grow luxuriantly and trees may reach a height of 30 m, with buttresses and large leaves as well as numerous climbers and epiphytes on the trunks. This type of forest often contains the richest flora on earth with more than 100 species per hectare consisting of several vegetation layers inside the canopy.

Many types of soils such as Alluvial, Lowland Podzolic, Peat Soils, Latosols, etc. cover the area. Due to the interrelationships between climate, topography, soil, etc., many kinds of forest formation types have been formed and environmental conditions can be assessed on the basis of the various types of forest formation.

Flow chart used in the analysis is shown in Fig. 9. The characteristics of the proposed system were; 1) Each thematic map with information on elevation and land-use was integrated as grid cell data file of 500 meter by 500 meter size, 2) According to the quality and quantity of available thematic maps, a three-step system was proposed for carrying out evaluations at each step, and 3) Vegetation types were used as a source of information for land evaluation.

Results of evaluations of areas suitable for paddy fields in applying the PATTERN method* are shown in Fig. 10 with six grades ranging from excellent to unsuitable.

* PATTERN method: abbreviation for "Planning Assistance Through Technical Evaluation of Relevant Number" method.

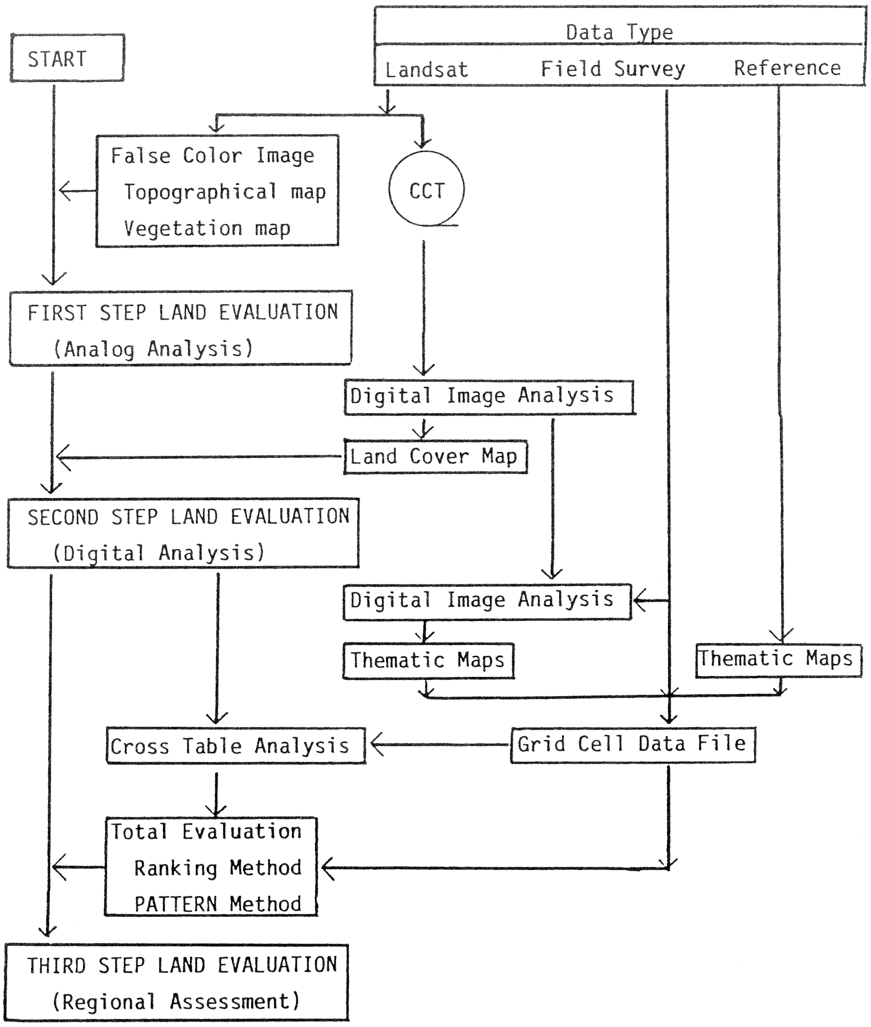

Fig. 9 Main flow of 3-Step Land Evaluation System.

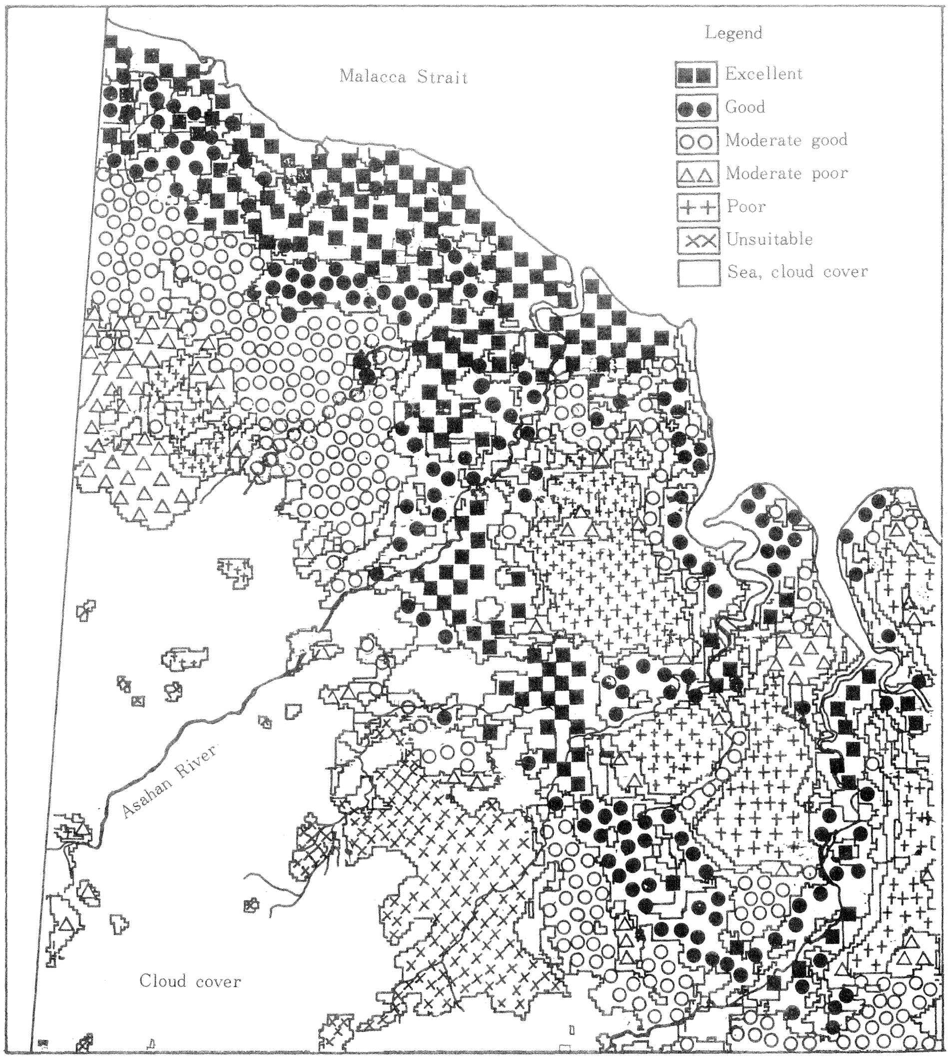

Fig. 10 Land evaluation map for paddy field development in Northern Sumatra using Landsat data.

Problems encountered in Landsat remote sensing

We are presently encountering many problems relating to the application of remote sensing techniques in agriculture in Japan using Landsat data. They include; 1) data gathering intervals, 2) spectral division and 3) resolution ability of MSS.

1 Data gathering intervals

Except for natural disasters such as flooding or fires, or damage caused by diseases and pests most natural phenomena relating to agricultural activities can be monitored through 18 and/or 16-day Landsat data gathering periods. The same conditions apply to grassland management. However, cloud cover percentages in Japan, especially in the cropping season

Table 3 Number of clear days in several cities of Japan

Name of cities	No of days with cloud cover below 15 %			
	January-March (90 days)	April-October (214 days)	November-December (61 days)	Year (365 days)
Sapporo	3	9	0	12
Sendai	7	8	6	21
Tokyo	19	15	13	47
Osaka	2	14	7	23
Fukuoka	7	10	3	20
Naha	0	4	1	5

From Annual Report of the Japan Meteorological Agency for 1981.

Table 4 Cloud cover rate in the Tokyo Scene of Landsat MSS received by the Earth Observation Center of Japan during 1981 to 1983

Year	No of scenes with cloud cover below 20%				Total MSS receipts
	January-March	April-October	November-December	Year	
1981	5	1	0	6	18
1982	0	0	1	1	11
1983	1	4	1	6	16

From National Space Development Agency of Japan for the Scene of Tokyo (pass/row, 116/35).

extending from April to October, are very high, as shown in Table 3. For example, in the Tokyo area, only 15 days out of 214 days of the cropping season are clear (cloud coverage of less than 15%) while 32 clear days are observed during the remainig 151 day-period which is not suitable for crop growth. Under the limitations of the present technology, it is very difficult to obtain satisfactory results from Landsat scenes when the cloud cover exceeds 20%. The actual cloud cover rate of the Tokyo scene (pass 116, row 35) computed from data collected from 1981 to 1983 (Table 4), shows that out of a total of 45 data receptions, for 13 of them, the cloud cover during the three-year period was below 20% with only 5 coinciding with the growing season. It is thus evident that the development of an all-weather sensor capable of penetrating the cloud cover such as the microwave sensor is essential in the agricultural areas of monsoon Asia to which Japan belongs.

2 Spectral division

Landsat MSS data provide us with a large amount of information on land resources. However, the spectral division of Landsat MSS (0.5-0.6, 0.6-0.7, 0.7-0.8 and 0.8-1.1 μm) is not always suitable for extraction of agricultural information. Therefore, the thematic mapper (TM) bands of Landsats 4 and 5, which will be soon in operation have been assessed for their capability to extract information on plant.

Bauer *et al.* (1978) compared the correlation coefficients of five different canopy variables between Landsat TM and MSS bands. A near-infrared band in TM, 0.76-0.90 μm, showed the highest correlation with soil cover and leaf area index, while the middle infrared band, 2.08-2.35 μm, showed the highest correlation of the six individual TM bands, with fresh biomass, dry biomass, and plant water content. These results illustrate the importance of making measurements in several regions of the spectrum, especially in the middle infrared wavelength region which is not covered by the Landsat MSS.

3 Resolution ability

As for the earth surface resolution, Landsat MSS affords a resolution of 80 m by 80 m, which is too coarse for application in agriculture in Japan. In 1985, it is anticipated that it will be possible to obtain TM data of a resolution of 40 m by 40 m, which may provide more precise information.

Many problems still remain to be solved. However, for the present time and near future, in order to manage and conserve agricultural resources and products, applications of remote sensing techniques appear to offer a definite potential.

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* Japanese with English summary.
** Japanese only. Titles are tentative translation from original Japanese titles by the author of this paper.

Discussion

Toutain, B. (GERDAT), **Comment:** Our Institute has a remote sensing division which has carried out monitoring work on the grass cover of the Sahelian region for several years. Next year we wish to prepare a program for the utilization of the European satellite SPOT to evaluate pasture resources in New Caledonia.

GENERAL DISCUSSION

Chairman: Cocks, P. S. (ICARDA*): Among the themes discussed in the past two days, the most important aspects dealt with the best way of using local resources, of increasing and improving the productivity of grasslands, the production of *Leucaena*, the development of tree crop and pasture systems, the ways in which international cooperation can contribute to the development of tropical and sub-tropical grasslands. Interdisciplinary methods of conducting research will be essential. Plant and animal scientists must work together with economists and anthropologists in improving grassland farming systems which will play a key role in this development. Indeed we must think in terms of livestock producing systems. Also efforts should be made to develop an appropriate technology since advanced techniques are not always suitable for the small farmers. It is important to demonstrate to the farmers that the application of a new system will be profitable to them.

We shall now consider the first topic which deals with the full utilization of the local resources. There are abundant resources in the tropics and particularly in the Asian region where the amount of precipitation is comparatively high. What is important is to define the amount, the quality and the methods of utilization, processing and preservation of these resources.

I would like to ask Dr. Nada to make a general comment on these aspects.

Nada, Y. (Japan): Before I went to the tropics, I thought that the processing of materials, in particular silage making would be difficult due to the high temperature and high rate of decomposition of the products. However I found that such procedure was comparatively easy. I assume that there must be significant differences in the composition of the microflora in the air or silage between tropical and temperate areas since rotting of silage was seldom observed there unlike in Japan. However, the decomposition of the materials is very rapid in the tropics, resulting in a loss of the nutritive value and energy. Studies on these aspects would be important.

Toutain, B. (GERDAT**): We have compared two types of silage, namely maize and sunflower and no differences were detected with regard to the techniques of processing. However, in feeding trials with two lots of weaners, the liveweight gain of the animals with sunflower silage was superior to that with maize silage.

Kitamura, Y. (Japan): We made silage in incorporating tropical legumes up to a proportion of 30% of the ration. No additives were used and the silage was of good quality. It might be possible to reach a proportion of 50% of legumes by using additives such as molasses.

Chairman: Cocks, P.S. (ICARDA): I would like to ask Mr. Chen to comment on the utilization of rice straw in Malaysia.

Chen, C.P. (Malaysia): Presently, work on straw treatment is being carried out on a large scale at MARDI***. Also in the Muda Irrigation Area, in the northern part of Malaysia, field experiments at the farmer's level have been conducted by treating straw with urea followed by direct feeding to the cattle. Good results were obtained but the main constraint is the motivation of the farmers. Attempts are being made at MARDI to conduct experiments on the treatment of straw with urea and ammonia on a large scale and on a long-term basis.

Mendoza, R.C. (The Philippines): The degree of utilization and incorporation of the by-products in the ration depends on the type of livestock. There are several methods

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* International Centre for Agricultural Research in the Dry Areas.

** Groupement d'Etudes et de Recherches pour le Developement de l'Agriculture Tropicale

*** Malaysian Agricultural Research and Development Institute to improve the digestibility of crop residues, with regard to the fiber content, ranging from plain wilting to chemical treatment with ammonia, urea and enzymes such as cellulase and urease.Pre-harvest factors must also be taken into account.It appears that the rate of application of nitrogen fertilizer affects the fibrosity index of straw. Crop variety is also related to the fibrosity index. In addition, cropping patterns should be systematized if a steady supply of high quality materials with a lower content of cellulose is to be obtained. Also the physical transformation of the fibrous structure of the residues could increase the digestibility.

Manidool, C. (Thailand): There are at least three ways of improving by-products: 1. By chemical treatment (urea, ammonia) for ensiling, 2. By fermentation using micro-organisms such as fungi. However in this case the cost of production is high and production must be on a large scale, 3. By using rice straw in conjunction with legume leaves (*Leucaena, Gliricidia, Erythrina*, etc.). This method is particularly suitable and successful for the small farmers.

Chairman: Cocks, P.S. (ICARDA): In Syria, there are varietal differences in straw quality related to the amount of leaves remaining after harvest. Grain yield is often positively correlated with straw quality and breeding work of grasses could be oriented toward this direction.

Could Dr. Jayawardana comment on the utilization of community and backyard land?

Jayawardana, A.B.P. (Sri Lanka): In Sri Lanka there are areas of land which have recently been demarcated by law for exclusive use as communal grazing grounds for farmers who do not own land. We plan to organize the farmers into cooperatives so as to have them manage these lands according to their needs.

Siregar, M.E. (Indonesia): In Indonesia sources of forage are found on roadsides, in rice bunds, on field boundaries and in forests in traditional farming. Improved species of legumes and grasses are introduced on roadsides and field boundaries, including tree legumes (such as *Leucaena, Gliricidia*, etc.) particularly for the farmers with small holdings who apply intensive cropping systems. Intercropping is practiced for increasing the production of forage crops, as in the case of legumes combined with corn in the upland fields. Seed multiplication schemes are also being implemented. In addition, agro-forestry is an other means of increasing forage production in the intensive cropping systems.

Chairman: Cocks, P.S. (ICARDA): Who covers the cost of development of improved forage along the roadsides?

Manidool, C. (Thailand): The government cooperates in providing the seeds of legumes used for the improvement of roadsides and oversowing of communal grazing lands.

Siregar, M.E. (Indonesia): The government (Departments of Agriculture, Forestry, Public Works, Internal Affairs) and USAID* subsidize the schemes aimed at increasing forage production and at preventing the erosion of watersheds. In addition, the farmers who are organized in cooperatives also bear part of the cost.

Abdullah Hj. B. (Brunei): In Brunei Darussalam, grazing of cattle and buffaloes along the roadsides is dangerous since the animals may be run over by cars. To prevent the losses associated with the accidents the government provides subsidies to enable the farmers to build barbed-wire fences. Communal grazing land is mostly restricted for use by buffaloes. Studies are in progress to improve the botanical composition of grasses and legumes (Para grass is particularly recommended in swampy areas) and to promote management practices such as rotational grazing. For cattle, intensive grazing could be promoted on communal grazing lands.

Chairman: Cocks, P.S. (ICARDA): It is difficult to transfer one form of management from

* US Agency for International Development

one country to another. For instance it may not be desirable to promote roadside grazing in Ethiopia due to the low fertility of the soil (phosphorus deficiency) although the botanical composition of the grasses and legumes is adequate.

We should proceed to the discussion of the second topic on the agenda, namely how to improve and increase the productivity of natural pastures in terms of animal production. Would Dr. Kitamura make any comment on this problem?

Kitamura, Y. Y. (Japan): The cultivars and species utilized are essentially adapted to the conditions peculiar to the respective regions. For instance, in Okinawa, *Stylosanthes* does not grow well in the northern part of the islands with alkaline soils whereas growth is satisfactory in the southern part of the highlands where soils are acid. Trials must be performed under the local conditions.

Siregar, M.E. (Indonesia): In Indonesia work on natural pastures has been carried out since 1978. In the dry areas of Sumba Island (speargrass is the dominant species) and South Sulawesi (alang-alang is the dominant species), improved legumes such as *Stylosanthes* and Siratro cultivar are being introduced in the natural grasslands. As a result, the carrying capacity increased from 1 head/ha to 8 head/ha. Research on breeding and selection is also underway. Collection of native species of legumes is being promoted in Sumatra and Sulawesi in collaboration with CIAT*. With regard to screening, collaborative work with CIAT and CSIRO** in relation to seed is also in progress. Selection is made for areas with high rainfall and low altitude, low rainfall and high altitude, low rainfall and low altitude and high rainfall and high altitude, respectively.

Jayawardana, A.B.P. (Sri Lanka): To improve natural grasslands pot and field trials are most important for the detection of deficiencies in micro-nutrients, in particular, in soil so as to bring about improvements with low inputs.

Mendoza, R.C. (The Philippines): Rainfall is a major climatic parameter in the tropics for the productivity of natural pastures which is likely to remain lower than that of improved pastures. In the Philippines, the management consists of low cost inputs and strategic fertilization. For grazing, stocking rate and stocking density should be distinguished in native pastures. For the breeding of species, productivity and persistence of the native pastures should be based on optimum diversity. A species should be selected on the basis of its competitiveness and associativity ability. The breeding objectives should involve species with well distributed growing points, both in terms of space and time. Species of grasses and legumes should be selected for good flower and seed persistence. Seed production is also possible in native pastures through strategic grazing.

Chairman: Cocks, P.S. (ICARDA): Could I ask Dr. Takahashi to comment on some aspects relating to the fertilization of pastures?

Takahashi, T. (Japan): The international cooperation between soil scientists and pasture agronomists is extremely important to identify deficiencies or excesses of nutrients, in particular micro-nutrients which are associated with special types of soils. Field experiments should be correlated with soil survey results.

Chairman: Cocks, P.S. (ICARDA): Could Dr. Maeno make some comments on the protein bank?

Maeno, N. (Japan): The introduction of legume-based improved pastures is very important to increase the productivity of grasslands. However, some inputs such as seed and fertilizers are necessary for the introduction of these improved methods. One of the alternatives is the introduction of legumes only as a protein bank. Part of the natural pastures could be completely replaced by legumes. This area will be used during critical stages of animal nutrition. This is an economic method to introduce improved

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* Centro Internacional de Agricultura Tropical

**Commonwealth Scientific and Industrial Research Organization pastures, which is advocated by the members of the Tropical Pasture Program of CIAT. Among the species of legumes, tropical Kudzu and *Desmodium ovalifolium* are particularly promising.

Chairman: Cocks, P.S. (ICARDA): Could Dr. Yoshiyama comment on seed production?

Yoshiyama, T.(Japan): In most of the tropical grasses, seed production and germination rate are low, even if the herbage production is high enough. Thus seed yield of grasses and legumes should be improved for the benefit of the farmers.

Chairman: Cocks, P.S. (ICARDA): We shall now move on to the topic of *Leucaena* production.

Mendoza, R.C. (The Philippines): *Leucaena* which originates from South America was thereafter naturalized in various tropical countries. Presently there are many ecotypes. Establishment is best achieved by direct seeding or cutting and the land preparation is important. The management of *Leucaena* will differ depending on the use, mainly for wood or leaf meal. To produce leaf meal, high density planting is required. Leaf yield is determined by the cutting height rather than by the cutting frequency. As regards the feeding quality, *Leucaena* is a good source of protein when leaves and stems are properly mixed (2/1 ratio for 20% protein). Intoxication of cattle by mimosine appears to depend on the composition of the rumen microflora. There are several ways of reducing the mimosine effects: 1. Soaking leaves in water enables to remove mimosine which is soluble in water, 2. Ferrous sulfate supplementation in the ration results in the decrease of the content of mimosine (a rate of 0.2 to 0.4% of ferrous sulfate makes it possible to double the proportion of leaf meal in the ration), 3. The increase of temperature leads to the decrease in the mimosine level. Also the content of mimosine depends on the area where *Leucaena* is grown. Soil factors and rainfall affect the mimosine content which increases with the amount of precipitation.

Siregar, M.E. (Indonesia): In Indonesia we use mostly the cultivars Peru and Cunningham and multilocational trials are conducted to identify the most suitable cultivars for a particular region. Establishment is by seed, optimum cutting height is 1 m and cutting intervals are 6 weeks, especially in areas with high rainfall. Feeding quality is good and a proportion of 40% of *Leucaena* leaves can be given to the cattle in the diet without experiencing any problem with mimosine.

Jayawardana, A.B.P. (Sri Lanka): In Sri Lanka *Leucaena* is found only in the lowland dry and wet areas. We are now evaluating the adaptation of *Leucaena diversifolia* and *L. shannoni* supplied to us by FAO* for the hill country with acid soils.

Chen, C.P. (Malaysia): In Malaysia the cultivars ML_1 and ML_2 give the highest yield. For establishment, mainly by direct seeding, liming is necessary (2ton/ha) and mulching in the early stages shortens the period of establishment. We also apply fertilizers, mainly P, calcium carbonate along with promoting nodulation. We do not encourage the farmers to establish *Leucaena* through cuttings or transplanting due to environmental conditions. Management is as follows: cutting height: 0.5 to 1 m, cutting frequency: 6 to 8 week intervals, liveweight gain: grazing without supplementation, in the case of beef production: 400 to 500 g/head/day, milk yield: 6 to 10 kg/head/day. We have not encountered any problem with mimosine since *Leucaena* accounts for 30% of the total intake due to the insufficient supply of the material.

Chairman: Cocks, P.S. (ICARDA): We shall now discuss some problems relating to the development of tree crop-pasture and forest-pasture systems.

Toutain, B. (GERDAT): I shall refer to the experience of researchers in Vanuatu who are promoting the grazing of cattle in coconut plantations. Presently cattle account for the second most important product of Vanuatu and excellent pastures in which Para grass is used are found under coconut trees. The problem is that emphasis is placed on the

* Food and Agriculture Organization

production of the crop only and less on animal production. As a result only a few experiments are carried out to improve pastures and little effort is made to evaluate the effect of changes in the spacing between trees to obtain better grazing land and increase animal production. It would be important to strike a balance between the improvement of pastures and the production of the crop.

Siregar, M.E. (Indonesia): In North Sulawesi, Bali cattle are grazing under coconuts and the production of both cattle and coconuts is excellent. We use *Brachiaria brizantha* and Puero and the pastures are being fertilized. Cattle are also grazing under rubber trees in South Sumatra and legumes such as *Stylosanthes* are being planted. Attempts of agro-forestry are being undertaken in Sumatra where animals are grazing in pastures under oil palms.

Manidool, C. (Thailand): I would like to comment on the development of tree crop-pasture or forest-pasture systems, particularly in the case of the combination of coconuts and pastures. Indeed three separate components have to be considered, namely the animals, the trees and the pasture plants. Particular care should be exercised in the management of the plant and soil nutrients because there may be a competition for these elements between trees and pasture species. Guinea grass is known to be a strong nutrient absorber from the soils unlike Cori grass which is now being recommended. Coconut palms require high levels of K and Mg while trace elements and P should be supplied to the cattle particularly in sandy soils where deficiencies in such elements are often recorded.

Chairman: Cocks, P.S. (ICARDA): We shall now move on to the general discussion of the last topic, namely the identification of areas where international cooperation could be promoted, including the exchange of genetic resources and information.

Maeno, N. (Japan): The exchange of information to enable the establishment of an "inventory of genetic resources" is essential for further development of animal husbandry in the tropics and subtropics.

Mochizuki, N. (Japan): The exchange of genetic resources is indeed important since they are the basis for the improvement and increase of the productivity of pasture plants through breeding and selection. A 5-year project for the exchange of germplasm between the USA and Japan was initiated and more than 2,000 accessions of grasses and legumes including new cultivars have been evaluated. Although the project was eventually completed, the exchange of materials is still in progress. A team of 2 scientists from the USA came to Japan to proceed to the exchange and evaluation of more than 700 accessions of *Zoysia* species and ecotypes collected in Japan, Korea and Taiwan. I agree with Dr. Maeno that the exchange of information for the establishment of an inventory of genetic resources should come first and be followed by the exchange and evaluation of important genetic resources of forage crops. In Japan, we have established an inventory of the genetic resources of forage crops and pasture plants.

Suzuki, S. (Japan): The National Institute of Agrobiological Resources is in charge of the coordination of activities relating to genetic resources. We also collaborate with various international agencies such as the IBPGR* to promote exchanges of germplasm and information on genetic resources. We plan to establish larger facilities for seed storage (including micro-organisms) and a data bank of genetic resources is being prepared. We also organize each year 3-month courses on genetic resources and plant breeding in cooperation with JICA** for young scientists.

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* International Board for Plant Genetic Resources
**Japan International Cooperation Agency

Toutain, B. (GERDAT): To facilitate the exchange of genetic resources, information on the phyto-sanitary regulations of the respective countries is essential.

Siregar, M.E. (Indonesia): I believe that the exchange of genetic resources of forage crops could be best achieved through the cooperation with IBPGR and UNDP/FAO since these organizations issue publications on these subjects.

Naito, T. (Japan): It appears that the tropical areas are not well suited to intensive production of livestock due to various constraints including climatic conditions, soil erosion, etc. Therefore the optimum utilization of natural grasslands requires careful ecological studies in relation to the succession of vegetation associated with grazing, burning and cutting as well as the adaptation mechanisms of species. Also studies on land utilization including the topography of the target area should be promoted. These studies should be undertaken on a long-range basis through the exchange of information among the nations.

Akiyama, T. (Japan): There are definite constraints in the application of remote stensing techniques in the tropical countries, which can be summarized as follows: 1. The cost is high and the facilities are often inadequate, 2. Landsat resolution ability at earth surface at present is as coarse as 80/80 m, 3. In the monsoon tropics, the cloud cover prevents the collection of good images. However this technique is very useful for the regional assessment of agricultural development since Landsat data enable to identify forest formation types, soil conditions and environmental problems such as flood and other natural disasters. For a more precise assessment of resources, remote sensing by airplane is most suitable, Finally the combination of remote sensing techniques with grassland ecosystems model, as proposed by Dr. Shiyomi, may be very useful for the long-term assessment of tropical grassland management.

Chairman: Cocks, P.S. (ICARDA): Could I ask Dr. Yoshiyama to make the final comments on the symposium?

Yoshiyama, T. (Japan): I feel that both the country reports and the special reports covering three main topics were most interesting. I do hope that the valuable information presented during the symposium will be most useful for the promotion of future research on grassland.

I should like to raise a few points:

1 In the establishment of artificial grasslands, the introduction of grasses and legumes adapted to the various regions is important to increase the productivity of the pastures, particularly in the semi-arid areas.

2 The treatment and preservation of forage to supply feed to cattle during the dry season must be considered.

3 It is important to select suitable grasses and to stabilize grasslands in taking account of the growth competition between grasses and trees in the humid tropics.

4 I was most interested by the methods proposed for the development of livestock feeding systems in tropical grasslands.

5 It is also important to select suitable cattle breeds for grazing, along with improving calf productivity, promoting the growth of cattle and devising methods for the prevention of cattle diseases, etc.

6 I would like to emphasize, finally, that it is very difficult to improve livestock production in the tropics and subtropics unless research on pasture and forage crops is enhanced. To achieve this objective, the exchange of researchers and information among the countries is of paramount importance.

Chairman: Cocks, S.P. (ICARDA): I would like to conclude in mentioning that the conference shows that the researchers involved in grassland improvement in the tropical and subtropical regions tend to form a very active and dynamic group within the agricultural community. Also when I visited some of the countries of Southeast Asia, I was impressed by the efforts made by the Japanese government in assisting the researchers engaged in such activities.