A STUDY ON THE RELATIONSHIPS BETWEEN HUMAN ACTIVITIES AND BIOSPHERE USING SATELLITE DATA

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A B S T R A C T

This study deals with the role of satellite remote sensing for monitoring global environment, and the analysis of world vegetation, potential arable land area, potential food production and the places of the CO2 fixation on land and sea. NOAA Global Vegetation Index (GVI) were used for world vegetation map, and potential arable land area. And chlorophyll distribution produced from NIMBUS7/CZCS data was used for estimation of the total capacity of CO2 fixation in the sea area.

Based on the results from above, the supportability of population with respect to the crop production and total capacity of CO2 fixation were estimated.

It is the first trial to analyze the relationships between global environment and two indices of human activity, supportable population and the ability of CO2 fixation as the result of human activity.

KEY WORDS: Global Environmental Problem, Vegetation, Chlorophyll density, CO2 fixation, Primary Productivity

1. INTRODUCTION

World population has doubled in the past 40 years and is now 5.3 billion.It is estimated to double again in the next 50 years, reaching 10 billion.

On the other hand, the annual extension rate of arable land is below 1%, a rate of growth much lower than that of the population growth. And the yield of cereals had been growing steadily from 1970 to 1985. Since the areas harvested have been constant for this period, the increase in the yield must be attributed to growing productivity. The growth rate of world population is lower than that of world GDP.

Consequently, the impact on the global environment by human economic activities is much stronger than the population increase.

This study will thus focus on the relation between vegetation diversity and human activity, such as food consumption. Additionally,since CO2 can be assumed to be the incarnation of human activity, defining the fixation parts on land and in the sea is necessary for discussing about the global incoming and outgoing of CO2. As a result the capacity of CO2 fixation on land and in the sea is estimated using NOAA GVI and NIMBUS7/CZCS respectively.

2. PREDICTION OF SUPPORTABLE POPULATION ON THE EARTH

2.1 Data

The data used in this study is largely diverted into two kinds, such as natural information to make Vegetation Map and social information to analyze the relationships between vegetation and human activities.

These data which has been used in this study are as follows.

2.1.1 Natural Information

1) Weekly GVI data from January 1983 to December 1987. The original GVI data which indicates the weekly density and vigor of the green vegetation is the resampling data of Normalized Vegetation Index (NVI) for the whole earth (except part more than 75 degrees North latitude and 55 degrees South latitude). The NVI is determined by following equation:

$$NVI = (Ch2 - Ch1)/(Ch2 + Ch1) \quad ....1)$$

where Ch1 and Ch2 are the data from cannel 1(visible red band) and 2(near infrared band) of the AVHRR. In order to eliminate the influence of cloud cover, the GVI is defined as a maximum value for four weeks of NVI.

2) Monthly averaged value of temperature, rainfall and moisture from January 1983 to December 1987, provided the Japanese Meteological Agency, detected at 2344 observation stations all over the world.

3) Bathymetric data.

2.1.2 Social Information

1) Population data quoted from World Population Prospects(U.N.,1988).

2) Agricultural Productivity data quoted from Production Year Book (FAO,1987).

3) Food consumption data quoted from Food Balance Sheet 1971-81 AVERAGE (FAO,1985).

2.2 Method

2.2.1 Concept Supportable population is estimated, according to the flowchart shown in Fig.1. The basic concept used in this paper is as follows.

1) The grassland on the world vegetation map with the conditions being an altitude of no more than 1000m and a latitude of no more than 60° is defined as potential arable land. Deforestation is not considered.

2) The following crops are selected as the principal foods in this study: wheat, paddy rice, barley, maize, sorghum, potatoes, sweetpotatoes, cassava, soybeans, millet, rye and oat. These 12 crops registered the largest production levels in 1988. Livestock and fishery products are not considered.

3) Crop production per hector is assumed to keep the highest level at present, and in potential arable land areas, except the present harvested areas, it is assumed to decline in a linear fashion, as shown in the Fig.2.

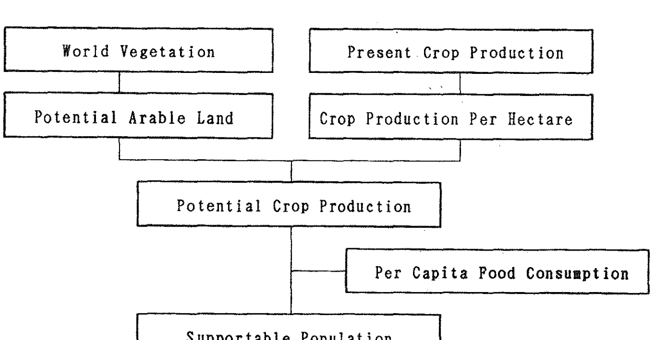

Fig.1 Calculation Flowchart of Supportable Population

4) Per capita food consumption is calculated by each country with a formula using net consumption divided by population. And in the calculation of the supportable population, crop imports and exports are not considered.

5) The base year is 1980.

In this paper, the method for vegetation classification is based on the result of the authors' study(Honda and Murai,1989). The the world vegetation map is shown in Fig.3.

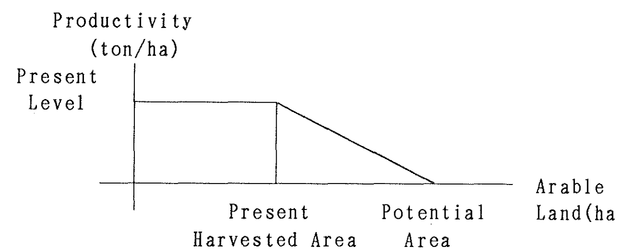

Fig.2 Assumed Productivity

2.3 Result

2.3.1 Potential Arable Land The potential arable land masses are extracted from the world's vegetation map, shown Fig.4. And Table 1 shows the regional distribution of the potential arable land. There exist some 21 million km2 potential arable lands, of which 40% is located in Asia and Europa.

2.3.2 Supportable Population on The Earth

The following three cases are set for the calculation of world's supportable population.

- Case1: Per capita food consumption is assumed to be the same level as the present in the respective countries.
- Case2: Per capita food consumption is assumed to be the world's average level in 1980 for all countries.
- Case3: Per capita food consumption is assumed to be the same level as that of the USA in 1980 for all countries.

The supportable populations for three cases are shown in Table 2, and the supportable population by the region is shown in Fig.5, respectively.

In Case1, Africa has a relatively high value in comparison with the present level, because of its lower per capita food consumption.

In Case2 and 3, North America has a very high supportable population above the present level.

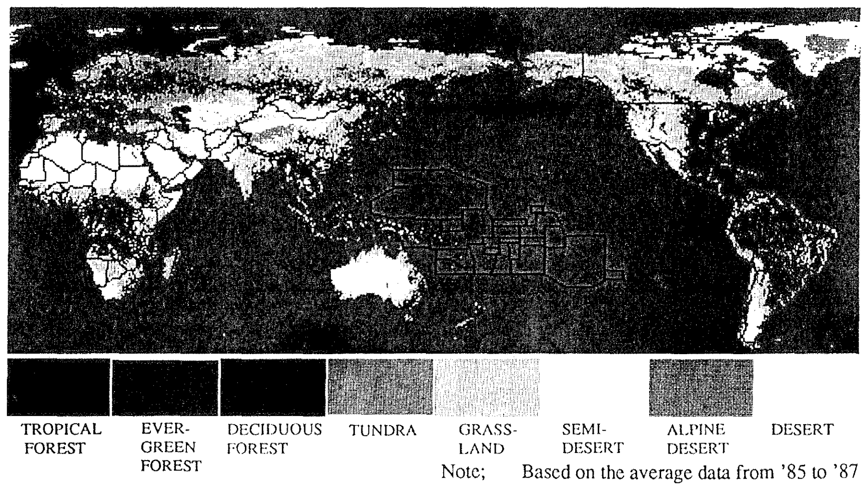

Fig.3 World Vegetation Map

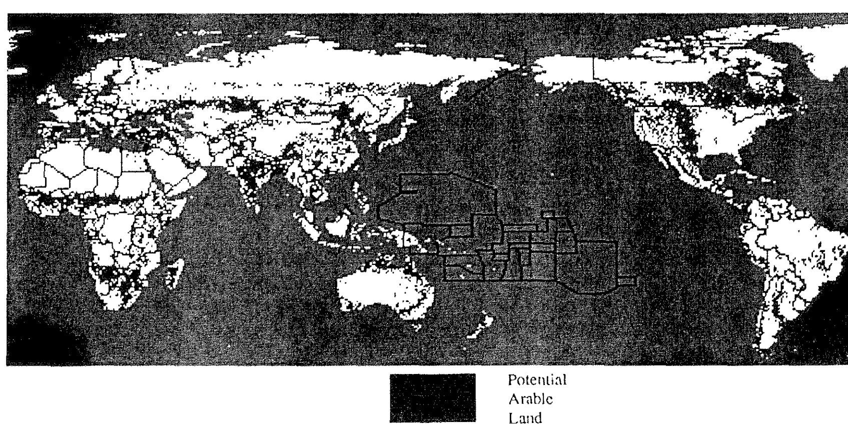

Fig.4 Potential Arable Land

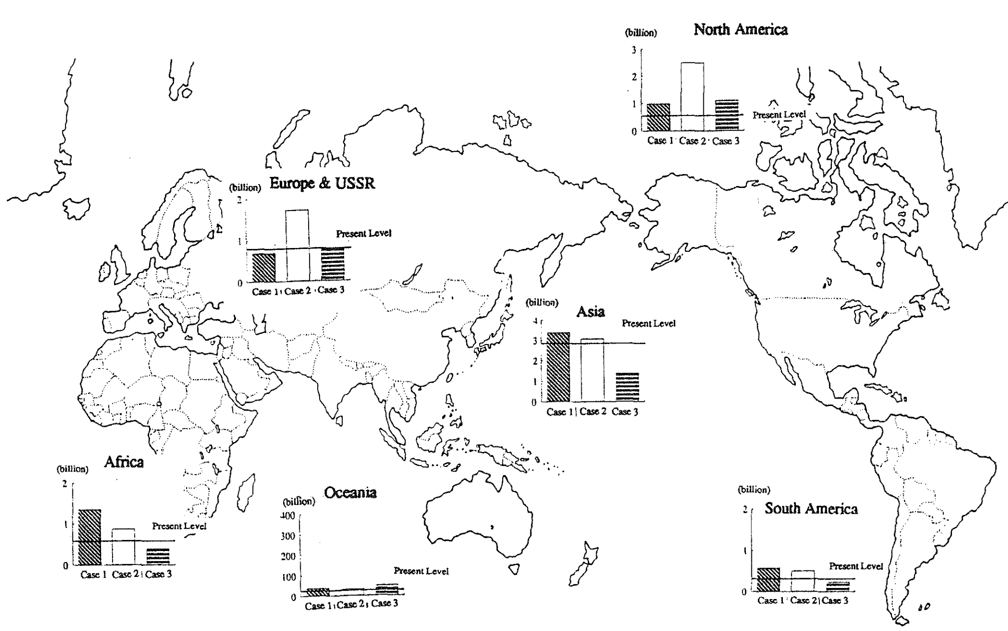

Fig.5 Regional Supportable Population

Table 1 Distribution of Potential Arable Land

($10^3 km^2$)

	Africa	North America	South America	Asia & Europe	Oceania	World
Potential Arable Land	4,681	4,604	1,446	8,832	1,812	21,375
Arable Land (1987)	1,668	2,671	1,163	7,752	478	13,732

Source; Arable Land; FAO "Production Yearbook 1988"

Table 2 Supportable Population (100million)

Case	Population (A)(1991)	Supportable Population(B)	B/A x 100(%)
Case 1	53	73	138
Case 2		90	170
Case 3		40	75

3. ESTIMATION OF TOTAL CAPACITY OF CO2 FIXATION BY VEGETATION

3.1 Data

The data used in this study is as follows;

1) World Vegetation Map (Honda and Murai, 1989)
2) NIMBUS7/CZCS-level3(monthly averaged chlorophyll density),provided from NASA(Feldman et al,1989). Chlorophyll density is estimated by Gordon's algorithm(Gordon and Morel, 1983).

3.2 Method

The calculation process of total capacity of CO2 fixation is shown in Fig. 6.

3.2.1 Capacity of CO2 fixation by vegetation on land The litter on land surface and in the soil can fix CO2,but the amount of that capacity can't be estimated because the data is lacked,so the capacity of CO2 fixation vegetation on land is estimated by net primary productivity and the CO2 discharge as the result of deforestation is not considered in this study. The parameter linking vegetation to net primary productivity is whittaker's, it is shown Table 3. The capacity of CO2 fixation on land is estimated by using the parameters of net primary productivity from Table 3 par each vegetation defined in the World Vegetation Map shown in Fig. 3.

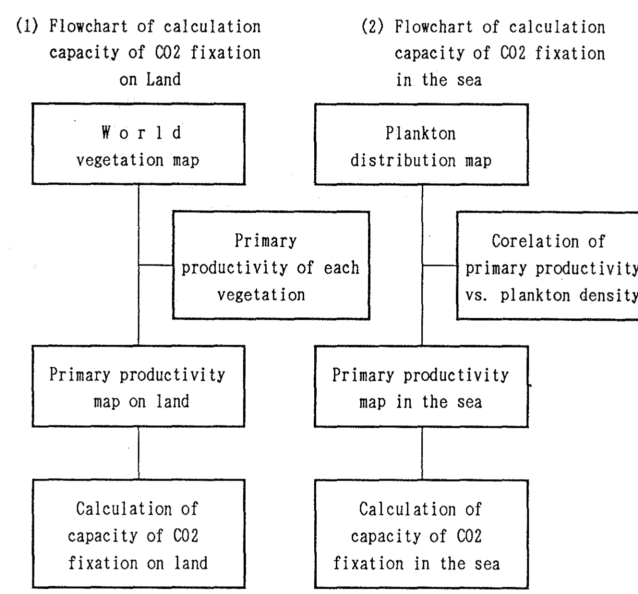

Fig.6 Flowchart of estimation of capacity of CO2 fixation

After the distribution of net primary productivity is yield, summing up the primary productivity par each mesh,the capacity of CO2 fixation by vegetation is estimated.

3.2.2 Capacity of CO2 fixation in the sea The capacity of CO2 fixation by vegetation on the sea is estimated by net primary productivity of plankton. The process to estimate the distribution of plankton is shown Fig. 7.

Table 3 Primary Productivity each Vegetation

Vegetation	Net Primaty Productivity Velocity ($gDW/m^2/year$) *
tropical forests	2200
evergreen forests	1300
deciduous forests	1200
tundra	140
green land	900
semi-desert	90
desert	90

* Dry-matter:Carbon content can be estimated as 45% of the dry matter

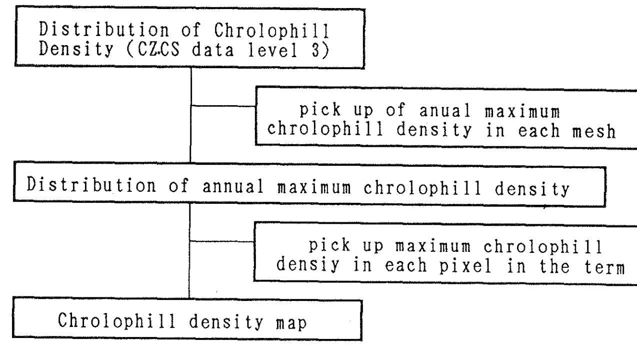

Fig.7 Flowchart to produce plankton map

The Chlorophyll distribution from Nimbus7/CZCS by Gordon's algorithm (see Fig. 8) is not effective in the region where aerosol density is high such as the region near Japan. But the value is relatively effective in the small blocks such as each sea region.

To estimate the primary productivity from the chlorophyll density, the correlation between chlorophyll density and primary productivity. But there is only one correlation made by Epply et al (1985) in near south and north America continent. It is as follows;

$$\log(\pi) = 3 + 0.5\log(Ck) \quad \ldots\ldots\ldots\ldots\ldots \; 2)$$

where π:primary productivity (mgCm-2d-1) and Ck:chlorophyll density(mgm-3).

In this study, firstly, Epply's correlation between density and net primary productivity is corrected by the observational data of primary productivity by Ryther (1963) and Koblents-Mishke et al (1970). Table 4 shows the corrected correlation in this study. Secondly, Using the new correlation, the primary productivity in each mesh is yield, and after summing up the capacity of CO2 fixation on the sea is yield.

Table 4 Correlation primary productivity(π:mgCm-2d-1) vs. chlorophyll density(Ck:mgm-3) in each sea area

Sea Area	Boundary of Sea Area	Net Primary Productivity *	Corelation
Tropical Sea Area	S20 -N30	0.05 - 0.15	$\log(\pi)=2.287+0.5\log(C_k)$
Subtropical Sea Area	S30 -S20	0.1 - 0.2	$\log(\pi)=2.580+0.5\log(C_k)$
	N30 -N20		$\log(\pi)=2.343+0.5\log(C_k)$
Temperate Sea Area	S50 -S30	0.33	$\log(\pi)=2.543+0.5\log(C_k)$
	N40 -N30		$\log(\pi)=2.406+0.5\log(C_k)$
Subfrigid Sea Area	N60 -N40	0.50 **	$\log(\pi)=1.685+0.5\log(C_k)$
North Sea	—	0.1 - 1.0	$\log(\pi)=2.516+0.5\log(C_k)$
North Atlantic Ocean	—	0.1 - 2.4	$\log(\pi)=3.142+0.5\log(C_k)$
North Pole Ocean	N60 -	0.01	$\log(\pi)=0.625+0.5\log(C_k)$
Antarctic Ocean	- S50	0.01 - 0.15	$\log(\pi)=2.171+0.5\log(C_k)$

* Net Primary Productivity in each sea area by Ryther(1963)
**Net Primary Productivity by Koblentz-Mishke(1970)

3.3 Result

The capacity of CO_2 fixation on land is 48.3 GtC/year(Gt:10^9t), in this study. Table 4 shows the result of comparison with the result from observational data.

The capacity of CO_2 fixation on the sea is 31.1 GtC/year.

Table 5 shows the result of comparison with the result from observational data.

Through the process above the primary productivity on land and in the sea is calculated.Fig. 9 shows the distribution of the primary productivity.

4.CONCLUSIONS

The following conclusions were obtained.

(1) Using the potential arable land selected from the world vegetation map, the supportable population was calculated. So it make possible to consider the relationships between the regional food balance and the human activities, and shows the limit of the earth to be recognized.

(2) Using world vegetation map and chlorophyll density map by Nimbus7/CZCS, capacity of CO_2 fixation by vegetation was estimated.

The father research will pay attention to the classification of the potential arable land and checking the distribution primary productivity locally by truth data.

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Table 5 Comparison the capacity of CO_2 fixation in this study with the observational data on land. (Unit : 10^9tC/year)

	Whittaker &Linkes	Box	Lieth	Whittaker	This study
NPP	49.5	47.7～56.6	55.3	52	48.3

*:Net Primary Productvity
NOTE;Observational data source is Box (1975)

Table 6 Comparison the capacity of CO_2 fixation in this study with the observational data in the sea.

	Ryther	Koblentz-Mishke	Box	Whittaker	this study
NPP *	20.0	23.0	19.9	25.0	31.1

*:Net Primary Productvity
NOTE;Observational data source is Box (1975)

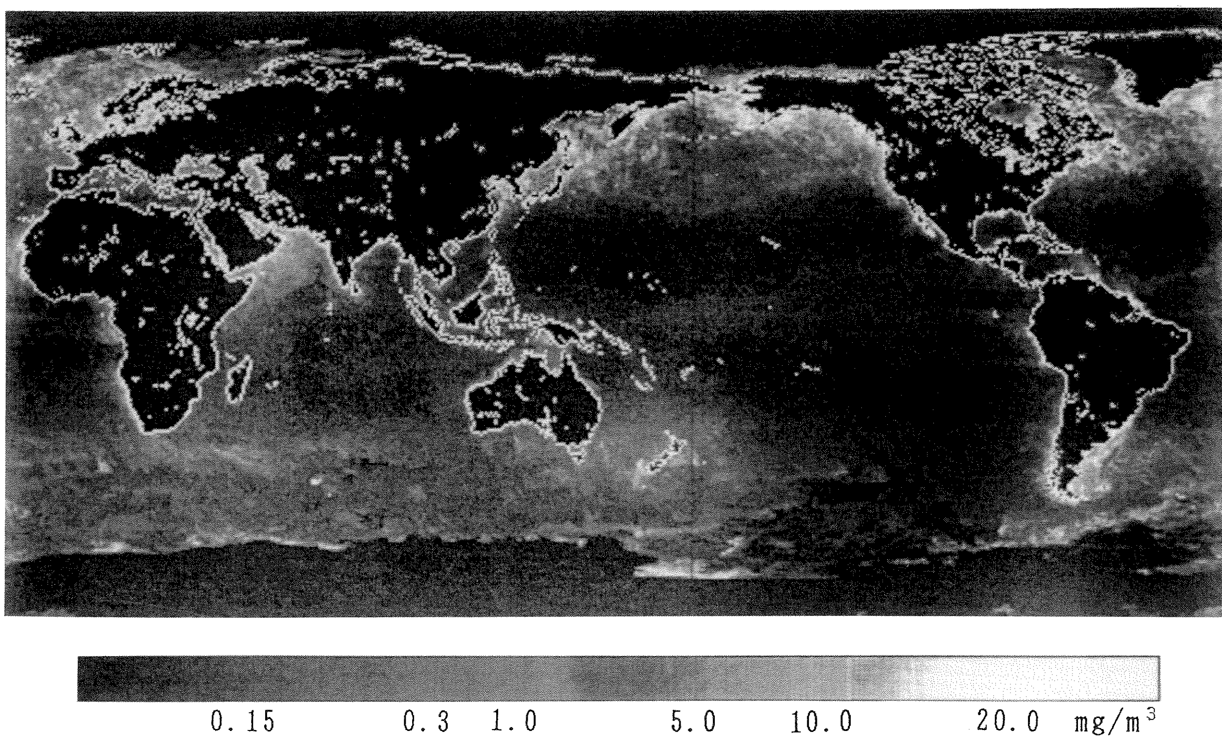

Fig.8 Chlorophyll distribution by Gordon's algorithm

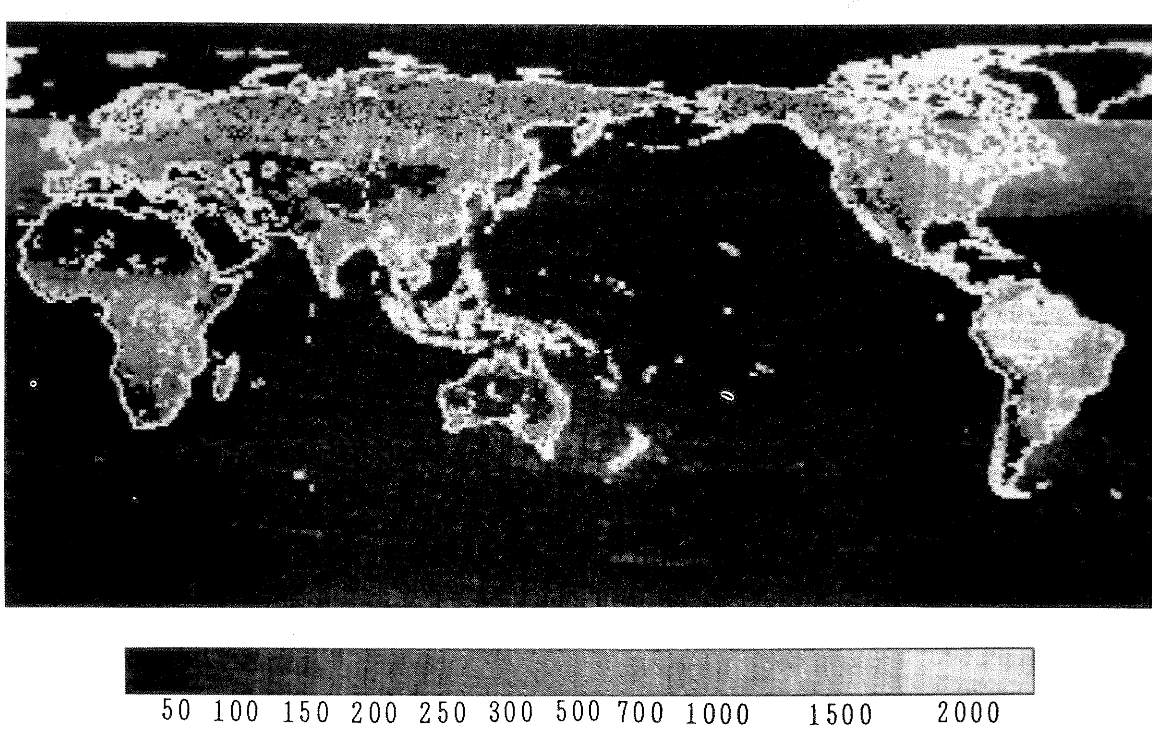

Fig.9 Primary productivity distribution on the earth