テレサインジャパン (2004) http://www.telesign.co.jp/new_map1000000.htm
Townshend, J.R.G. (1992) Land cover: International Journal of Remote Sensing, 13, 1319-1328.

研究課題　中国･インドの穀物生産量監視のための光合成型穀物指標の開発
課題番号　A2003-3-3（P2003-20）
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概要：
中国・インドの巨大な人口増問題と新たな水資源制約時代を背景に，現代における穀物需給の体制上の問題点と水資源不足の視点から，穀物生産量について新たな光合成型のモニタリング法が必要である。人口の巨大な両国における水制約の条件下では，従来からの有効積算気温や植生現存量ばかりでなく，日射と作物の水ストレスをも考慮した穀物生産指標を新たに開発することが重要となる。本研究は，世界気象データと衛星による植生指標を用い，日射・有効気温・植生現存量・気孔開度を考慮した光合成型の穀物生産指標をモデル化し，水資源不足時代における穀物生産量を早期に監視する方法を提案した。小麦・米・トウモロコシ等の穀物生産量の中で水稲を最も重視した。水稲は食糧問題の中で単位面積当たりの収穫量が小麦より高いことから人口扶養力が大きい。また，水資源を最も多く必要とし，水配分の視点から重要な作物となっているからである。

## 1. Introduction

Given the atmospheric phenomenon of global warming, shortage of fresh water resources is now an obvious environmental restriction on the world' s capacity to support life. Unusual reductions in the discharge in the lower reaches of irrigation rivers are being observed, and a continuing fall in the groundwater level as a result of water usage. Such well-known organizations as the World Bank, the Worldwatch Institute (Sandra Postel, 1999) and World Water Council (2003) have warned about the present unsustainable use of water resources for irrigation in China, India, and the U.S., which have significant influence on the total quantity of grain production.

This work aims to develop a predictive method of monitoring the grain quantity in production that would be useful in the present era of increasing world population that needs both food and water. Knowledge of an impending bad harvest in China or India would assist in the planning of both Japanese internal affairs and foreign policy, reducing the economic and social strains caused by the consequent leap in grain prices and improving the security of the food supply; Japan produces only about 40% of its own grain. The author believes that a specific organization should be established to monitor grain production in the context of the social circumstances and security of the food supply in areas of Asia.

## 2. Method for monitoring crop production

Many conventional crop studies have correlated the grain quantity in production with the growth index of Growing Degree Day GDD, or with water stress indices such as stress degree day.

$$GDD = \frac{T_{\max} - T_{\min}}{2} - T_b \quad (1)$$

where, $T_{max}$ is the maximum daily air temperature, $T_{min}$ is the minimum daily air temperature, and $T_b$ is a threshold temperature for the crop, below which physical activity is inhibited and equal to 10℃.

Rasmussen (1998) gave the net primary production NPP according to the following formula:

$$NPP = \varepsilon \int_0^t (aNDVI + b) \cdot PAR \cdot dt \quad (2)$$

where ε is the efficiency coefficient, t is the time, a and b are regression coefficients, and PAR is the photosynthetically active radiation.

The present research seeks to develop a photosynthesis-type of monitoring method by measuring the water stress so as to improve the formula (2) presented by Rasmussen. The final form of the photosynthesis rate is defined in formula (3), which takes into consideration the solar radiation, air temperature, stomatal opening, and vegetation biomass.

$$PSN = \frac{a \cdot APAR}{b + APAR} \cdot f_{Syn}(T_c) \cdot \beta_s \cdot eLAI \quad (3)$$

where, PSN is the photosynthesis velocity, APAR is the absorbed photosynthetically active radiation, $\beta_s$ is the stomatal opening, a and b are Michaelis -Menten constants, $T_c$ is the canopy temperature, eLAI is the effective leaf area index, and $f_{ster}$ is the sterility response function of air temperature.

The integrated photosynthesis type of crop production index CPI is defined by the following formula concerning the period from seeding $t_s$ to harvest $t_h$.

$$CPI = \int_{t_s}^{t_h} PSN \cdot F_{Ster}(T_c) \cdot dt \quad (4)$$

where $F_{ster}$ is the response function of temperature sterility effects on crop production.

Many researchers have presented crop simulation models that involve growth of crops and incorporate remote sensing data from previous years. However, it is desirable to express the mechanism of growth and filling more simply than in these models, which are complex and contain many empirical constants (Monteith 1996, Sinclair and Seligman 1996). By measuring growth of crop vegetation using remote sensing instead of simulation, the present paper estimates the photosynthesis rate by treating the growth of crop as a known variable.

## 3. Results by growing indices and crop production index

Fig.1 shows the distribution of the vegetation index NDVI in Asia using a data set derived from NOAA AVHRR by Tateishi (2001). Fig.2 presents the photosynthesis-based crop production index CPI taking into consideration the vegetation index NDVI as vegetation biomass as well as solar radiation and effective air temperature GDD. The values of the Crop Situation index at Kuki site in Saitama prefecture are included in the figure. The CPI index clearly shows the poor harvest due to low temperatures in 1993, and that due to lack of sunshine in 1998,and captures also the quantitative difference between the good harvest in

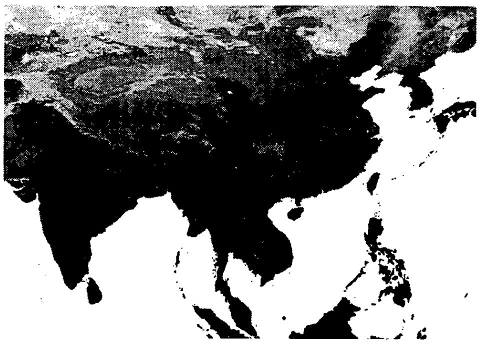

Fig.1. Distribution of NDVI in Asia.

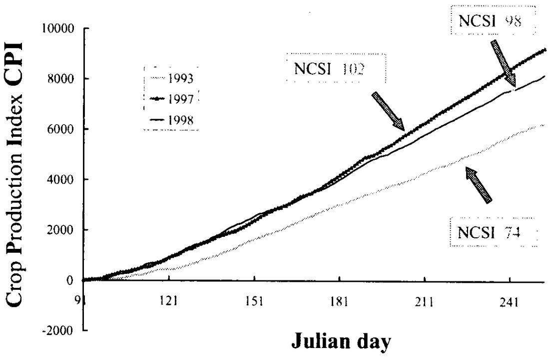


Fig.2. Daily variation of crop production index CPI at the Kuki site in Japan with values of the crop situation index.

1997 and these poor harvests. The discernment ability is much greater than the growing indices GDD and iNDVI. The photosynthesis-based crop production index CPI turns out to be a good index for monitoring. The author (Kaneko, 2003b) is also proposing a CPI that accounts for sterility below air temperatures of 18.5 centigrade and injury above 40 degrees (Matsui et al. 1997).

Monitoring of the demand for crop production requires new indices for water stress defined by spectral reflectance of leaves using remote sensing. A growth experiment of paddy rice in a temperature gradient chamber (TGC) controlled greenhouse was conducted at an experimental farm at Matsue in Shimane prefecture, in which infrared and visible spectrum data were obtained using a spectral reflectance radiometer. The water stress experiment aims to define water stress indices from the reflectance spectrum of short wavelength infrared and thermal infrared rays, with simultaneous measurement of the spectrum from the water surface and soil. At present, the CPI index is evaluated by setting the stomatal opening to 1 on the assumption that there is no water stress at the validation sites.

## 4. Conclusions

The model proposes to use world weather data in the monitoring model, specifically daily weather data for China and India. Without simulating the growth of crops, remotely sensed data can give the vegetation biomass of the crops in both countries using satellite data. Conventional predictive monitoring based on the growing index GDD derived from the effective air temperature was inaccurate. The author proposes a photosynthesis-based crop production index CPI taking into consideration such factors as solar radiation, air temperature, vegetation biomass, and stomatal opening using satellite data and world weather data. The present CPI index proved more accurate than the conventional cumulative GDD and the integrated NDVI as a crop production index for early monitoring of paddy rice. Organization of crop surveillance using accurate quantitative models based on daily data should be established as routine in view of the consequences for Japan of problems with crop growth, threatening our food security. Strategies for crisis management should be available in advance. Technical collaboration and information supply for early warning by the monitoring method proposed in this paper would be useful in guiding agricultural policies of Asian circumference countries.

References
Kaneko D (2002). Estimation of global solar radiation using world weather data for early monitoring of crop production by satellites, Proceedings of 6th symposium on water resources, Tokyo, 677-682. (In Japanese with English abstract).
Kaneko D, and Onishi M. (2003). Proposal of early monitoring method for crop production in China and India in the recent era of water resources restriction Environmental Systems Research, Japan Society of Civil Engineering, 31, 235-244. (In Japanese with English abstract).
Kaneko D, Onishi M. (2003b). Modeling on indices for monitoring crop production using meteorological data and Vegetation Index NDVI, Japanese Journal of Crop Science, 72(Extra issue 2), 92-93. (In Japanese)
Matsui T, Namuco OS, Ziska LH and Horie T, (1997). Effects of high temperature and $CO_2$ concentration on spikelet sterility in indica rice, Field Crops Research, 51, 213-219.
Monteith J L, (1996). The quest for balance in crop modeling, Agronomy Journal, 88, 695-697.
Rasmussen MS, (1998). Developing simple, operational, consistent NDVI-vegetation models by applying environmental and climatic information: Part II. Crop yield assessment, International Journal of Remote Sensing, 19(1), 119-137.
Tateishi R (2001). Twenty-year global 4-minute AVHRR NDVI dataset, CEReS, Chiba University.

研究課題　アジア地域における地球観測衛星画像と地理情報の相互運用システムの構築と運用について

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概要：

本共同研究では，地球観測衛星画像等の地理情報をインターネット上で相互利用するための試作システムを構築した。地理情報システム分野で検討が進んでいる Web GIS の標準技術を適用した WMS（Web Map Server）を CEReS に導入し，アジア地域における衛星画像（アジア土地被覆図）を配信するシステムを構築した。

標準技術を用いることで，分散システムの相互接続性が確保される。今後，試作システムを活用し，CEReS や宇宙航空研究開発機構（JAXA）等の機関が有する衛星データや地理情報データなどの地域環境情報データベースを融合的に利用するシステムへと発展させることが期待される。

＜成果＞

1. 研究の目的

千葉大学の CEReS と宇宙航空研究開発機構（JAXA）では，地球観測衛星データや，地理情報データなどの地域の環境把握に有用なデータを保有している。これらのデータを地域環境情報データベースとして相互利用するために，地理情報交換のための標準技術を用いて，ネットワーク分散型のデータベースの相互利用システムを構築する。