H-3.4 Digital Database for Diagnostic Analysis of Environment in Northern and Northeastern Part of China

Contact Person Kuninori OTSUBO
Vice Division Director
National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki 305-0053, JAPAN
Tel: +81-298-50-2417 Fax:+81-298-50-2576
E-mail: kuninori@nies.go.jp

Total Budget for FY 1998-FY2000: 6,210,000Yen (FY2000: 2,070,000Yen)

Abstract Northern and northeastern China is the largest base of crop production in China. It is very important to keep and increase the land productivity in this area for food supply and sustainable development of China in the21st century. In order to evaluate the potential productivities and possible increase of crop production, we, at first, developed a set of digital maps including the base maps, socioeconomic maps, meteorological maps, soil maps, and land use/cover maps at a scale of 1:1,000,000 (or a ground resolution of about 1km). As a result, a set of maps have been produced, which include crop potential productivities under different limiting factors, and the possible increase of production for each crop by improving those limiting factors

Key words Digital map set, Potential land productivity, Northern and Northeasten China, Land use

1. Introduction

Northern and Northeastern parts of China are ones of the largest areas for grain production in China. To keep or increase the land productivity in this area is very important for food supply and sustainable development of China in the 21st century. In order to estimate the land productivity, we established and compiled a series of maps, including both geophysical and socioeconomic components, using Arc/View GIS. A regional model for estimation of potential land productivity has been also developed.

2. Research Objectives

This work concerns the natural and socioeconomic factors related to crop production and sustainable land use in northern and northeastern China The research objectives are to produce 1-km grid scale digital maps of those factors and to develop a geographic information system for estimating the land productivities (LPGIS) in this area.

3. Research Method

The crop potential productivity was defined as the Photosynthetic Potential Productivity (P_Q), Thermal Potential Productivity (P_T), Climatic Potential Productivity (P_W) and Land Potential Productivity (P_L) in order. Here, P_Q refers to the biomass (dry matter) produced by high photosynthetic plants under the hypothesis that all environmental factors are most suitable for the growth of plants except for the constriction of light. P_T is mainly constricted by two factors, light and temperature. P_W is constricted by water deficit condition as well as light and thermal conditions. Finally, P_L is estimated through revising P_W by an effective coefficient of soil *f(L)*, which describes the status of land quality being related to soil properties and land degradation condition. These concepts can be theoretically expressed as:

$$P_L = \Sigma Q_m\, f(Q) \cdot f(T) \cdot f(W) \cdot f(L) = P_Q \cdot f(T) \cdot f(W) \cdot f(L) = P_T \cdot f(W) \cdot f(L) = P_W \cdot f(L) \qquad (1)$$

Here, Q_m is the solar radiation of each month during growing period; *f(Q)* is an effective coefficient of photosynthesis; *f(T)* is an effective coefficient of temperature; *f(W)* is an effective coefficient of moisture; *f(L)* is an effective coefficient of soil.

Firstly, *f(Q)* can be estimated according to Yu and Zhao (1982)[1)] as follows:

$$f(Q) = \Omega \cdot \varepsilon \cdot \varphi \cdot (1-\alpha) \cdot (1-\beta) \cdot (1-\gamma) \cdot (1-\rho) \cdot (1-\varpi) \cdot (1+8\%) \cdot s \cdot H^{-1} \qquad (2)$$

where, Ω is ability to fix CO_2 by plant; ε is the ratio of visible radiation to the total radiation; φ is the light quantum efficiency, α is the albedo; β is the ratio of radiation arriving to ground surface through leaves of vegetation to the total radiation; ρ is the absorptivity of non-photosynthetic organs; γ is the light saturated degree; ϖ is the ratio of respiration, s is the economic coefficient, and H is the energy required for creating 1g dry matter (10^6J/kg). All the parameters in formula (2) are varied along with crop types[1)].

Secondly, *f(T)* also varies depending on plants, and is a function of temperature and growing period as shown by formula (3) (Gao, 1995)[2)]

$$f(T) = f_t(T) \cdot f_t(N) \qquad (3)$$

in which $f_t(T) = [(T - T_1)(T_2 - T)^a]/[(T_0 - T_1)(T_2 - T_0)^a]$

$a = (T_2 - T_0)(T_0 - T_1)$

$f_t(N) = 1 + (N - N_0)/(1.7N_0)$.

T is temperature in each growing period; T_0 is the most suitable temperature; T_1 is the lower limited temperature; T_2 is the upper limited temperature[1)]; N is the effective growing period (days), and N_0 is the number of days during May to September.

Thirdly, $f(W)$ was determined by the ratio of actual evapotranspiration (ET_a) and potential evapotranspiration (ET_0), which describes water deficit status of crops and defined as water deficit index (*WDI*) (Wang *et.al.*, 1999)[3)]. K_y is crop index.

$$f(W) = K_y \cdot ET_a / ET_o = K_y \cdot (1 - WDI) \qquad (4)$$

The effective coefficient of soil, *f(L)* describe the land quality and is related to soil texture, soil nutrition, land degradation and so on. Simply, it can be estimated according to formula (5).

$$f(L) = a_1F_1 + a_2F_2 + a_3F_3. \qquad (5)$$

Here F_1, F_2, F_3 refer to proportions of the arable land at first, second and third classes, and a_1, a_2, a_3 are empirical coefficientsat 1.0, 0.8 and 0.6, respectively (Tang, 1997)[4)].

4. Results and Discussion

We have developed 1-km grid maps of potential productivities for main crops under different limiting factorsand possible increases of crop production due to improvement of limiting factors. All these maps were overlaid with administrative boundary of county or provincial level and a statistic database of potential productivities and possible increase of production for each crop have also been produced at both county and provincial level.

(1) Potential productivities

We found that either P_Q or P_T did not show much difference across areas in our study area, which might reflect homogeneous temperature and solar radiation conditions in the region. In contrast, P_W and P_L showed a wide range of spatial variation, which reflects the heterogeneity of water and soil conditions. P_Q for each crop increases gradually from northeast to southwest, which is coordinating with the distribution of solar radiation, and P_T for each crop decreases gradually from south to north according to the spatial change of temperature. P_W and P_L decrease generally from southeast to northwest, but both have a large range of spatial differences depending on the complex impat of heat, water and soil conditions. Comparing among crops, we found that the potential productivities of corn and rice are much bigger than those of sorghum and bean, which isbecause the growing periods of the latter are shorter than those of the former, and the effectiveness of radiation transfer into organic matter is less in the latter then the former.

(2) Possible increase of crop production

As mentioned above, our model can estimate possible increase of each crop production under different measures, such as the improvement of heat, water, soil conditions and agricultural techniques. We just show maps of possible increase of grain production in Fig.-1. Here the grain production refers to the average values of the production of corn, rice, wheat, bean and sorghum and Y96 means average yield of four crops.

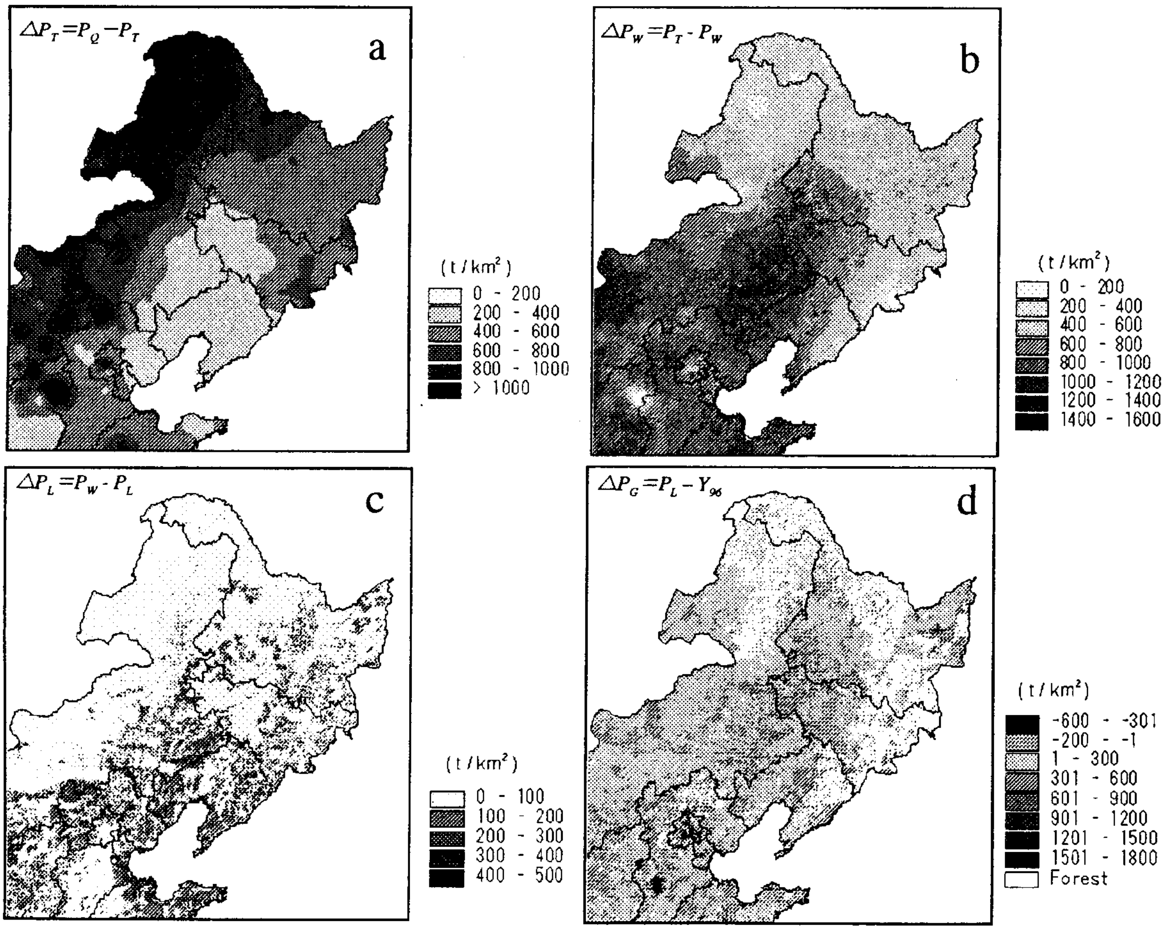

Fig.-1 Example maps showing the possible increase of crop production under different constraint conditions

Measures to improve the thermal condition are, for example, to build warming house, to use ground-surface covering, and to supply artificial heat source. The possible increase of grain production by improving thermal condition, ΔP_T, increases gradually from southeast to northwest (Fig.-1), which is coordinated well with the distribution of temperature. Namely, ΔP_T is large in the northern area with low temperature, but low in the southern area with high temperature. Comparing P_T with P_Q, we can find that the constriction of temperature make the crop production decrease about 10-30% in the southern part, such as Liaoning, Hebei and Shangdong provinces, and >50% in the northern part such as Heilongjiang province and Inner Mongolia Autonomous region.

One effective measure to improve water condition is to change rainfed cultivation into irrigated cultivation, which leads a large increase of crop production. The possible increase of ΔP_W, is achieved by improvement of both heat and water conditions, therefore, its spatial distribution is rather complex (Fig.-1). ΔP_W is very large in the western arid and semi-arid area where precipitation is less than 400 mm. In such areas, the water deficit causes a more than 50% reduction of crop production, such as corn, bean, sorghum and millet. On the other hand, the water condition is relatively good in the Northeast China Plain, so ΔP_W is small because the water deficit only causes a less than 20% reduction of crop production.

Natural soils are not very much suitable for crop production. To improve soil condition means to change soil texture, soil nutrition and soil degradation conditions. From the map of ΔP_L shown in Fig.-1, we can find that the possible increase of crop production by improving soil conditions is large in both the coast area around the Bohai Sea and the mountainous area. The dominate soil in the former is Coastal colonchaks with high salt content. In the latter, soils are easily eroded. On the contrary, ΔP_L is relatively small in the vast plain areas, where the soil condition is relatively good for cultivation.

Possible increase of ΔP_G can be achieved by the development of new seed, rational application of fertilizer, improvement of planting techniques, and protection of plant disease. Fig.-1 shows the difference of evaluated land productivity and the actual grain yield at 1996 in arable land derived from county-level statistic data of China. This result shows that the actual yield at 1996 is less than the potential one in most part of the area, which suggests that land productivity can be improved. Some areas, even small, where the actual yield is bigger than P_L are considered to have well-organized irrigation systems, or a good management and high technology.

Finally, we believe that crop production in northern and northeastern China will at last increase by 2-3 times and reach the thermal productivity (P_T) in the future. According to Gao[2)], the actual yield of corn and rice at several experimental fields in the Northeast China Plain has reached 1500 t/km^2, which has reached the level of thermal productivity. However, it is still a long way to realize that for the whole area. From the tendency of increase of crop yield during 1979-1996, we predicted that it will take more than 50-60 years for the whole area to achieve the thermal productivity.

5. Conclusions

In order to evaluate the potential productivities and possible increase of crop production, we developed a set of digital maps including base maps, socioeconomic maps, meteorological maps, soil maps, and land use/cover maps at a scale of 1:1,000,000(a ground resolution of about 1km). Then, a set of maps have been produced, which include crop potential productivities under different limiting factors, and the possible increase of production for each crop by improving those limiting factors

Although crop production can be increased by improving heat, water, soil conditions and agricultural technology, we have to keep in mind that many environment problem might be resulted from these activities. For example, (1) hugeamounts of plastic materials are used for the improvement of thermal condition, which may became direct pollutants in the field; (2) application of large amount of chemicals and fertilizer for the improvement of soil nutrition, which may cause serious soil and water pollution; (3) relocation of water and cultivation in the slope land for the improvement of water condition, which will cause many environmental problems, such as soil erosion, salinization and desertification. All these problems will then feedback to agricultural production system, and disturb the regional sustainable development.

References

1) YU, H and ZHAO, F.: Light and Thermal Resources and Photosynthetic Thermal Productivity, Acta Meteorologica Sinica, 1982, p.8.
2) GAO, S.: Research on Agro-climatic Productivity and Strategy of Utilization in Northern China, China Meteorological Press, 1995, Beijing.
3) WANG Q. and TAKAHASHI, H.: A Land Surface Water Deficit Model for an Arid and Semi-arid Regions: Impact of Desertification on the Water Deficit Status in the Loess Plateau, China. J. Climate, 1999, 12, pp.244-257.
4) TANG, H. and YE, L.: Comparative Study on Methodology of Land Production Potential, China Press of Agricultural Technology, 1997, Beijing.