Average soil potential productivity of Hunan Province, China, 1981-2010

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Abstract: The dataset of soil potential productivity of Hunan province of China is produced at 1km resolution based on progressively calculating models and the data of climate, soil and terrain by using GIS (Geographic Information System) technology. The aim of this study is to get the pixel based soil potential productivity data in 1km resolution from the table based statistical data in administrative regions and polygon based in administrative county boundary GIS data. The dataset includes data about the photosynthetic potential productivity, light and temperature potential productivity, climatic potential productivity and soil potential productivity. The data also covers temperature correction coefficients, moisture correction coefficients and soil correction coefficients. The geographic distribution of predicting soil potential productivity coincides with the one of actual crop productivity.

Keywords: Hunan province; photosynthetic potential productivity; light and temperature potential productivity; climate potential productivity; soil potential productivity
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1 Introduction

The dataset of soil potential productivity of Hunan province of China is produced based on progressively calculating models and the data of climate (collected from 1981-2010), soil and terrain. This datasets in 1km resolution includes four sub- datasets, including that of photosynthetic potential productivity, light and temperature potential productivity, climatic potential productivity and soil potential productivity. Three correction coefficients are also included in the data. They are temperature correction coefficient, moisture correction coefficient and soil correction coefficient.

2 Metadata of average soil potential productivity of Hunan province, China, 1981-2010

The descriptions of the annual average soil potential productivity of Hunan province

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Table 1 Summary of the SoilProduData_Hunan_1981-2010 Metadata

Full name of dataset	Annual average soil potential productivity of Hunan province from 1981 to 2010		
Short name of dataset	SoilProduData_Hunan_1981-2010		
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Geographical region	Hunan province, China, 30°08′-24°38′N, 108°47′-114°15′E		
Year of the dataset	1981-2010		
Spatial resolution	1000 m		
Data format	ARCGIS Grid	Dataset size	25.7MB
Data publisher	Global Change Research Data Publishing and Repository, DOI:10.3974/		
Data access and services platform	Global Change Research Data Publishing and Repository, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, http://www.geodoi.ac.cn National Data Sharing Infrastructure of Earth System Sciences of China, http://www.geodata.cn		
Academic editors	LIU Chuang, SHI Ruixiang, JIANG Dong, HE Jinshu		
Data sharing policy	The authors of the dataset agree to publish the data here according to the Article I of Data Sharing Policy of the Global Change Data Publishing and Repository, which states that the dataset can be used freely for research, education, and decision making; any users for commercial uses should get formal permission from IGSNRR/CAS.		

from 1981 to 2010 (SoilProduData_Hunan_1981- 2010) are recorded. These information include the dataset full name, dataset short name, corresponding author, authors, geographical region of the dataset content, year of the dataset, number of the dataset tiles, dataset spatial and temporal resolution, dataset format and size, data publisher, data sharing platform and contact information, technical editors, foundation and the data sharing policy. Table 1 below summarizes the main metadata elements of the SoilProduData_Hunan_1981-2010 dataset.

3 Methods

3.1 Photosynthetic potential productivity

Photosynthetic potential productivity is the theoretical maximum crop yields per unit of land area in the assumption, the temperature, moisture and nutrients are all kept under optimum condition, which is determined by the production of solar radiation. The formula is as following:

$$Y_Q = 10^5 / C*F*E*Q$$

Where Y_Q is photosynthetic potential productivity per unit of land area (kg/hm^2), F is the largest light energy utilization; E is crop economic factor; C is energy conversion factor for dry matter (kc/g); Q is solar radiation (kc/cm^2).

3.2 Light and temperature potential productivity

Light and temperature potential productivity is the potential crop yield calculated from photosynthetic potential productivity by considering the affection of temperature on the production, which is determined by the local solar radiation and temperature in the assumption that moisture, soil condition and other ecological condition are appropriate. The correction model is as follows:

$$Y_T = f(T) \cdot Y_Q$$

Where Y_T is light and temperature potential productivity per unit of land area (kg/hm^2), $f(T)$ is temperature correction coefficient, Y_Q is the photosynthetic potential productivity (kg/hm^2).

$$f(T) = n/365$$

Where n is the number of frost-free days.

3.3 Climate potential productivity

Climate potential productivity is the potential crop yield calculated from light and temperature potential productivity by considering the affection of moisture on the production, which is determined by the local solar radiation, temperature and moisture in the assumption that soil condition and other ecological condition are appropriate. The correction model is as following:

$$Y_W = f(W) \cdot Y_T$$

Where Y_W is climate potential productivity per unit of land area (kg/hm^2), $f(W)$ is the moisture correction coefficient, Y_T is light and temperature potential productivity (kg/hm^2)

$$f(W) = \begin{cases} \dfrac{R}{E} & R \le E \\ 1 & R > E \end{cases}$$

Where R is average annual precipitation, E is average annual evaporation.

3.4 Soil potential productivity

Soil potential productivity is the potential crop yield calculated from climate potential productivity by considering the affection of soil on the production. The correction model is as following:

$$Y_s = f(S) \cdot Y_W$$

Where Y_s is soil potential productivity per unit of land area (kg/hm^2), $f(S)$ is soil correction coefficient, Y_W is climate potential productivity (kg/hm^2). The research performed by Luo[1] suggested that the soil potential productivity for the first- class quality soil can achieve 60 % of climate potential productivity, for the second- class quality soil can achieve 30% and for the third- class quality soil can achieve 15%. In order to ensure the grid data can be smoothly distributed in space, the soil correction coefficients adopted were listed in Table 2

Here PI is soil quality grade index, which is represented by the geometric mean of several soil factors including terrain, soil texture, fertility and soil pH.

$$PI = \sqrt[5]{E \cdot S \cdot pH \cdot F \cdot T}$$

Table 2 Correction coefficient for multi-grading land

Classes	Soil quality grade index PI	Soil correction coefficients $f(S)$
I	$PI < 0.5$	0.4PI
II	$0.5 \leqslant PI < 0.7$	0.5PI
III	$PI \geqslant 0.7$	0.7PI

Table 3 Evaluation index and contribution function of land productivity

Factors	Expression functions
soil comprehensive fertility (F)	$f(F) = \begin{cases} 0.2 & level\ 1{:}1.0 < SCORE \le 1.5 \\ 0.4 & level\ 2{:}1.5 < SCORE \le 2.5 \\ 0.6 & level\ 3{:}2.5 < SCORE \le 3.5 \\ 0.8 & level\ 4{:}3.5 < SCORE \le 4.5 \\ 1 & level\ 5{:}4.5 < SCORE \le 5.0 \end{cases}$
Soil texture (T)	$f(F) = \begin{cases} 1 & loam \\ 0.72 & loamy\ clay, sandy\ loam \\ 0.57 & silty\ clay, clay \\ 0.43 & silt \\ 0.29 & sand \end{cases}$
Soil pH (pH)	$f(pH) = \begin{cases} 1 & (pH \le 4, pH \ge 9) \\ 1 - \dfrac{\lvert pH - 7 \rvert}{7} & (4 < pH < 9) \end{cases}$
Elevation (E)	$f(E) = \begin{cases} 1 & e \le 100\ m \\ 0.8 & 100\ m < e \le 300\ m \\ 0.6 & 300\ m < e \le 500\ m \\ 0.4 & 500\ m < e \le 1000\ m \\ 0.2 & e > 1000\ m \end{cases}$
Slope (S)	$f(G) = \begin{cases} 1 & (g \le 7) \\ 1 - \sin\left(\dfrac{g - T}{2\pi}\right) & (7 < g < 25) \\ 0 & (g \ge 25) \end{cases}$

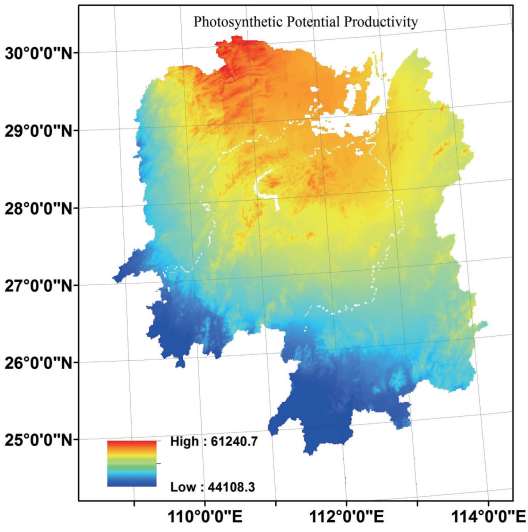

Figure 1 The potential YQ productivity at 1 km×1 km grid level in Hunan province

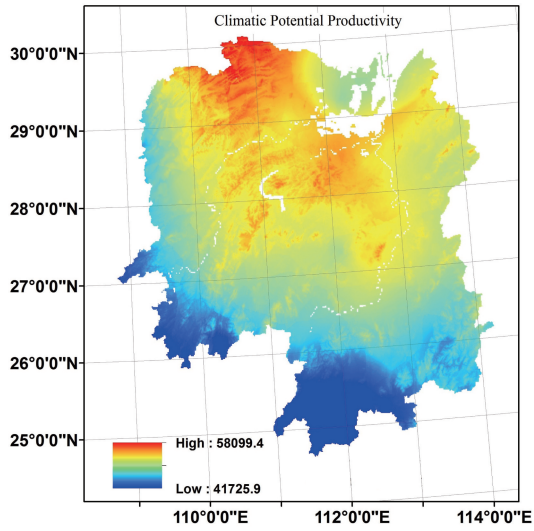

Figure 2 The potential YT productivity at 1 km×1 km grid level in Hunan province

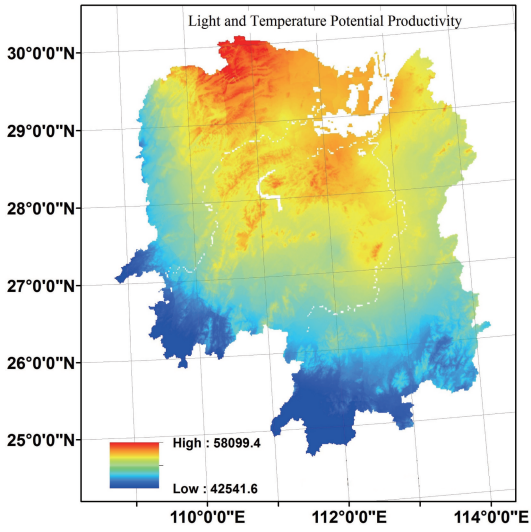

Figure 3 The potential YW productivity at 1 km×1 km grid level in Hunan province

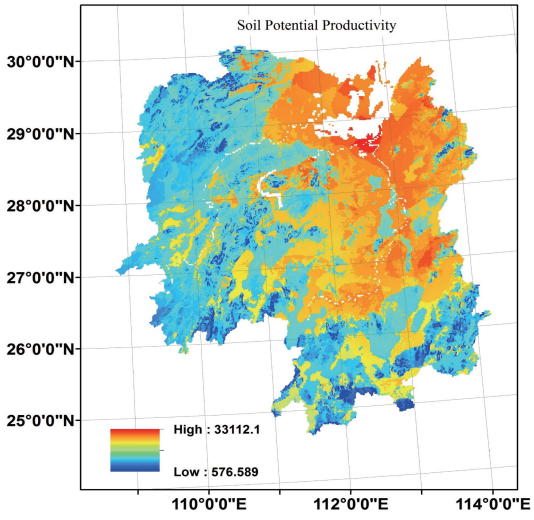

Figure 4 The potential YS productivity at 1 km×1 km grid level in Hunan province

Where E is elevation, S is slope, pH is soil pH, F is soil comprehensive fertility, T is soil texture. Referring to the research achievements about soil evaluation index system[2- 4], Table 3 list the factors and their expression functions used in the soil quality evaluation.

The photosynthetic potential productivity, light and temperature potential productivity, climatic potential productivity and soil potential productivity of Hunan province are shown in Figure 1 to 4.

4 Dataset quality control and validation

The meteorological data[5] (average annual solar radiation, temperature, precipitation and evaporation from 1981- 2010) used in producing this dataset is acquired from China

Table 4 The statistics of potential productivity and actual output of grain in 2010 in each city of Hunan province, China

Name of city	photosynthetic potential productivity, (kg/hm^2)	light and temperature potential productivity, (kg/hm^2)	climatic potential productivity (kg/hm^2)	soil potential productivity (kg/hm^2)	actual output of grain (2010) (kg/hm^2)
Zhangjiajie	57870	54739	54739	16159	4500
Xiangxi	54043	51697	51697	15760	4755
Chenzhou	51738	49108	48780	18478	5445
Changde	57964	54561	54152	24845	5625
Yongzhou	49713	48132	47097	18519	5640
Huaihua	53182	50868	50868	17697	5685
Yiyang	57221	54108	53737	24579	5730
Shaoyang	53358	50930	50816	18703	5820
Yueyang	56381	53466	52825	28618	5820
Hengyang	53980	51918	51914	25239	5835
Loudi	56282	53125	53125	22222	6030
Changsha	56399	52942	52942	27186	6600
Xiangtan	56363	53482	53482	25942	6870
Zhuzhou	54640	51771	51771	24312	6915
Average	54938	52203	51996	22018	5805

Meteorological Data Sharing Service System (http://cdc.cma.gov.cn); Soil data (fertility, soil texture, soil pH) were collected from soil map of China in 1:4, 000,000 scale and atlas of soil fertility quality at 1:4,000,000 scale, which were all supplied by Data Sharing Infrastructure of Earth System Science (http://www.geodata.cn); terrain data (elevation, slope) were extracted from China DEM dataset (1km resolution), which is supplied by Data Sharing Infrastructure of Earth System Science (http://www.geodata.cn).

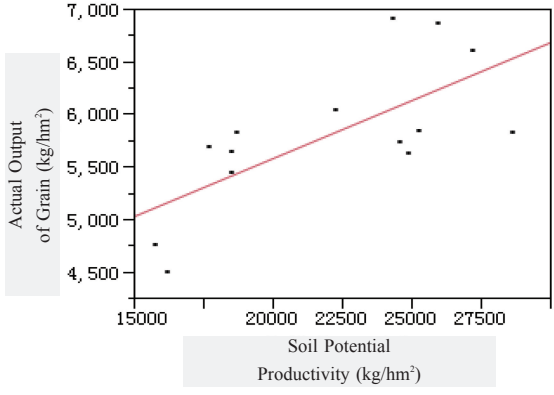

Figure 5 Plot of soil potential productivity and actual output of grain of Hunan province

We took the mean value of all the grids belong to each of administration cities as its potential productivity, and compared it with actual output of grain per hectare of each cities in Hunan province (the data were collected from rural statistical yearbook of Hunan province, 2011). The results are shown in Table 4.

The relationship between actual output of grain and estimated soil potential productivity is shown in Figure 5. The regression R^2 is 0.5. Soil potential productivity is an estimated maximum value in theory, while actual output of grain only achieve approximately 30% of estimated soil potential productivity given the affection from actual industry layout, the influence of human activities and other social economic factors. However both showed a good linear relationship in magnitude. There is great potential for the increase of crop production in Hunan province.

5 Conclusion

The dataset of soil potential productivity of Hunan province is produced at 1 km resolution based on progressively calculating models and the basic data of climate (solar radiation, temperature, precipitation and evaporation), soil (fertility, soil texture and soil pH) and terrain (elevation, slope). This dataset has good spatial coherence with actual output of grain of Hunan province, and highly reflects the potential productivity of Hunan province. It is a part of important information for spatial planning of land and resources of Hunan province.

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