Development of China digital soil map at 1:50,000 scale

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Abstract
In order to meet the increasing demands for soil information of high resolution by different disciplines such as agriculture, environment, economy, and so on, a China Digital Soil Map at 1:50,000 scale (CDSM-50,000) has been developed since 1999. Soil and soil nutrient paper maps at 1:50,000 scale and soil profile records were collected from 2,300 counties of China. These maps and records were achieved during the period of the 2nd Chinese National Soil Survey from 1979 to 1985. A data model of CDSM-50,000 was developed, which contains 9 map layers. Data of about 150,000 soil profiles were, for the first time, integrated into CDSM-50,000. Every profile contains dozens of soil physical and chemical properties, such as soil depth, texture, organic matter, pH value, contents of N, P, K, S, etc. Soil nutrient information of plough layer samplings during the period from 1999 to 2008 was also collected and integrated into CDSM-50,000. To merge different county soil maps with different mapping standards into one map according to the data model of CDSM-50,000, a complicated soil data processing procedure was developed. Map data of 1,100 counties had been already merged to CDSM-50,000. The data model was approved to be successful to organize all soil survey information of China in the last 30 years. Hundreds of examined soil profiles were collected from 5 provinces to test the reliability of developed CDSM-50,000. A quite nice coherence was found between CDSM-50,000 and the reality of soil type distribution. The finished digital soil maps were applied to cropland nutrient management, arable land fertility evaluation, strategy for controlling eutrophication and for study for climate change. This shows that CDSM-50,000 has played a great role for agriculture and environment.

Key Words
Digital soil map, soil profile, large scale, soil quality, organic matter.

Introduction

In China the arable land resources are very limited. According to newly published data, the arable land area is 121.7 million hectares and the per capita arable land area is 0.092 hectares (Ministry of Land and Resources of China 2009), just 40% of the world average. In the available arable land resources there are only 1/3 are fertile soil. The rest are low or middle-low yield arable land. For achieving food security and environment safety of the world most populated country, it is very important to understand the spatial and temporal variation of soil quality precisely. In the beginning of 1980's, a detailed soil survey work was carried out in the whole country. For every counties, hand drawn soil maps at 1:50,000 scale were finished based on large amount of soil profile observation. Since the very few hand drawn copies of paper maps and soil profile records were storied in provincial or even in county bureaus separately, damages are seriously due to acute organisation reform during last 30 years. Purposes of the study are to digitalize these paper soil maps and records, to develop one digital soil model for the whole country, to merge the 2,300 county soil maps and records together, and to enhance the application of soil information in agriculture, environment and economy.

Status of Soil Survey Work in China

A brief soil survey was carried out during the period from 1958 to 1960 in China (Li 1992; Anonymous 1964). A national soil map at 1:10,000,000 scale was drafted (Anonymous 1978). A more detailed soil survey work was finished during the period from 1979 to 1985 (Li 1992). Dozens of thousand of soil scientists and technicians were involved in the work. Based on large amount of soil profile observation and soil sampling, maps of soil and soil nutrient content at 1:50,000 scale were drawn for every county separately. Records of about 150,000 selected soil profiles, which presented main soil types of 2,300 counties in the whole country, were made. Each record contains dozens of soil characteristic such as soil mother material, texture, and contents of soil organic mater, total nitrogen, available phosphorus, potassium and pH in different soil layers with a profile depth of about 1-2 meter. In this survey, status of soil quality of the whole country in the beginning of 1980's was recorded. Recently, continuous attention has been paid to a better understanding of soil quality. A national investigation for soil pollution has been started. Also a national new investigation for soil nutrient status has been carried out since 2005. In these two investigations, geo-coordinates of sampling spots have been acquired by using GPS. Main outputs of soil survey in China in last 50 years were summarized in Table 1.

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Table 1. Soil survey and investigation work in China.

Period	Content	Main Output	Scale	
			Main	Range
1958-1960	Soil Survey	Soil Map of China, Report	1:10,000,000	
1979-1985	Soil Survey	Soil Maps, Reports (2,300 counties)	1:50,000	1:25,000-1:200,000
		Soil Maps, Reports(28 Provinces)	1:500,000	1:200,000-1:1,000,000
		Soil Map of China, Report	1:1,000,000	
	Nutrient Status	Soil Nutrient Maps (2,300 counties)	1:50,000	1:25,000-1:200,000
		Soil Maps (28 Provinces)	1:500,000	1:200,000-1:1,000,000
		Soil Nutrient Maps of China	1:4,000,000	
2000s	Nutrient Status	Database, Reports (most counties of China)		
	Soil Pollutants	Database, Reports (most regions of China)		

Data Model of CDSM-50000 (China Digital Soil Maps at 1:50,000 scale)

Original paper maps of soil and soil nutrient content at 1:50,000 scale and profile records finished in 1980s have been collected from different counties and provinces. Results of soil nutrient status sampled in 2000s were also collected national widely. According to the temporal and geographical features of soil information, a data model with 9 map layers was developed (Table 2). Soil information of 1,100 counties has already been digitalized and merged into CDSM-50,000 (Figure1). The data model has been approved to be successful to organize the miscellaneous soil survey information at county level obtained from 1980s up to now. Hundreds of examining soil profiles was collected from 5 provinces to test the reliability of developed CDSM-50,000. Quite nice coherence was found between CDSM-50,000 and the reality of soil type distribution.

Table 2. Data model of CDSM-50,000 (China Digital Soil Maps at 1:50,000 scale)

Map layers	Geo-feature	Temporal feature
Soil types	Polygon	1979 to 1985
Organic matter	Polygon	
Total nitrogen	Polygon	
Available phosphorus	Polygon	
Available potassium	Polygon	
pH	Polygon	
Soil profiles	Point	
Soil profiles	Point	2000s
Plough layer soil samples	Point	

Mapping of CDSM-50,000

To merge different county soil maps with different mapping standards into one map according to the data model of CDSM-50,000, a complicated soil data processing procedure was developed. By using this procedure Soil Map of China at 50,000 scale has been developed and plotted. The whole map contains 24,000 sub-maps. Two map layers concerning with soil information and necessary basic geographic information (Figure 2). One layer shows distribution of soil types, which was demonstrated by using Soil Classification System developed and widely applied in China (Anonymous 1998). Also soil classification system developed by Gong, which was more adjacent to the system applied in USA was parallel listed (Gong 1999). Through linkage between two soil classification systems, scientists of other country can easily find out the required soil information. The other map layer is soil profiles, which was, for the first time, introduced into the map. Positions of representative profiles of main soil types were labelled on the map (Figure 2). Tables of soil profile characteristics were attached on the map, which showed physical and chemical features of different depth of every representative soil profile labelled on the sub-map. An example was demonstrated in Table 3. The basic geographic information on the soil map includes map layers for administration region, water system, residential area and topographical information.

Application

By using CDSM-50,000, it is easy to get detailed soil information from different places and period in China. Besides improving crop nutrient management for farmers, CDSM-50,000 has also been applied in research works. An analysis of soil fertility changes of arable land in China was showed simply by calculating data provided by CDSM-50,000 (Table 4). It showed that the content of soil organic matter in arable land in about 25 years increased by 33% in China. If we use the arable land area with 121.7 millions hectares and plough layer depth with 20 cm, the net increase of carbon arrived to 953 million tons for the whole country. That means 3,494 million ton carbon dioxide has been additionally fixed in soils. Through advanced farming

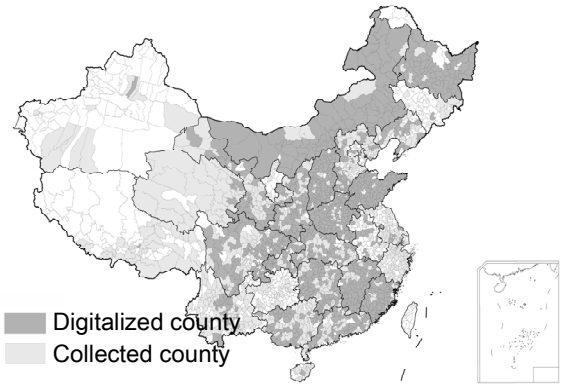

Figure 1. The collected and digitalized soil information by using model of CDSM-50,000.

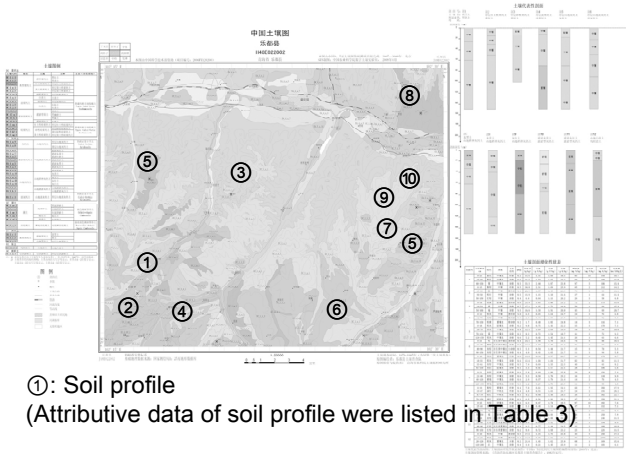

Figure 2. Soil Map of China, Sub-map: Ledu, Ledu county, Qinghai Province.

Table 3. Example table of soil profile characteristics*

Profile Lable**	Parent material	Soil layer	Soil depth cm	Soil texture	pH	OM (g/kg)	Total N (g/kg)	Total P (g/kg)	Total K (g/kg)	Available P (g/kg)	Available K(g/kg)	EC (mg/100g)
①	loess	A	0-12	silty clay loam	9	6.3	0.65	1.64	24.7	2	76	6.8
		B1	12-70	silty clay loam	8.9	2.3	0.44	1.55	23.5	2	82	5.3
		B2	70-150	silty clay	9.2	1.7	0.4	1.85	24.8	3	116	7.1
②	old red soil deposit	A1	0-15	silty clay loam	8.5	30.8	2.31	1.69	25.9	2	212	14.2
		A2	15-30	silty clay loam	8.4	23.9	1.87	1.45	24.6	3	88	16.1
		B	30-50	silty clay loam	8.5	13.9	1.13	1.1	21.6	1	64	11.4
		C	50-150	silty clay loam	8.4	6.4	0.64	1.13	20.2	3	58	6.8
③	loess	A	0-18	sandy loam	8.2	9.8	0.75	1.43	22.2	3	170	7.1
		B1	18-70	silty clay loam	8.4	12.3	1.09	1.69	19.9	3	94	10.8
		B2	70-124	silty clay loam	8.2	8.2	0.72	1.54	18.7	2	72	9.2
		C	124-150	silty clay loam	8.6	5.2	0.43	1.45	21.1	1	63	6.6

*Example Table was attached to Soil Map of China, Sub-map Name: Ledu, Ledu county, Qinghai Province, Soil profiles were sampled and analysed in 1982-1983.
**Profiles listed in Table 3 were labelled on figure 2.

Table 4. Change of soil organic matter, available P and K of China.

Soil parameters		1979 to 1985	2000s	Increase
Organic matter*	(%)	1.82	2.42	33%
	n	1,151,366	85,512	
Available phosphorus**	(mg/kg)	7.9	18.8	138%
	n	907,502	56,515	
Available potassium***	(mg/kg)	105	119.08	13%
	n	667,673	45,225	

* Determination of C; ** Determined mainly by Olsen method; *** Abstracted by NH_4OAC.

practices and soil fertility improvement in China, not only yield increased greatly, but also 139.9 million ton carbon dioxide additionally fixed annually during the last 25 years. It also shows that the concentration of soil available phosphorus increased by 138% and the concentration of soil available potassium increased slightly. With large number of soil samplings from the whole country, the analysis provides a reliable nutrient variation of arable land. Also other evaluations of arable land fertility changes, food security, and environment safety in the country, in a region or in a watershed have been implemented with the help of CDSM-50,000 (Li 2004; Zhang *et al.* 2004). With completeness and continuous enrichment of CDSM-50,000, it will play more important roles in agriculture, environment and research works.

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