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Adaptation of Soil Judging to Northeast China

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ABSTRACT

Soil Judging teaches students important skills for field identification of soil types, properties, and interpretations for use. The adaptation of Soil Judging in Northeast China can be beneficial to students as well as government agencies and the private sector. The objective of this study was to adapt Soil Judging to the Northeast region of China by a graduate student from China, who was trained using an undergraduate course in Soil Judging and a regional Soil Judging competition. Unlike the U.S., China has 14 soil orders, with six soil orders somewhat similar to the ones found in the Southeast region of the U.S. A Southeastern Region Soil Judging Handbook was used for newly developed teaching materials for Northeast of China (including tables of soil physical and chemical

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properties, topographic maps, and scorecards). These new teaching materials can significantly improve soil education and mitigate problems associated with land use management.

Key Words: Asia, agriculture, environment, education, farming, land use, urbanization

INTRODUCTION

Soil classification is an important component in the exchange and advancement of soil knowledge worldwide. Field description and laboratory analysis results are a foundation of soil classification. Various attempts have been made to correlate Chinese Soil Taxonomy with U.S. classification, but the need to further study the comparability lower classification levels still remains (Shi *et al.,* 2004). Field and laboratory analysis provide essential data for soil classification, and there is a need to compare the use of the soil data at the field level in China and the US. Soil Judging is used in many countries of the world (e.g. USA and Germany) to train soil scientists to describe, classify, and interpret soil for different uses. The first International Soil Judging Contest took place in June 2014 at the 20th World Congress of Soil Science in Korea.

Adaptation of soil judging education to China can improve this soil science knowledge exchange, and can potentially alleviate land use problems in China by educating students and planners about important soil properties related to land use such as: soil infiltration rate, hydraulic conductivity, available water, soil wetness class, and soil interpretations related to suitability for dwellings with basements, septic tank absorption field, and local roads and streets.

Soil infiltration rate is the velocity at which water enters the soil, and it is one of the most important soil physical characteristics. It affects soil water availability for plant use and groundwater recharge, and is related to soil erosion and water runoff (Lipiec *et al*., 2006). It is affected by soil texture in the surface horizon (A) and it depends on soil texture (e.g. rapid for sand, loamy sand, or sandy loam texture with soil organic carbon more than 1.2%). Northeast China is a predominantly agricultural area. Tillage practices could greatly affect soil macro porosity and infiltration characteristics, which consequently affect water runoff and soil erosion (Kemper *et al*., 2012). However, years of conventional tillage has resulted in increasing soil erosion and degradation problems as well as decrease in soil infiltration rates (Liu *et al*., 2010).

Soil saturated hydraulic conductivity is a quantitative expression of soil ability to transmit water under a given hydraulic gradient in the subsurface horizons (Julià *et al.* 2004). It is affected by soil texture, rock fragment, presence of restrictive layers (e.g. fragipan), structure, presence of redoximorphic depletions and color in the surface horizons (e.g. high, moderate, low). Soil texture is important for determining septic tank absorption field suitability (e.g. slight, moderate, or severe limitation). For example, Han *et al.* (2009), reported that a thick subsurface plow pan lowered the soil saturated hydraulic conductivity and additions of straw and organic manure resulted in increased saturated hydraulic conductivity. In another study by Zhang *et al.* (2013), high leachate levels of municipal solid waste were measured in the landfills in Southern China.

Currently, ninety percent of villages in China don't have enough drainage channels and waste water treatments facilities, which results in the pollution of drinking water and the aquatic environment (Dong *et al*., 2012).

Available soil water capacity is the water held between field capacity and permanent wilting point and it is calculated to a depth of 150 cm of the soil or other thickness if the soil horizons are unfavorable for roots (Karathanasis *et al*., 2013). The available water calculations factors are (cm of water/cm of soil): 0.05 for sands, loamy sands; 0.15 for textures not included in other classes, and 0.20 for silt loam, silt, and silty clay loam (Karathanasis *et al*., 2013). Zhou *et al*. (2005) note that laboratory-determined data for the available soil water capacity (ASWC) are often lacking is soil profiles databases in China. Geospatial analysis of ASWC showed the following pattern: higher ASWC values in the east compared to the Western part of China, and ASWC values are reduced from south to the north, except for the Northeastern part of China (Zhou *et al*., 2005).

Soil wetness class is the rate at which water is removed from the soil by both runoff and percolation and it is influenced by landscape position, slope gradient, infiltration rate, surface runoff, and permeability (Karathanasis *et al*., 2013). Redoximorphic features and soil color are used to determine the soil wetness class (Karathanasis *et al*., 2013). Ma and Fu (2006) reported evidence of drying trend over Northern China from 1951 to 2004. Topographic wetness index was highly correlated with soil organic matter content (Pei *et al*., 2010).

Suitability for dwellings with basements is affected by the following factors: flooding or ponding frequency, slope (%), depth to seasonally high water table, depth to soft rock "saprolite" (Cr) or depth to hard rock, cm (R) (Karathanasis *et al*., 2013). The degree of limitation varies from slight to moderate or severe (Karathanasis *et al*., 2013). Urbanization is widespread in China with the largest expansions in the Eastern Plain and the southeast (Liu and Tian, 2010).

Septic tank absorption field suitability is affected by the following factors: flooding or ponding frequency, slope (%), depth to seasonally high water table, limiting hydraulic conductivity, depth to soft rock "saprolite" (Cr) or depth to hard rock, cm (R) (Karathanasis *et al*., 2013). The degree of limitation varies from slight to moderate or severe (Karathanasis *et al*., 2013). Septic tanks are used in many parts of the country, but there is a lack of appropriate waste water collection and treatment facilities in the rural areas (Chen *et al*., 2014). Lu *et al*. (2008) reported groundwater contamination from poor management of septic tanks in the southern coastal area of China, but the description of the study area raises many questions about septic tank absorption field suitabilities in the first place due to shallow water table, highly permeable soils, and frequent floods (especially in the areas with impervious surfaces).

Suitability for local roads and streets is affected by the following factors: flooding or ponding frequency, slope (%), depth to seasonally high water table, depth to soft rock "saprolite" (Cr) or depth to hard rock, cm (R) (Karathanasis *et al.*, 2013). The degree of limitation varies from slight to moderate or severe (Karathanasis *et al.*, 2013). Soil properties have significant impact on suitability for roads and streets in China as demonstrated by Du *et al*. (1999) by examining shrink-swell potential of natural and disturbed soils. Another study, by Fu *et al*. (2012), assessed land resources carrying capacity in Fujian Province of East China by using ecological suitability analysis in geographic information systems (GIS), and selecting altitude, slope, land use type, distance from resident land, distance from main traffic roads, and distance from environmentally sensitive area as the sensitive factors. Increased pressure on soil resources from urbanization and agriculture was also reported by Li (2012) in the context of urban-rural interactions patterns and dynamic land-use.

The objectives of this study were to develop a scorecard and recommendations for potential adaptation of Soil Judging education to the Northeast region of China.

MATERIALS AND METHODS

Study Site

Northeast China, is one of China's geographic and economic regions and it is composed of Heilongjiang, Jilin and Liaoning Provinces with variable soils (Fig. 1, Table I, TABLE II). The largest plains in China are located in the Northeast region, which is rich in natural resources, culture, and economic development. It has a total surface area of about 1,370,000 km^2 and a population of about 121,000,000 (China Statistical Yearbook, 2012). The Northeast region has a semi-humid climate with an annual precipitation from

500 to 600 mm, with 90% of the precipitation falls as rain between April and September. It includes two of six ecological regions of China: the cool, subhumid Dongbei Plain (natural vegetation is a forest-steppe or meadow-steppe), and the cool, subhumid Da Hinggan (taiga forest), Xiao Hinggan and Changbai Mountain ranges (mixed needle- and broad-leaved forests) in the Northeast (ISSAS and ISRIC, 1994).

Soil Judging requires excavation of soil profiles, setting up slope stakes, scorecards (Fig. 2, 3), tables of soil physical and chemical properties (Fig. 4), and a set of abbreviations (TABLE III), and soil judging equipment (Table IV). Score cards used for grading in soil judging competitions must be adapted to local soils and classification. Training for a 2013 soil judging competition at Tennessee Tech University enabled a graduate student from Northeast China to become familiar with several of the soil orders in Northeast China that are also present in the Southeastern United States (e.g. Alfisols, Entisols, and Inceptisols).

Equipment needed for Soil Judging in Northeast China

A set of tools that must be provided for each student involved in a soil judging completion includes: a score card, official rules, an abney level or clinometer, garden spade, bucket, clip-board, soil collection trays, water bottle, measuring tape, a calculator, a pencil, and a Mussel color chart (Table IV). All items needed for a soil judging kit can be purchased locally in Northeast China (Table IV).

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Laboratory analysis

Soil samples to provide soil physical and chemical data for the students could be analyzed in any one of the several soil nutrient analysis laboratories in Northeast China: Northeast University Institute, and Liaoning Provincial Institute of Meteorology.

Topographic maps

Soil profile locations were mapped as Geographic Infomation Systems (GIS) point shape-file files using ArcMap 10.2. Digital elevation models (DEM) surrounding each soil profile location (at a 30m resolution) were acquired from the ASTER digital elevation map (http://asterweb.jpl.nasa.gov/gdem.asp). Contour maps were created using the contour tool in ArcMap to create 30m topographic maps over the extent of the DEM.

Courses background

Soil judging course can be incorporated in various soil science courses currently taught in Northeast China, for example: Jilin University (Environmental Soil Science); Heilongjiang University (Soil Science); Harbin Institute of Technology (Soil Science and Soil Mechanics), and Liaoning Agriculture University (Soil Geography, Land Resource Science). Sectors that can also potentially benefit directly from soil judging education in China are the agriculture, housing and town planning, transportation, and health services.

Learning management system

Modular Object-Oriented Dynamic Learning Environment (Moodle) is a free source e-learning software platform, which can be used for storing course materials, and assessing student's learning via electronic quizzes and tests (https://moodle.org/). Computer laboratories and ready access to the internet are available in most universities in the Northeast China.

RESULTS AND DISCUSSION

There three versions of Chinese soil classifications:

- Chinese Soil Taxonomic Classification System, 1st Proposal (1991), which distinguished 13 soil orders (Primarosols, Vertisols, Aridisols, Isohumols, Spodisols, Siallisols, Ferrallisols, Fersiallisols, Aquisols, Halosols, Anthrosols, and Andisols).

- Chinese Soil Taxonomic Classification System, Revised Proposal (1995), which distinguished 12 soil orders (Ferrasols, Alfisols, Semi-alfisols, Pedocals, Aridisols, Desert soils, Amorphic soils, Semi-aqueous soils, Aquous soils, Alkali-saline soils, Anthrosols, and Alpine soils).

- In 2001, China adapted "3rd" classification system with 14 soil orders: Histosols, Anthrosols, Spodosols, Andosls, Ferralosols, Vertosols, Aridosols, Halosols, Gleyosols, Isohumosols, Ferrosols, Argosols, Cambosols, Primosols (Zitong and Ganlin, 2007) with five soil orders (Argosols, Anthrosols, Isohumosols, Halosols and Histosols) found in the Northeast region of China (Table II, Table III) and correlated with soil taxonomy (ST) by Shi et al. (2004).

Newly developed soil judging scorecard (Fig. 2) is adapted for the third soil classification system (2001), but it can be adapted to previous classifications as well. Comparison of Chinese and U.S. soil field description and classification revealed common and dissimilar items used in the newly adapted scorecard (Table III). In Part A. Morphology of the scorecard the following items were different in Chinese classification compared to the US classification: prefix, master horizon abbreviations, boundary distinctness thicknesses, and structure. Part B. Soil Profile and Interpretations of the scorecard is a new addition to the Chinese Soil Classification System since no comparable tables were found. In Part C. Site Characteristics of the scorecard the following items were different in Chinese classification compared to the US classification: position of the site, soil slope intervals, surface runoff and erosion potential (determined by experiment in China). In Part D. Soil Classification of the scorecard the following items were different in Chinese classification compared to the US classification: Epipedons, subsurface horizons, and soil orders.

In order to demonstrate how to use soil judging scorecard, soil profile CN 34 (ISSAS and ISRIC, 1994) was used to fill out the "practice" soil scorecard (Fig. 1, 2, 3) with markings in red color, which provides user with answers (Mikhailova and Post, 2014). In addition to soil judging scorecard, other supplemental materials are used: 1) Soil physical and chemical properties (Fig. 4), 2) optional topographic map of the area (Fig. 5), 3) textural triangle (not shown, but it is the same used in both China and USA), 4) abbreviations of distinctness of soil boundary, texture, modifiers of rock fragment quantity and size, structure grade, structure shape, consistence, redoximorphic features (Tables III, Yun, 2014), 5) tables of surface and soil erosion potential classes (Yun, 2014), and 6) tables of soil use interpretations for dwellings with basement, septic absorption fields, and local roads and streets (Yun, 2014). Soil profile CN 34 is one of the reference soil profiles of the People's Republic of China published in ISIS 4.0 data sheet. It has been classified as Silti-Chromic Cambisol (Eutric) in FAO/UNESCO (1988) classification, and as Typic Ustochrept, fine-silty, mixee, mesic in the USDA/SCS Soil Taxonomy (1992), and as Haplic cinnamon soil in Chinese Soil Taxonomy and Classification (1991), and as Cambisol in Chinese Soil Taxonomy and Classification (2001). The ISIS 4.0 data sheet for CN 34 was used to fill out the scorecard. In Part B, infiltration rate was determined to be medium based on soil texture (SiL/SiCL) and soil organic carbon content (0.7%) in the Ap horizon (Karathanasis *et al*., 2013). Hydraulic conductivity was determined to be medium based on subsurface horizon characteristics (Karathanasis *et al*., 2013). Available water was calculated based on depth of 150 cm x 0.20 (multiplier for SiL and SiCL in all of the horizons) (Karathanasis *et al*., 2013).. Soil wetness class is > 150 cm (not wet at depths of less than 151 cm) based on lack of redoximorphic features through the soil profile (Karathanasis *et al*., 2013). Soil interpretation for dwellings with basements, septic tank absorption fields, and local roads and streets was "2 = moderate" based on Yun (2014) using the following criteria:

Flooding or ponding (None), Fig. 4, Slope (7-15%), depth to seasonally high water table and depth to soft rock "saprolite", Cr (cm) > 100 cm, and depth to hard rock, R (cm) > 150 cm. In this case, slope (7-15%) was the moderate degree of limitation for all three uses. In Part C, surface runoff class was "rapid" based on 10% slope and "medium" infiltration in the Part B of the scorecard (Yun, 2014). In Part C, erosion potential was "very high" based "rapid" surface runoff and SiL/SiCL surface horizon texture in the Part A of the scorecard (Yun, 2014).

In general, U.S. scorecard can be used in China with necessary modifications depending on the region and soil interpretations to be used. The scorecard can further adapted to simultaneously train the user to describe and classify soil in multiple soil classifications.

CONCLUSIONS

The introduction of soil judging to Northeast China may serve as a low cost, nontraditional way of teaching students and government workers simple and efficient techniques of land management and use. Northeast China has the basic infrastructure for a successful introduce of soil judging competitions to schools (middle and high schools, colleges, and universities), and various government sectors such as agriculture, health, road construction and building and town planning sectors. Soil nutrient analysis data can be obtained from any of the soil nutrient analysis laboratories in Northeast China.

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Fig. 9. Clemson University Soil Judging team (He Yun, graduate student from China is far right) 2013 Southeastern Regional Soil Judging Competition in TN Tech University, TN.

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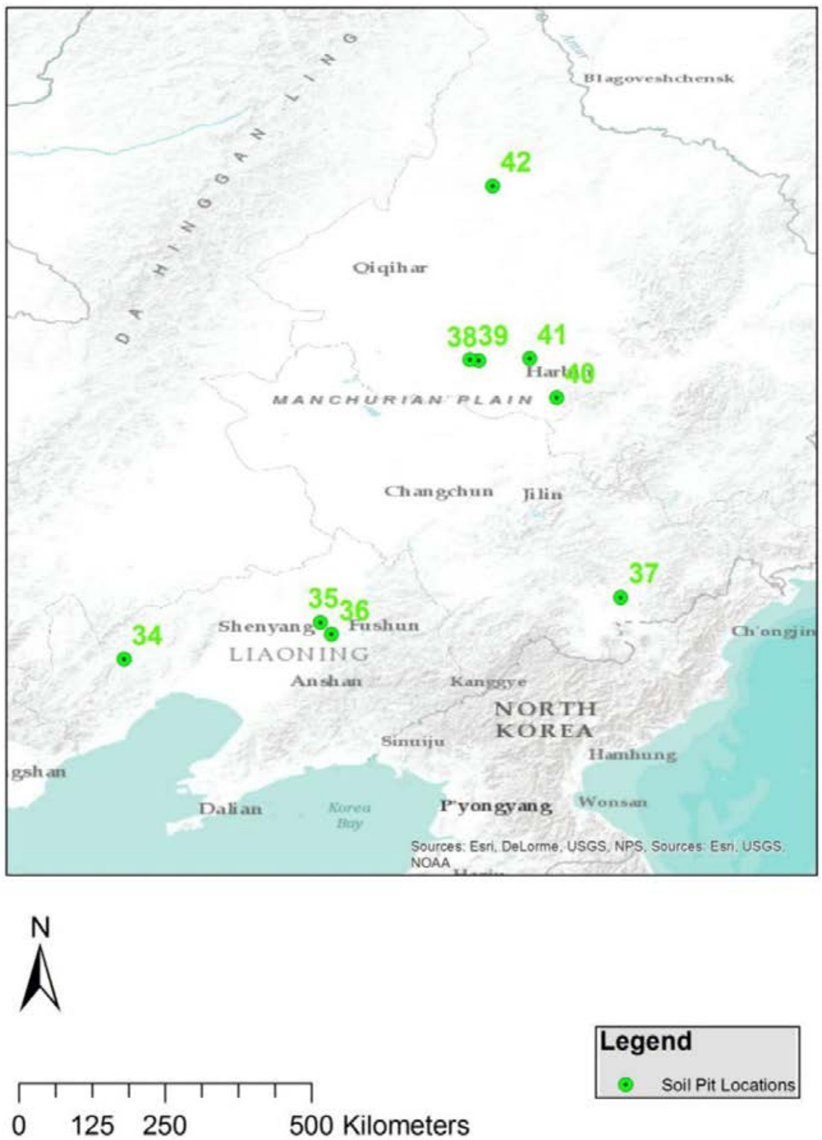

Fig. 1. Map of Northeast of China with soil pit locations (adapted from ISSAS and ISRIC, 1994).

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Soil Judging Scorecard

Site 34
No. of Horizons 3
Depth to be described 150 cm
Nail in 3rd horizon @ 80 cm

Contestant ____________________

A. Morphology

Horizon						Texture			Color			Structure		Consist.	Redoximorphic Features			Score
Pre.	Master	Sub	No.	Lower depth	Bound. distnct.	Rock fragmnt modif.	USDA class	Clay content	Hue	Val.	Chr.	Grade	Shape	Moist	Redox conc. y/n	Redox depltn. y/n	Red. matrix y/n	
1	3	2	1	3	1	1	3	1	1	1	1	2	2	1	1	1	1	27
_	A	p	_	15	A	_	SiL/SiCL	29	7.5YR	4	6	B	H	B	N	N	N	
_	B	w	1	65	G	_	SiCL	33	5YR	3	4	C	F	C	N	N	N	
_	B	w	2	150+	_	_	SiCL	33	5YR	4	8	C	I	B	N	N	N	

B. Soil Profile and Interpretations

Infiltration Rate (5)
____ Rapid
_x_ Medium
____ Slow

Hydraulic Conductivity (5)
____ High
_x_ Moderate
____ Low

Available Water (5)
____ Very Low ≤ 7.5 cm
____ Low > 7.5 and ≤ 15.0 cm
____ Moderate > 15.0 and ≤ 22.5 cm
_x_ High > 22.5 cm

Soil Wetness Class (5)
_x_ > 150 cm
____ 101-150 cm
____ 51-100 cm
____ 25-50 cm
____ < 25 cm

Soil Interpretations (2 each)
_2_ Dwellings with Basements
_2_ Septic Tank Absorption Field
_2_ Local Roads and Streets
(1 = slight, 2 = moderate, 3 = severe limitations)

Part A ________
Part B ________
Part C ________
Part D ________
Total ________

Fig. 2. Front side of scorecard for Northeast China Soil Contest (adapted from Karathanasis et al., 2011). Text in red color is a teaching-aid for practice in the field. During Soil Judging competitions, the red text is not used.

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C. Site Characteristics

Position of Site (5)
_____ Depression
_____ Drainage Way
_____ Flood Plain
_____ Footslope
_____ Stream Terrace
__x__ Upland

Parent Material (5)
_____ Alluvium
_____ Colluvium
__x__ Residuum

Soil Slope (5)
_____ Nearly Level (0 to 3%)
_____ Gently Sloping (>3 to 7%)
__x__ Sloping (>7 to 15%)
_____ Moderately Sloping (>15 to 25%)
_____ Strongly Sloping (>25 to 35%)
_____ Steep (>35%)

Surface Runoff (5)
_____ Ponded
_____ Very Slow
_____ Slow
_____ Medium
__x__ Rapid
_____ Very Rapid

Erosion Potential (5)
_____ Very Low
_____ Low
_____ Medium
_____ High
__x__ Very High

Part C Score __________

D. Soil Classification

Epipedons (5)
_____ Mollic
__x__ Ochric
_____ Umbric
_____ Fimic
_____ Salic

Subsurface Horizons
and Characteristics (5 each)
_____ Albic
_____ Argic
_____ Argic
__x__ Cambic
_____ Claypan
_____ Alkalic
_____ Salpan
_____ None

Order (5) Chinese Classification (2001)
_____ Argosols
_____ Isohumosols
_____ Halosols
_____ Anthrosols
_____ Histosols
__x__ Cambisols

Part D Score __________

Fig. 3. Back side of scorecard for Northeast China Soil Contest (adapted from Karathanasis et al., 2011). Text in red color is a teaching-aid for practice in the field. During Soil Judging competitions, the red text is not used.

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PIT 34

No. of horizons ___3___

Depth to be described ___150 cm___

Nail in the 3rd horizon @ ___80 cm___

HORIZON	OC (%)	BS (%)
1	0.7	23
2	0.3	52
3	0.2	44

Flooding: NONE

Ponding: NONE

Fig. 4. Soil physical and chemical properties for the soil profile No. 34 in Liaoning Province, Chaoyang, China (adapted from ISSAS and ISRIC, 1994).

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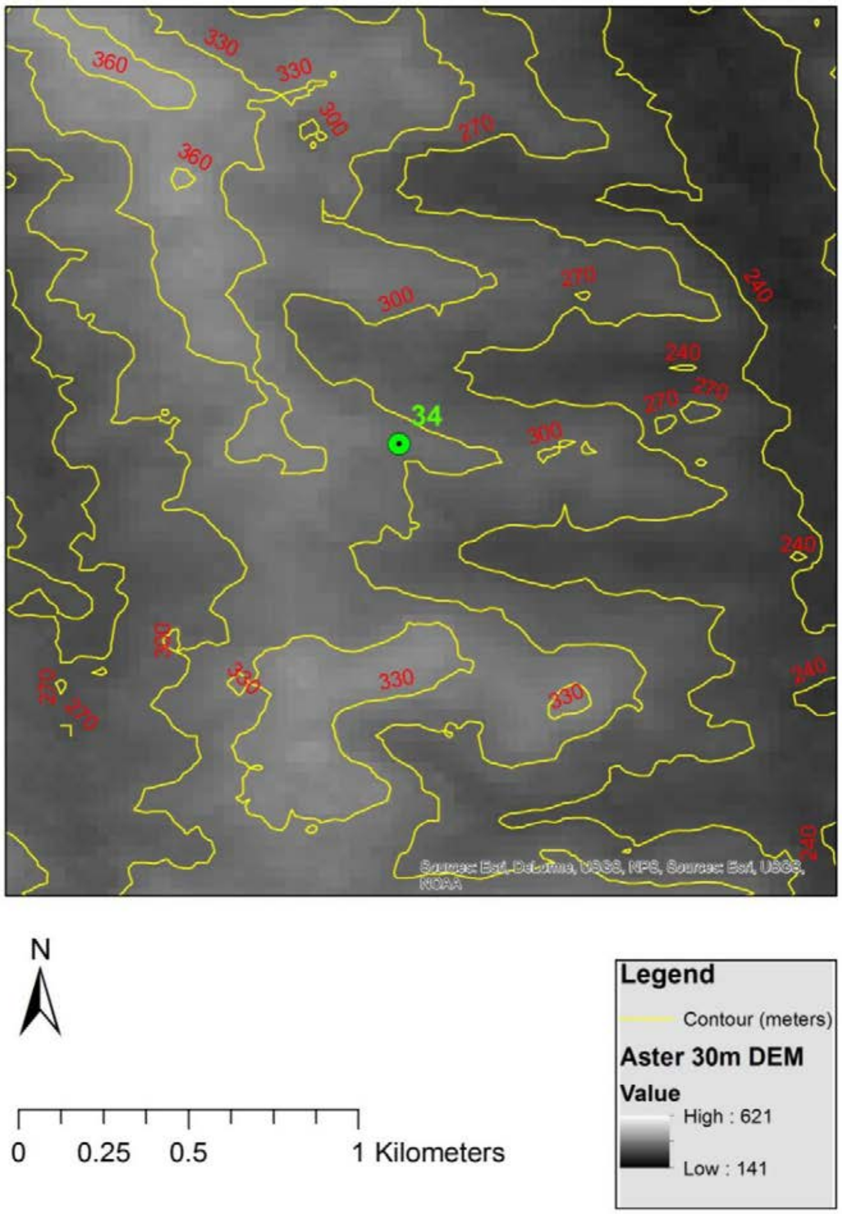

Fig. 5. Topographic map for the soil profile No. 34 in Liaoning Province, Chaoyang, China (adapted from ISSAS and ISRIC, 1994).

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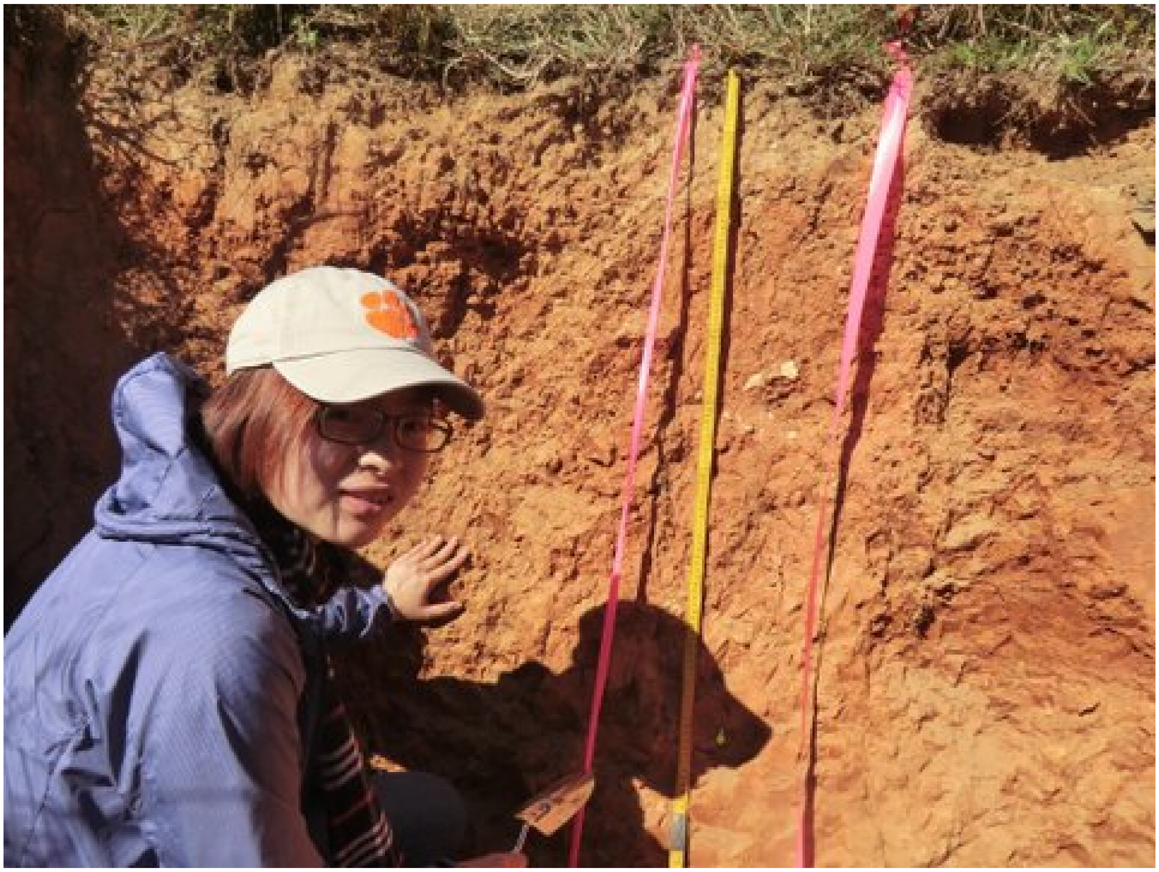

Fig. 6. Examining a no-pick zone of the practice soil profile during 2013 Southeastern Regional Soil Judging Competition in TN Tech University, TN.

Fig. 7. Slope determination in the field.

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Fig. 8. Texture by feel during 2013 Southeastern Regional Soil Judging Competition in TN Tech University, TN.

Fig. 9. Clemson University Soil Judging team (He Yun, graduate student from China is on the far right) 2013 Southeastern Regional Soil Judging Competition in TN Tech University, TN.

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List of Tables

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TABLE I

General information of the Northeast of China (Source: China Statistical Yearbook, 2012).

Province	Capital	Population (2010)	Area	Population density	Land-use
			km^2	people/km^2	
Heilongjiang	Harbin	38,312,224	454,000	84.38	Logging, timber, industry, farming
Jilin	Changchun	27,462,297	187,400	146.54	Logging, timber, farming
Liaoning	Shenyang	43,745,323	145,900	299.83	Farming, industry,

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TABLE II

Soils of the Northeast China according to 2001 Chinese Classification System.

Heilongjiang	Jilin	Liaoning
Chinese Classification, 3rd proposal (2001)		
Argosols	Argosols	Argosols
Isohumosols	Isohumosols	Isohumosols
Halosols	Halosols	Anthrosols
Histosols		Halosols
Cambisols		Cambisols

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TABLE III

Comparison of Chinese and U.S. soil description and classification used in the soil judging scorecard based on Southeast region of USA and Northeast region of China.

Scorecard	U.S. (Source: Soil Survey Staff, 1999)	China (Source: Institute of Soil Science, 1991)
A. Morphology		
Prefix	1, 2…	-
Master horizon abbreviation	O, A, E, B, C, R	O, K, A, E, B, G, C, R
Horizon Sub	a, b, c, g, h, k, m, n, p, q...	a, b, c, g, h, k, m, n, p, q...
No.	1, 2, 3	-
Lower depth	cm	cm
Boundary distinction	A (<2cm), C (2-6cm), G (6-16cm), D (>16cm)	A(<2cm), B(2-5cm), C(5-12cm), D(>12cm)
Rock fragment	Percent by volume	Percent by volume and the rock size

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USDA class	Texture-by-feel (Textural triangle)	Texture-by-feel (Textural triangle)
Clay content	Particle size, texture-by-feel	Particle size, texture-by-feel
Color	Munsell Color Chart	Munsell Color Chart Describe by words
Structure grade	SLS, WK, MO, ST	SLS, WK, MO, ST
Structure shape	GR, PL, MA, PR, SG, ABK, SBK	Platy, Scaly, Prismatic, Columnar, Prismatic Blocky, Lumpy, Core shape, Granular, Pellets, Crumb
Consistency (moist)	L, Fi, FR, VFi, VFR, EFi	L, Fi, FR, VFi, VFR, EFi
B. Soil profile and Interpretations		
Infiltration rate	Determined from scorecard	By experiment
Hydraulic conductivity	Determined from scorecard	By experiment

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Available water	Determined from scorecard	By experiment
Soil wetness class	Determined from scorecard	-
Soil interpretations	Determined from scorecard tables	-

C. Site characteristics

Position of site	Depression, Drainage Way, Flood Plain, Footslope, Stream Terrace, Upland (Field observations, topographic maps)	Mountain, Hills, Plain, Plateau, other
Parent material	Alluvium, Colluvium, Residuum	Alluvium, Colluvium, Residuum
Soil slope	Nearly Level(0-2), Gently Sloping(2-6), Sloping(6-12), Moderately Sloping(12-20), Strongly Sloping(20-30), Steep(>30)	<3, 3-7, 7-15, 15-25, 25-35, >35
Surface runoff	Ponded, Very Slow, Slow, Medium, Rapid, Very Rapid	By experiment
Erosion potential	Very Low, Low, Medium, High, Very High	By experiment

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D. Soil classification

Epipedons	Mollic, Ochric, Umbric	Mollic, Ochric, Umbric, Fimic, Salic
Subsuface horizons and characteristics	Albic, Argillic, Cambic, Fragipan, Lith. Discontinuity, Lithic Contact, Paralithic Contact, None	Albic, Cambic, Agric, Argic, Claypan, Alkalic, Salipan, None
Order	Based on data	Based on data

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TABLE IV

Soil Judging equipment per person and cost in China.

No.	Equipment/supplies	Cost in US	Cost in China (RMB as of 1/30/14)
1.	Abney level, clinometers, or other hand level	1	150
2.	Knife	3.5	20
3.	Water bottle	0.5	3
4.	Munsell Color Chart	150	1000
5.	Scorecards and supplemental materials	0.5	1
6.	Calculator	2	10
7.	Mechanical pencil	0.5	2
8.	Measuring tape and nail	1	3
9.	Clip board	1	10
10.	Containers for soil samples	0.5	20
11.	Bucket	1	6
	Total	185.5	1225