Predicting and mapping soil properties using proximal/remote sensing

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Outlines

1、Introduction

2、Soil Proximal Sensors

3、Soil Remote Sensing

Precision agriculture

Quantitative soil-landscape modeling

Global soil C monitoring

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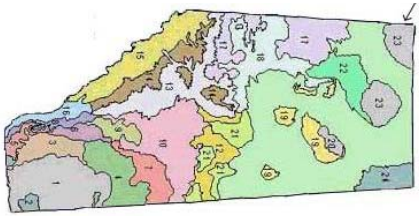
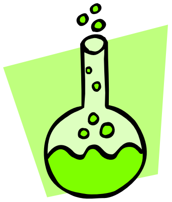


Soil map (soil type or soil properties)

Fine resolution | Grid -based | Functional properties

Wet chemistry methods to extract soil properties are cost effective and time consuming

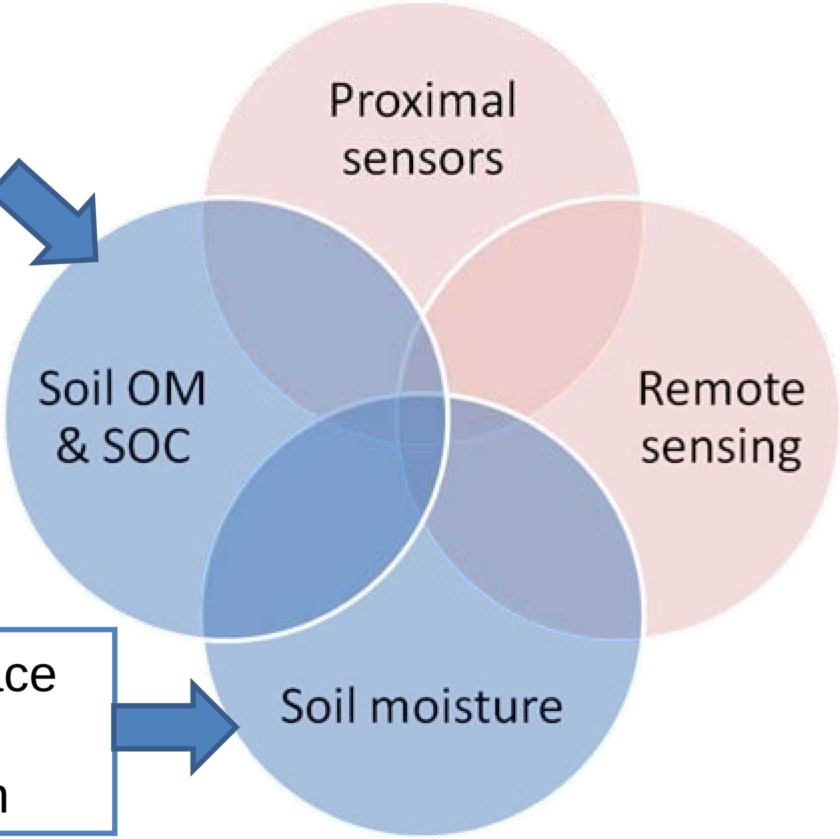


How to develop methods that use the *minimum number* of soil samples possible to *minimize the costs*

Accordingly, *non destructive technologies*, such as field proximal sensors or remote sensing methods can provide important vantages.

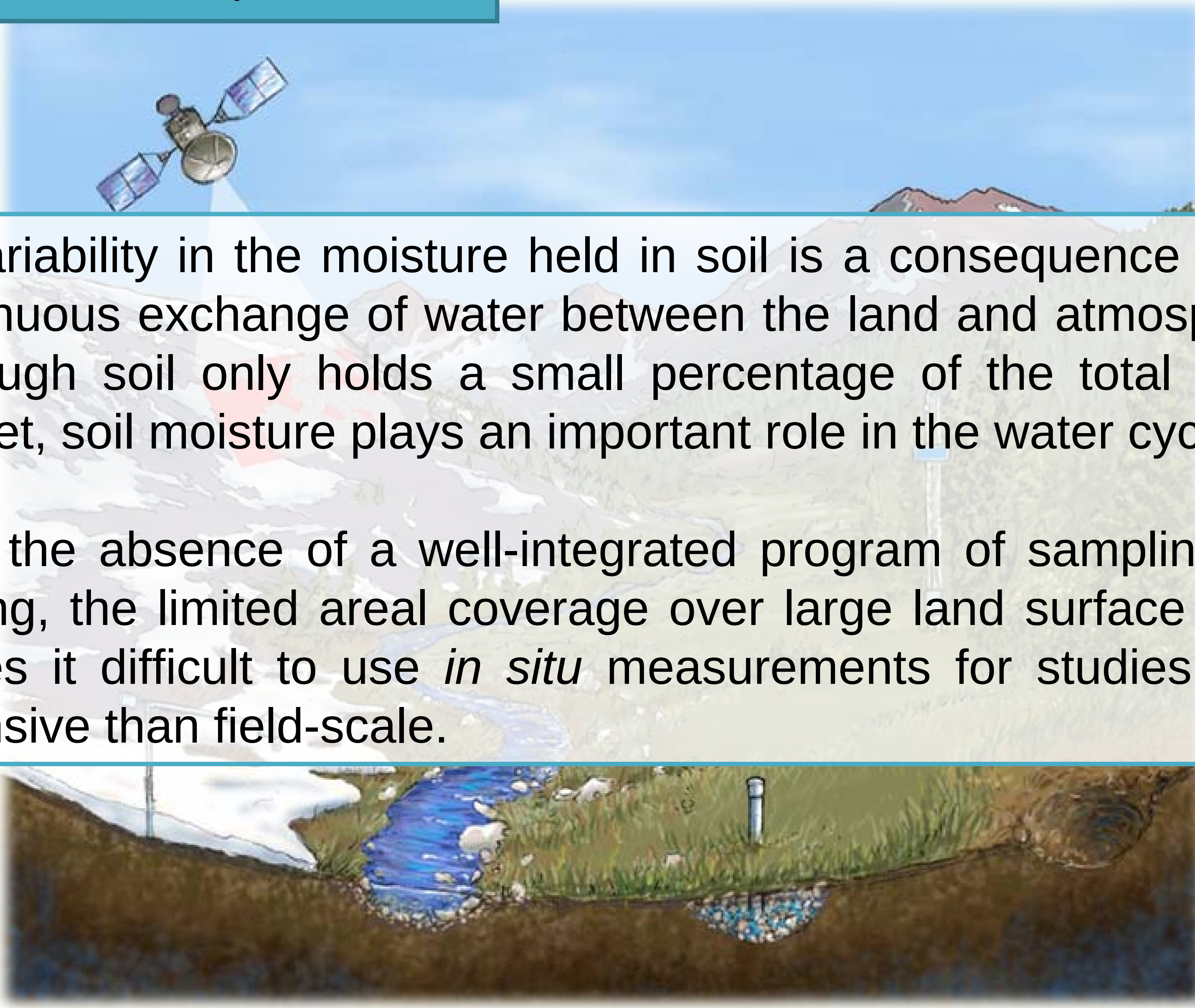
The capacity and potential of the proximal sensors / remote sensing on monitoring and mapping of some key functional properties of soil , such as soil moisture, organic matter and carbon.

- ✓ effect on the interactions between soil and plants
- ✓ related to soil quality



- ✓ plays a leading role in surface water and energy balance
- ✓ available for plant utilization

◆ Soil moisture (土壤水分）



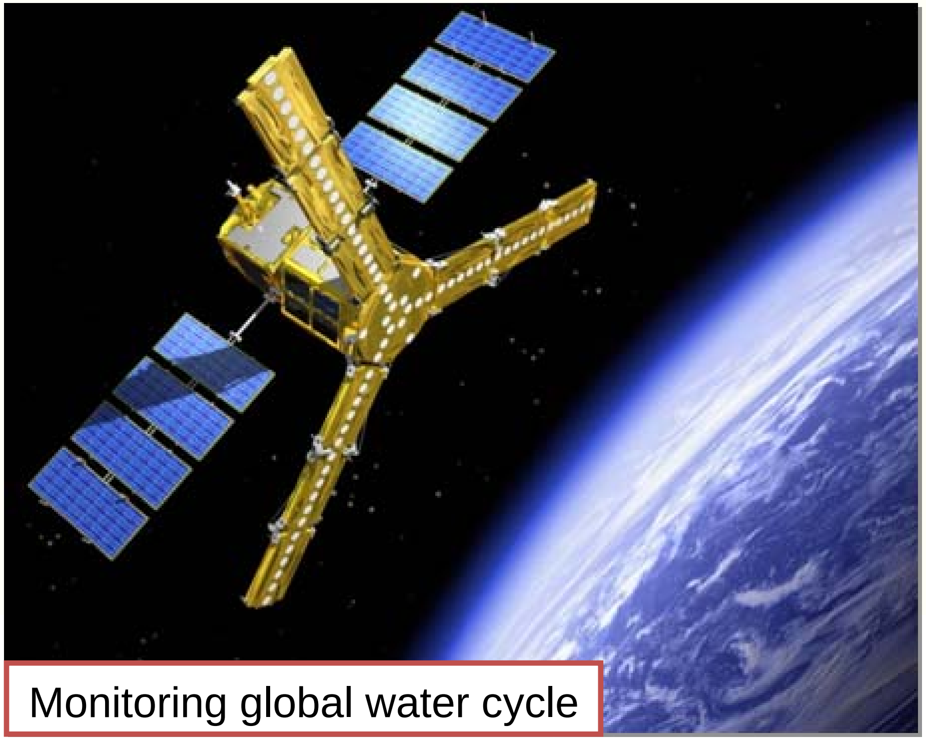
◆ Variability in the moisture held in soil is a consequence of the continuous exchange of water between the land and atmosphere. Although soil only holds a small percentage of the total global budget, soil moisture plays an important role in the water cycle.

◆ In the absence of a well-integrated program of sampling and scaling, the limited areal coverage over large land surface areas makes it difficult to use *in situ* measurements for studies more extensive than field-scale.

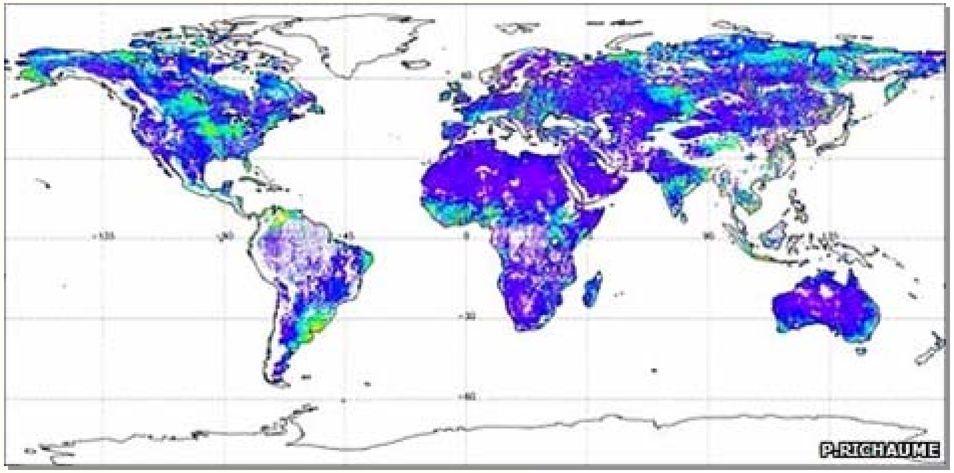
Roger Bales, University of California

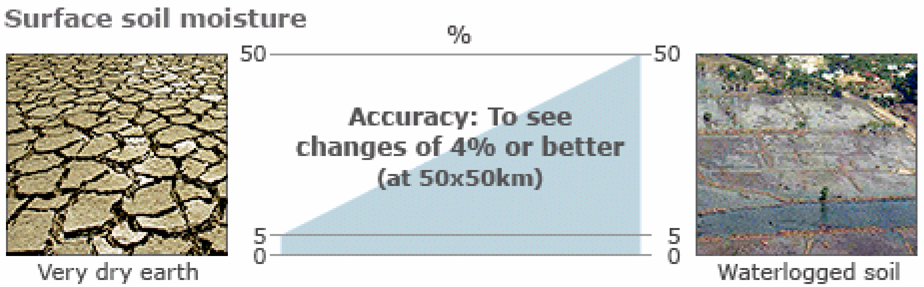
◆ Monitoring and mapping soil moisture by satellite

Remote sensing can be advantageous owing to its continuous temporal and spatial cover- age. It is the most promising approach for soil moisture estimation involving large areas



Monitoring global water cycle



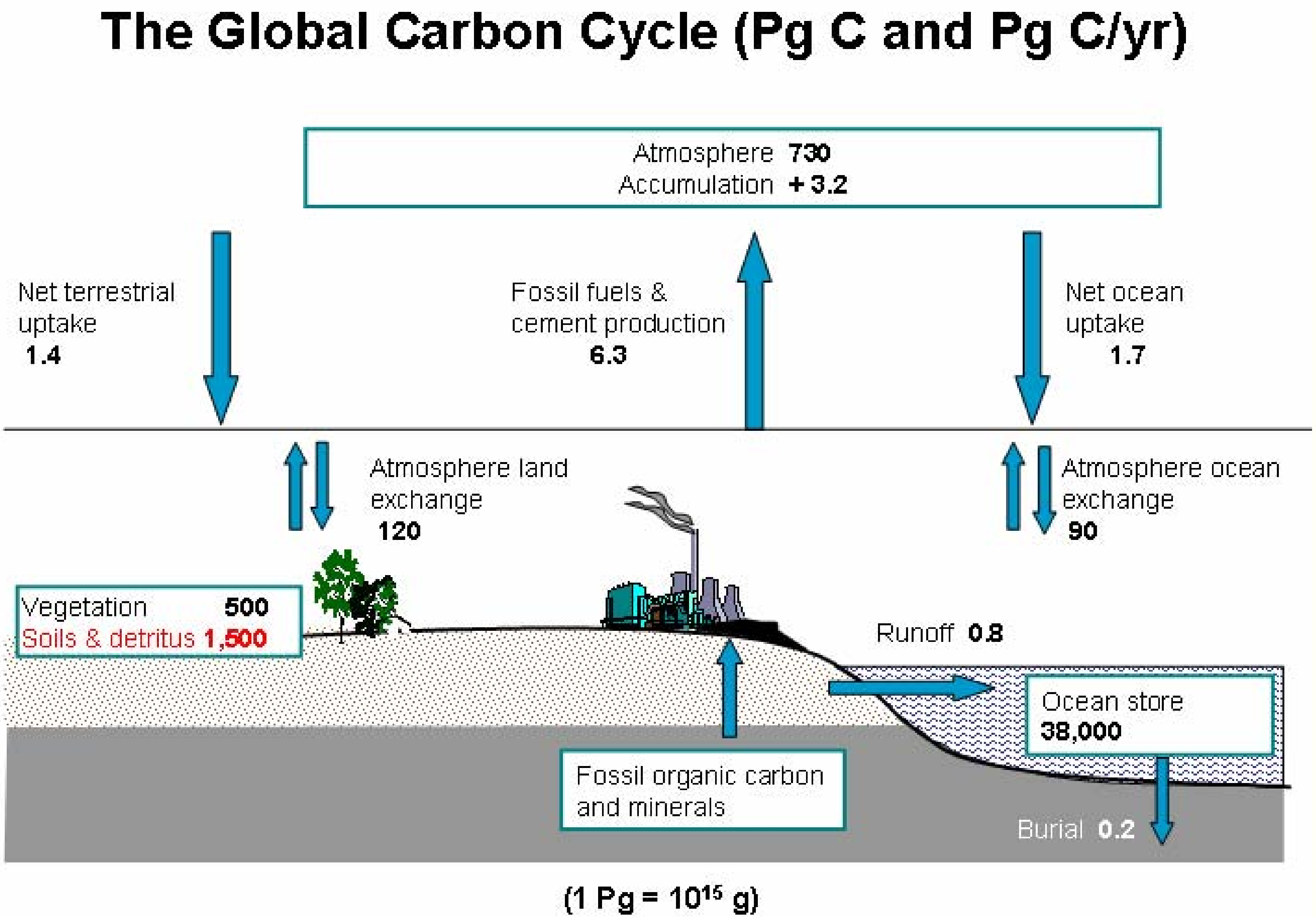


Soil Moisture and Ocean Salinity satellite (SMOS)

Launched in November 2009, the European Space Agency. SMOS makes global maps of soil moisture every three days to improve our understanding of the water cycle, benefit to agriculture and water resource management, climate modeling, forecasting floods.

Satellite spots soggy soil. Nature news. 2010.6.30

◆ Soil carbon （土壤碳）



Post W. M. et al. Soil carbon pools and world life zones. ***Nature***, 1982,298, 156 - 159

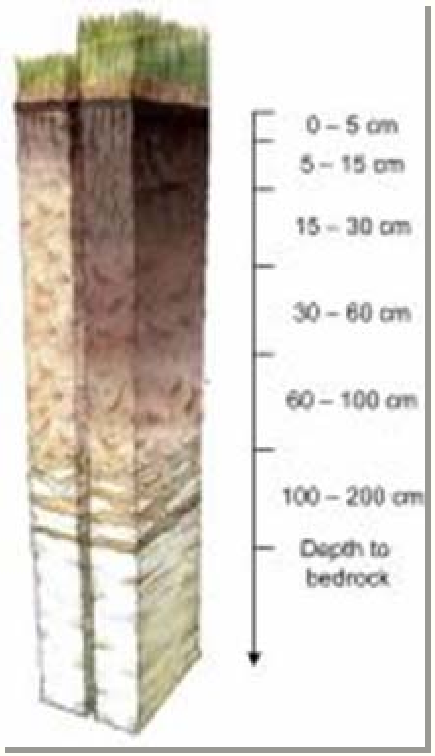
◆ Global soil map 全球土壤图库

GlobalSoilMap.net

Ten soil properties will be predicted at each location. These are:

（1）total profile depth (cm)
（2）plant exploitable (effective) soil depth(cm)
（3）organic carbon (g/kg)有机碳
（4）pH
（5）sand (g/kg),（6）silt (g/kg)
（7）clay (g/kg)
（8）gravel (g/kg) 砾石
（9）bulk density (mg/m^3) 容重
（10）available water capacity (mm)有效水容量

Additional soil properties：
（1）ECEC (cmol$_c$/kg) 有效阳离子交换量
（2）EC (dS/m) 电导率



◆ Global soil map 全球土壤图库

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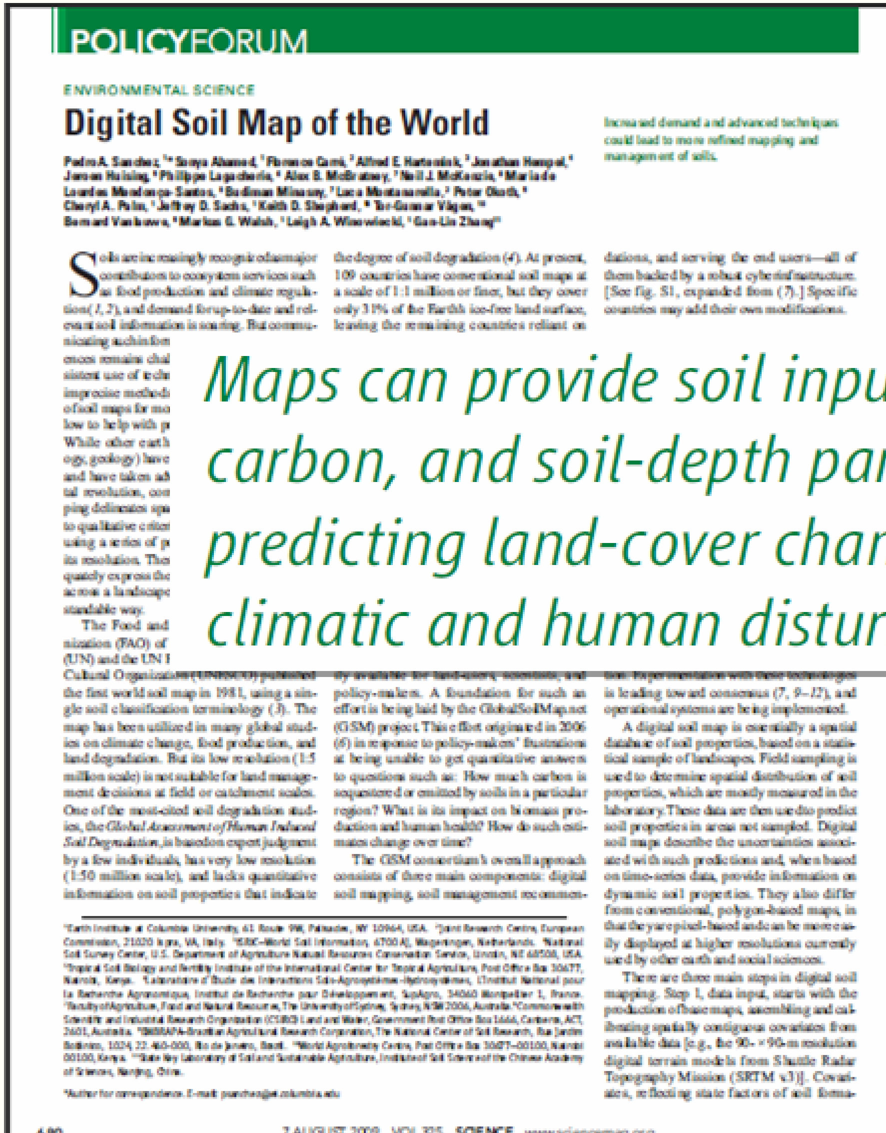
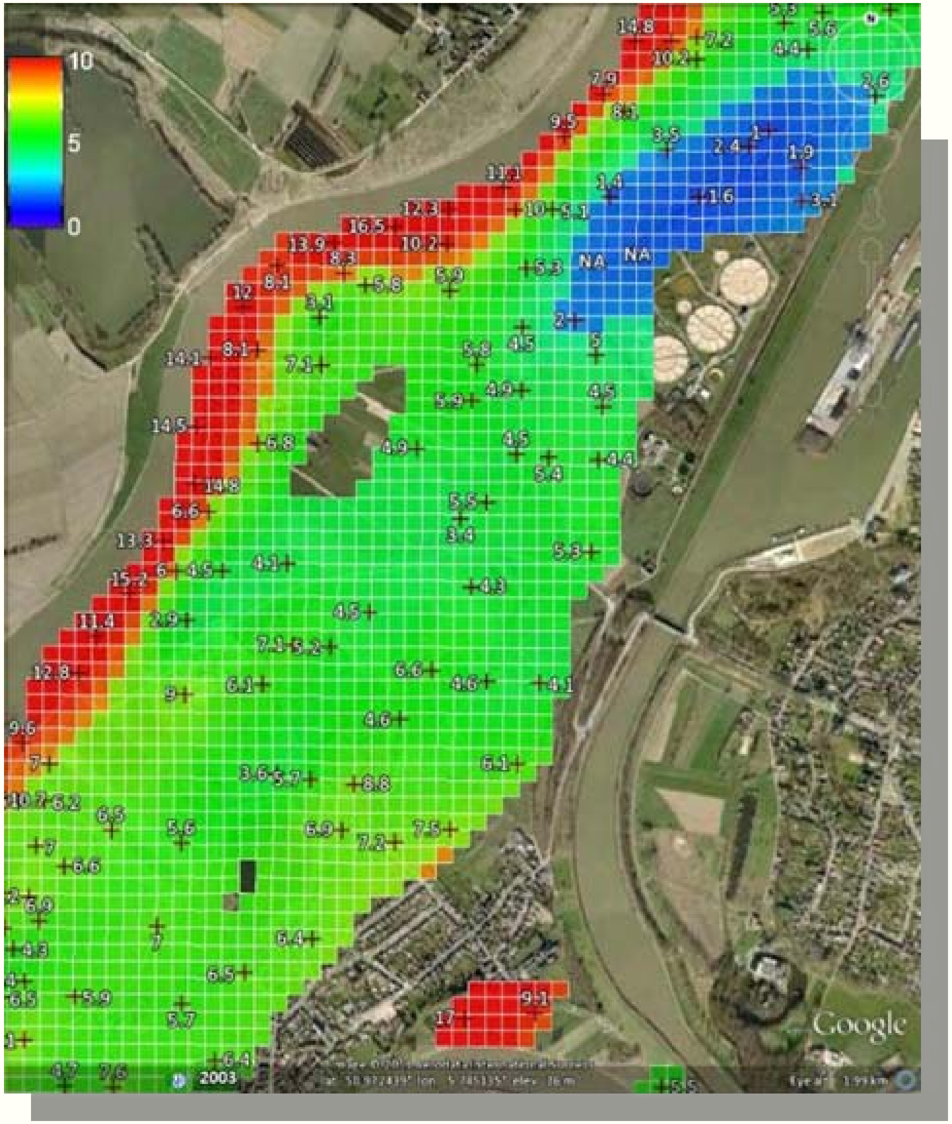


Maps can provide soil inputs (e.g., texture, organic carbon, and soil-depth parameters) to models predicting land-cover changes in response to global climatic and human disturbances.

Sanchez P A et al. Digital soil map of the world. ***Science***. 2009,325:680-681

◆ Global soil map 全球土壤图库



Predictions of **organic matter** (Meuse data) visualized using polygons (KML)

◆ Precision agriculture and food security
粮食安全与精确农业

PERSPECTIVE

Precision Agriculture and Food Security

Robin Gebbers[1]* and Viacheslav I. Adamchuk[2]

Precision agriculture comprises a set of technologies that combines sensors, information systems, enhanced machinery, and informed management to optimize production by accounting for variability and uncertainties within agricultural systems. Adapting production inputs site-specifically within a field and individually for each animal allows better use of resources to maintain the quality of the environment while improving the sustainability of the food supply. Precision agriculture provides a means to monitor the food production chain and manage both the quantity and quality of agricultural produce.

To secure food supplies for the future requires adequate quantities and quality of agricultural produce, intensive yet environmentally safe production, and the sustainability of the resources involved. In addition, the ability to track food materials from production through processing, storage, and retail provides added capability to respond to changing market conditions, ensure proper food nutrition and safety, and affect national and international policies related to food security.

Precision agriculture, or information-based management of agricultural production systems, emerged in the mid-1980s as a way to apply the right treatment in the right place at the right time (1–3). Increasing awareness of variation in soil and crop conditions, combined with the advent of technologies such as global navigation satellite systems (GNSSs), geographic information systems (GISs), and microcomputers, serve as the main drivers (1, 2). Initially, precision agriculture was used to adapt fertilizer distribution to varying soil conditions across an agricultural field. Since then, additional practices have evolved, such as automatic guidance of agricultural vehicles and implements, autonomous machinery and processes, product traceability, on-farm research, and software for the overall management of agricultural production systems.

Apart from field crop production, precision agriculture technologies have been applied successfully in viticulture and horticulture, including orchards, and in livestock production, as well as pasture and turf management. Applications range from the tea industry in Tanzania and Sri Lanka to the production of sugar cane in Brazil; rice in China, India, and Japan; and cereals and sugar beets in Argentina, Australia, Europe, and the United States (4). Despite differences in the types of technology and the areas of adoption, the goals of precision agriculture are threefold. First, to optimize the use of available resources to increase the profitability and

[1]Department of Agricultural Engineering, Leibniz-Institute for Agricultural Engineering (ATB), Max-Eyth-Allee 100, D-14469 Potsdam, Germany. [2]Biological Systems Engineering Department, University of Nebraska–Lincoln, 203 Chase Hall, Lincoln, NE 68583–0726, USA.

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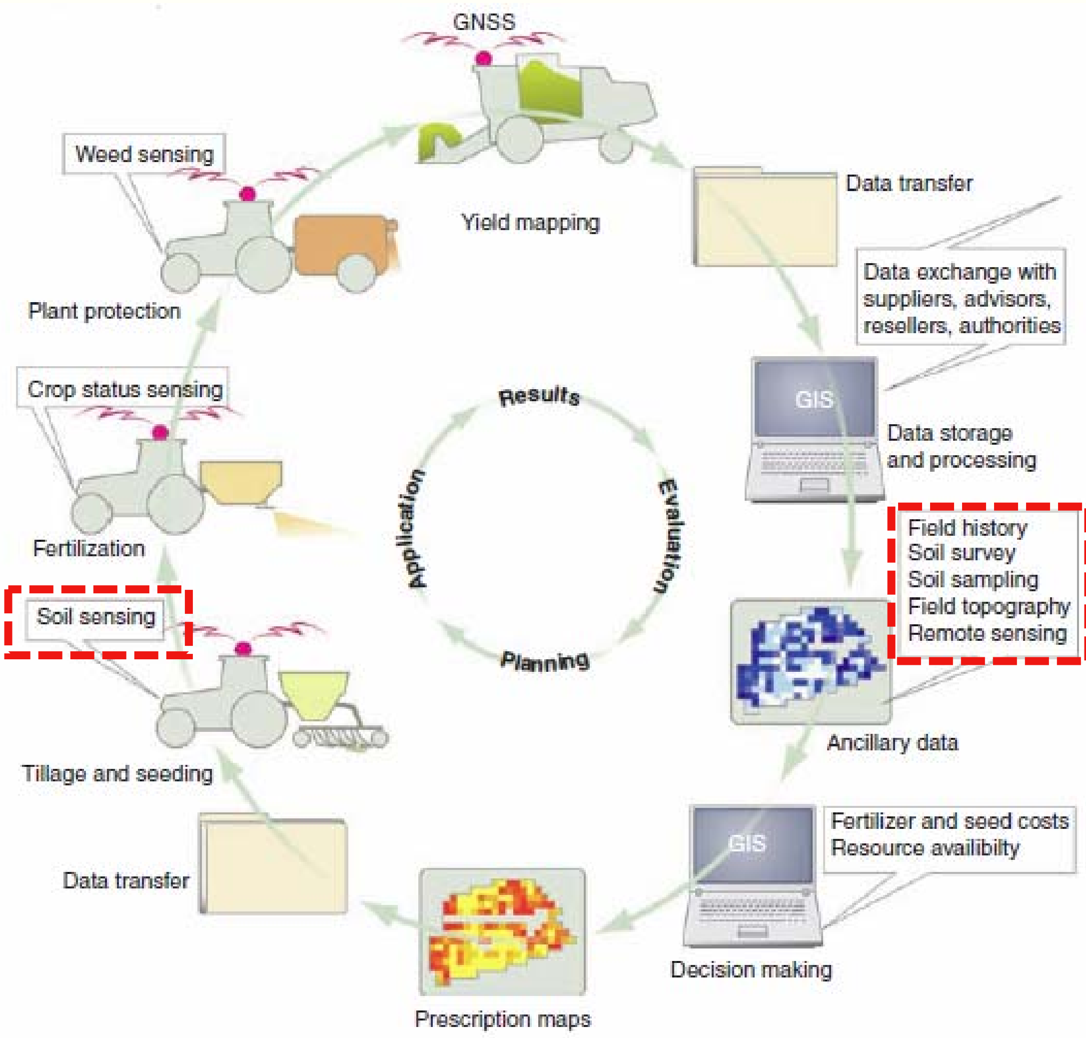
Apply the right treatment in the right place at the right time

Variation in soils and crops

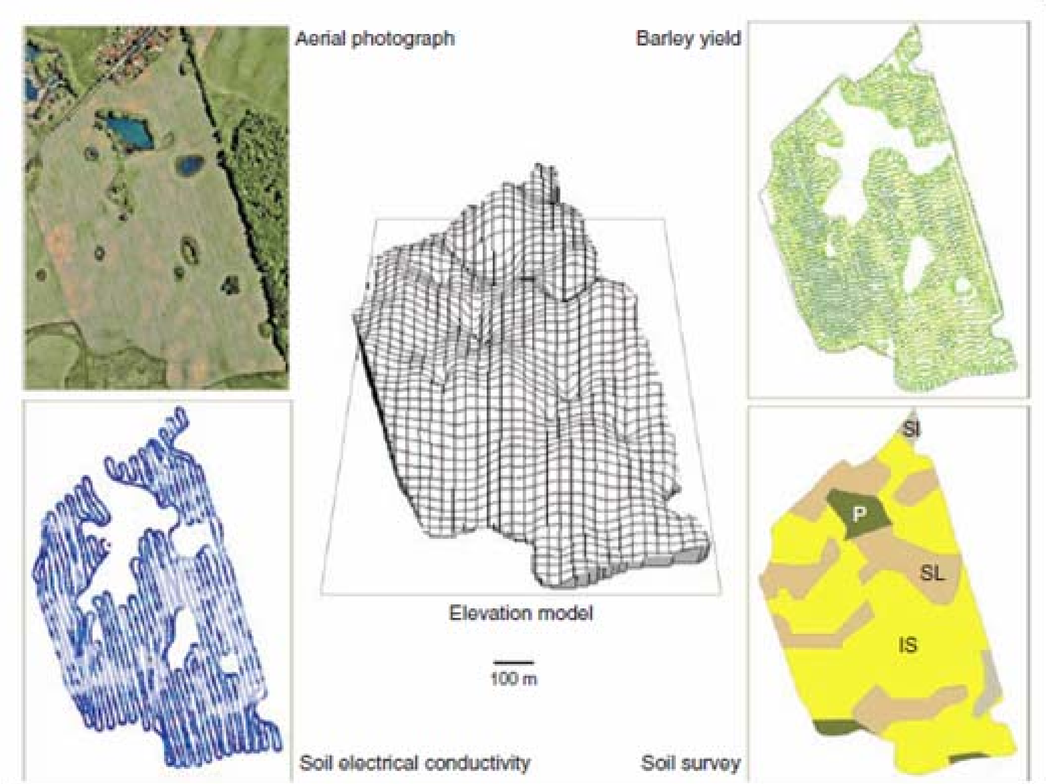
Soil and crop sensing



Gerbbers R and Adamchuk V I. Precision agriculture and food security. ***Science***. 2010,327:828-831

◆ Precision agriculture and food security 粮食安全与精确农业

Relevant properties of soil productivity are **soil moisture**, **clay content**, **organic matter content**, **nutrient availability**, **pH**, **bulk density**.



Proximal soil sensing allows for a more direct detection of soil attributes than remote sensing (8). Three types of sensors are commercially available: electrical or electromagnetic sensors that measure electrical resistivity/conductivity or capacitance; optical sensors that obtain visible and near-infrared (Vis-NIR) spectra from within the soil; and electrochemical sensors that use ion-selective membranes to detect the activity of ions such as hydrogen, potassium, or nitrate. Soil compaction sensors for site-specific tillage will also be available in the near future.

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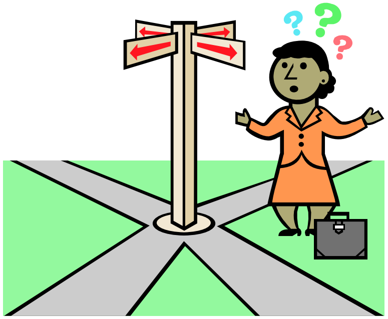
Standard, share 标准/规范/共享

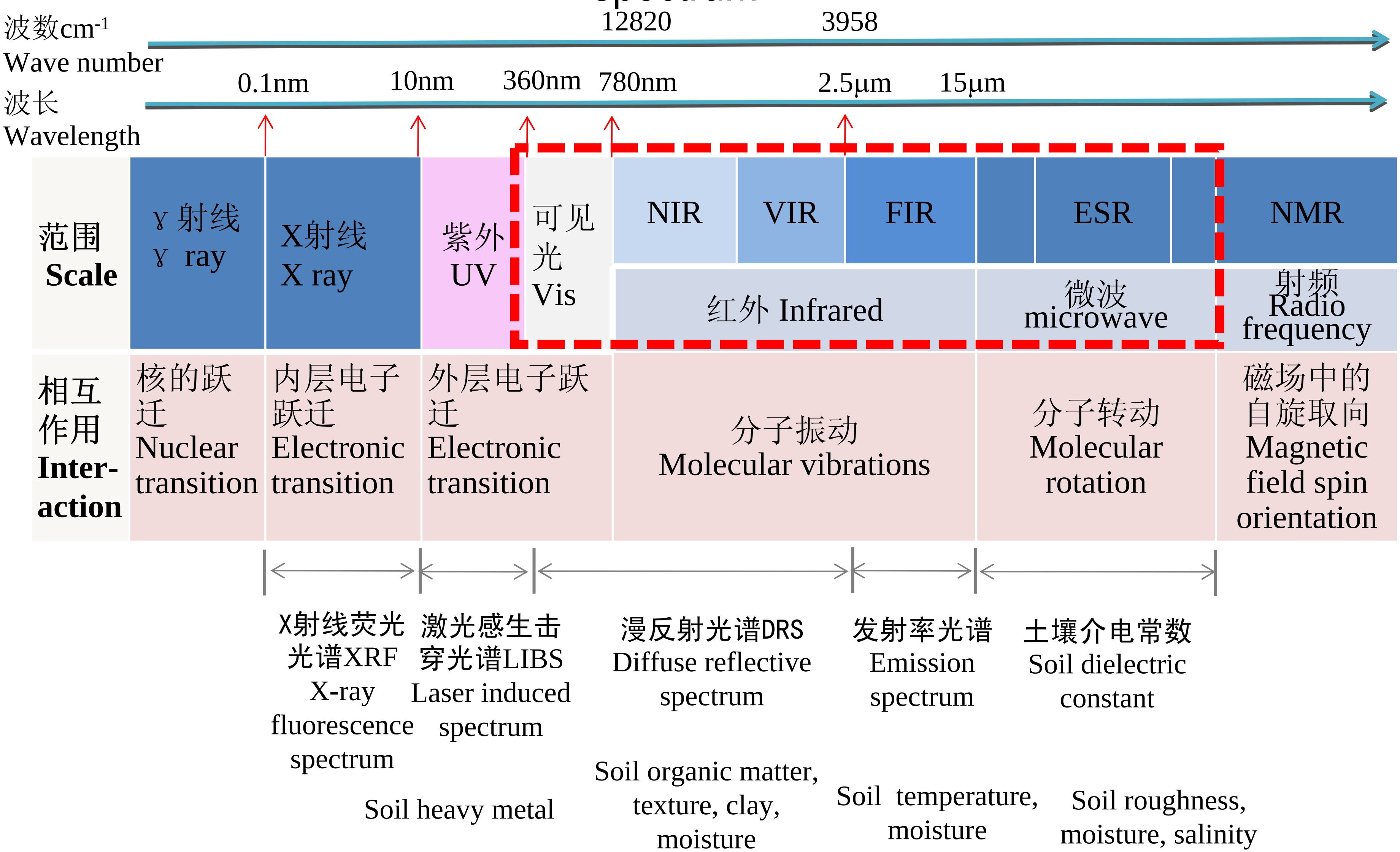
2.3 Soil proximal sensors in field

From lab to field 土壤光谱测试手段走向农田



Electromagnetic spectrum 电磁波波谱

Spectral signatures of materials are defined by their reflectance or absorbance, as a function of wavelength in the electromagnetic spectrum



Electromagnetic spectrum 电磁波波谱

EM Range			γ-rays		X-rays			UV – Visible – Infra red							Micro and Radio waves						
Frequency (Hz)			10^{22}		10^{18}		10^{16}	10^{15}	10^{13}	10^{12}		10^{10}	10^{8}		10^{7}		10^{6}	10^{2}			
Wavelength (m)			10^{-12}		10^{-10}		10^{-8}	10^{-6}	10^{-5}	10^{-4}		10^{-2}	10^{1}		10^{2}		10^{3}	10^{6}			
Technique	INS	TNM	Active γ	Passive γ	XRF	XRD	UV	vis	NIR	mid–IR	LIBS	Micro	WSN	TDR	FDR	Capac	GPR	EMI	ER	ECh	Mech
Bio-Chemical																					
Carbon	D			i	D			d	D	D	D										
Nitrate-nitrogen										i	I							i	i	D	
Phosphorus	D				D				i	I											
Potassium				D					i	I										D	
Major nutrients	D				D				i	i	D									D	
Micronutrients	D				D		D		i	i	D									D	
Total Iron	D			i	D			i	I	I	D										
Iron oxides				i			D	D	D	D											
Heavy metals	D				D			i	I	I	D										
CEC				I					I	I								i	i		
Soil pH				I					I	I			D							D	
Buffering capacity									I	I										I	
Salinity																		D	D	D	
Physical																					
Colour								D													
Water content	D	D	D	I				i	D	D		D	D	D	D	D	D	I	I		D/I
Matric potential									I	I									D		
Clay				I				i	D	D								I	I		
Silt				I					I	I								i	i		
Sand				I					i	D								I	I		
Clay minerals				I	I	D		i	D	D	I							i	i		
Soil strength																					D
Bulk density			I	I					I	I							D				I
Porosity																					D

Viscarra Rossel et al. Advances in Agronomy, 2011

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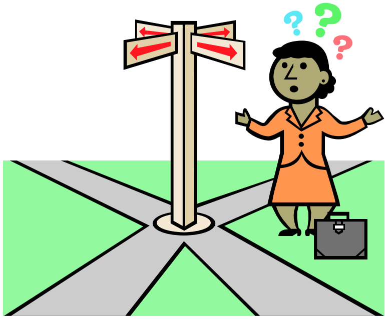
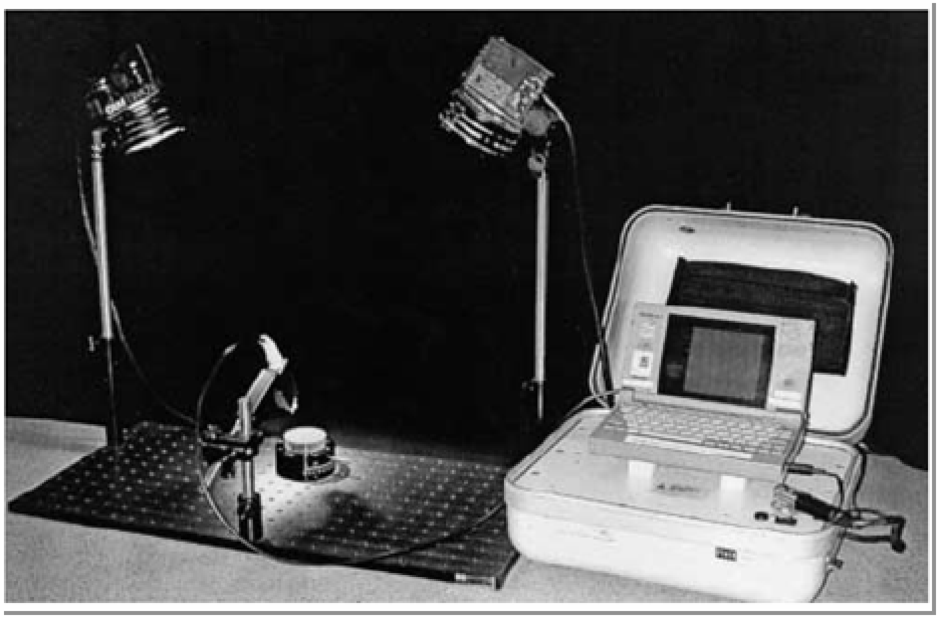
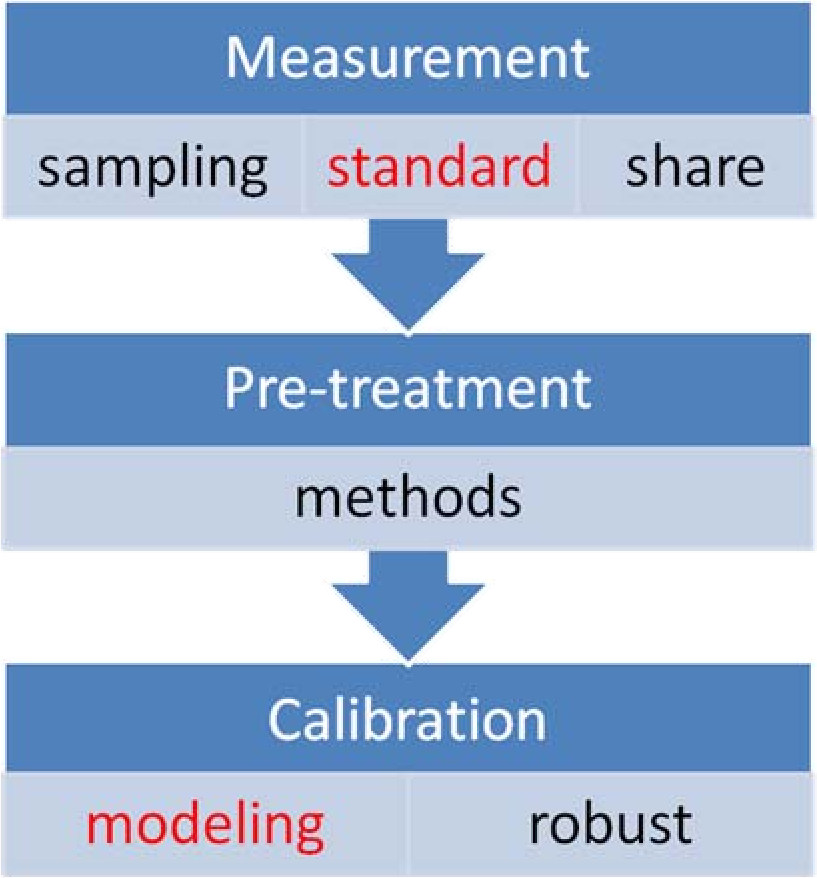


☐ Procedure of soil spectral library

Soil reflectance spectroscopy → Diffuse reflectance spectroscopy (DRS)

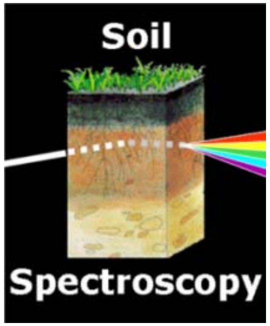




Procedures of development and application of soil spectral library

Shepherd. Development of reflectance spectral libraries for characterization of soil properties. SSSAJ 66 (2002) 988–998

◻ The global soil spectral library (GSSL)



GSSL (VIS/NIR, mid-IR)全球土壤光谱库

2008，Raphael A. Viscarra Rossel（CSIRO Land and Water）organized the “The Soil Spectroscopy Group”.

◎ 样品的典型性； ◎测试的规范性； ◎ 应用的可靠性

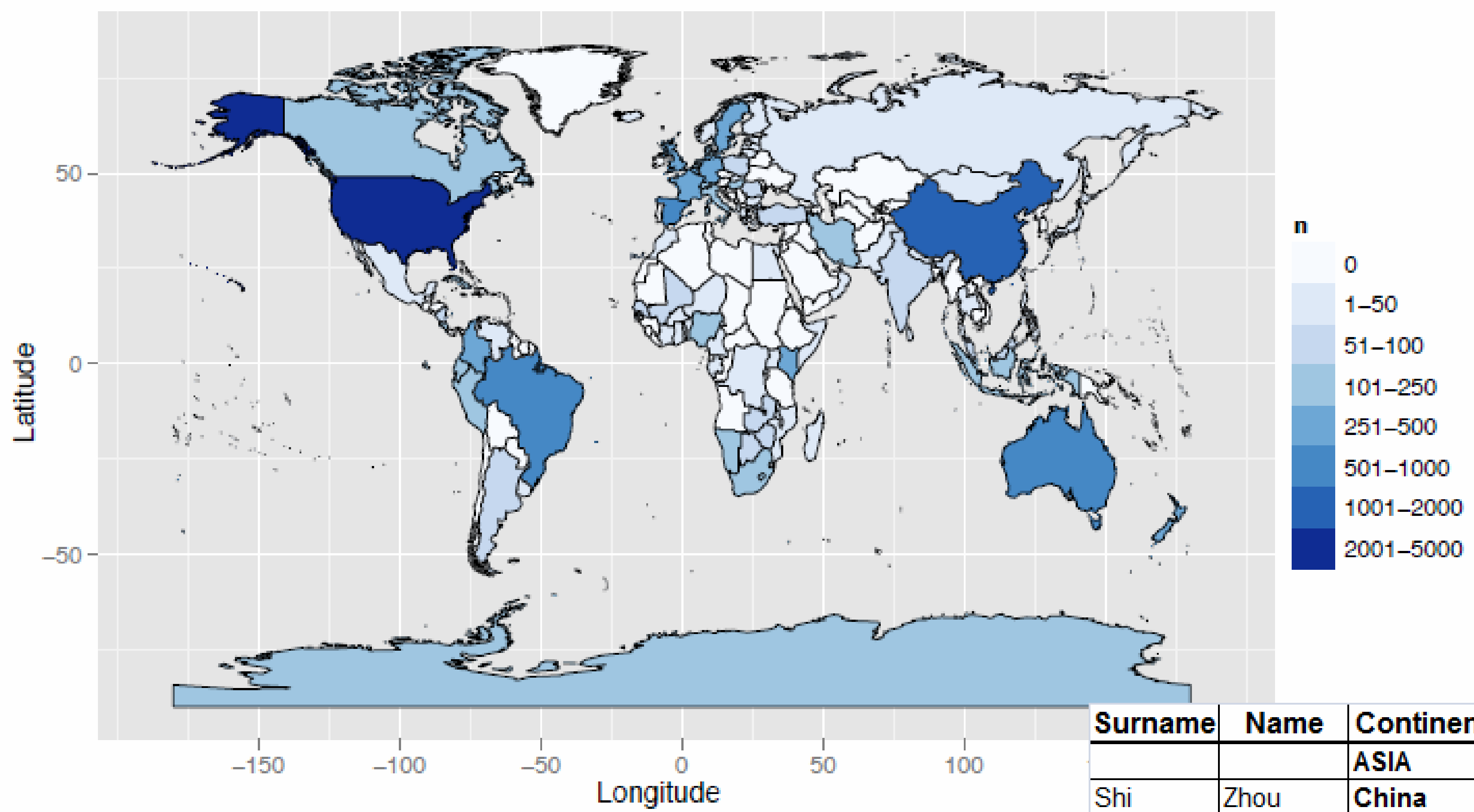
不同土壤的差异能否被漫反射光谱(DRS)所探测?

Soil variation can be characterized using Diffuse reflectance spectroscopy (DRS)?

能否利用现有数据建立全球土壤特性光谱校准模型?

How can we make Global Soil Spectral Calibration of soil properties using existing data

The global soil spectral library (GSSL)



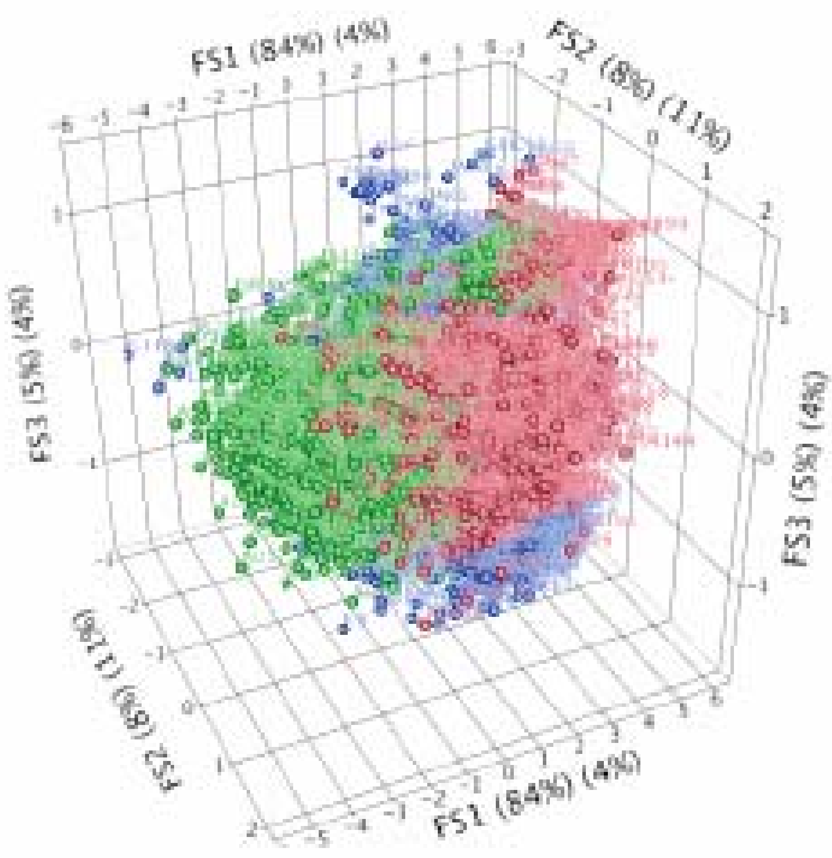
Surname	Name	Continent/Country
		ASIA
Shi	Zhou	**China**
Shibusawa	S.	**Japan**
Hache	Carolina	
Hong	Young	**Korea**
Chung	Sunok	
Kim	Hakjin	
Ben-Dor	Eyal	**Israel**
Platonov	Alexander	**Uzbekistan**

16000+ spectra come from 90+ countries

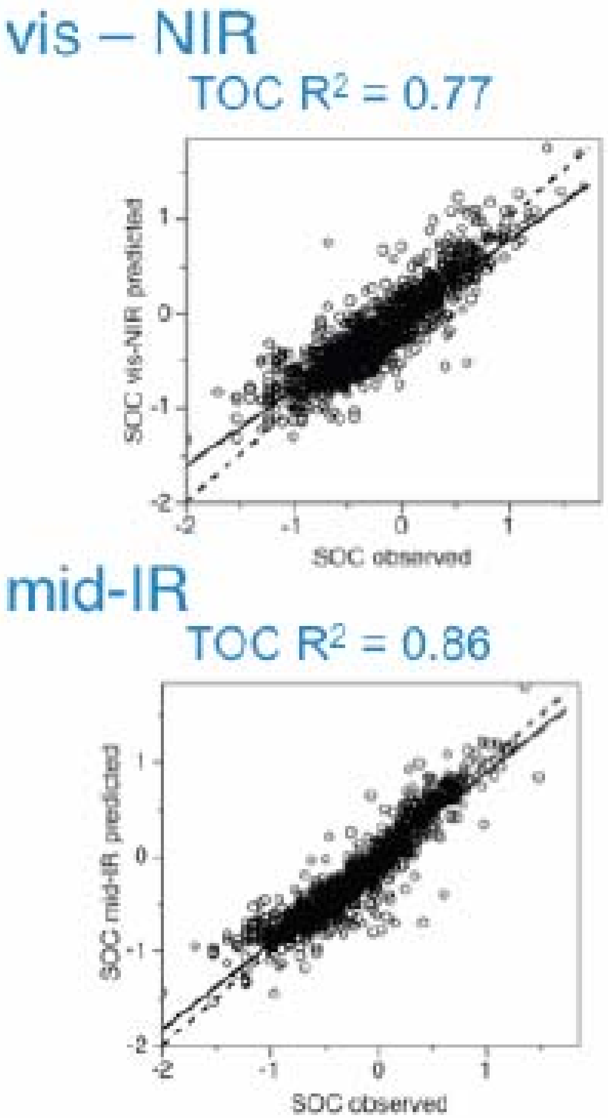
All measured with vis-NIR and some with mid-IR

from Raphael VISCARRA ROSSEL

Spectroscopic calibration to soil TOC from GSSL



Calibrations to soil OC after clustering PLS scores



The soil spectral library of China (SSLC)

locations	Soil type	Samples
河南	潮土	48
四川	水稻土	78
	紫色土	56
东北	黑土(1)	418
	黑土(2)	90
江西	红壤	195
陕西	褐土	36
西藏		44
浙江	紫色土	12
浙江	水稻土	449
浙江	滨海盐土	153
湖南	红壤	9
新疆	水稻土	193
	…	

First stages, The soil spectral library of China (SSLC) collected more than 2000 soil samples, built the linking network among several universities and institutions in China.

Supported by Ministry of education of China (MOE)

☐ Soil sampling in Tibet （色季拉山、雅鲁藏布江等地）

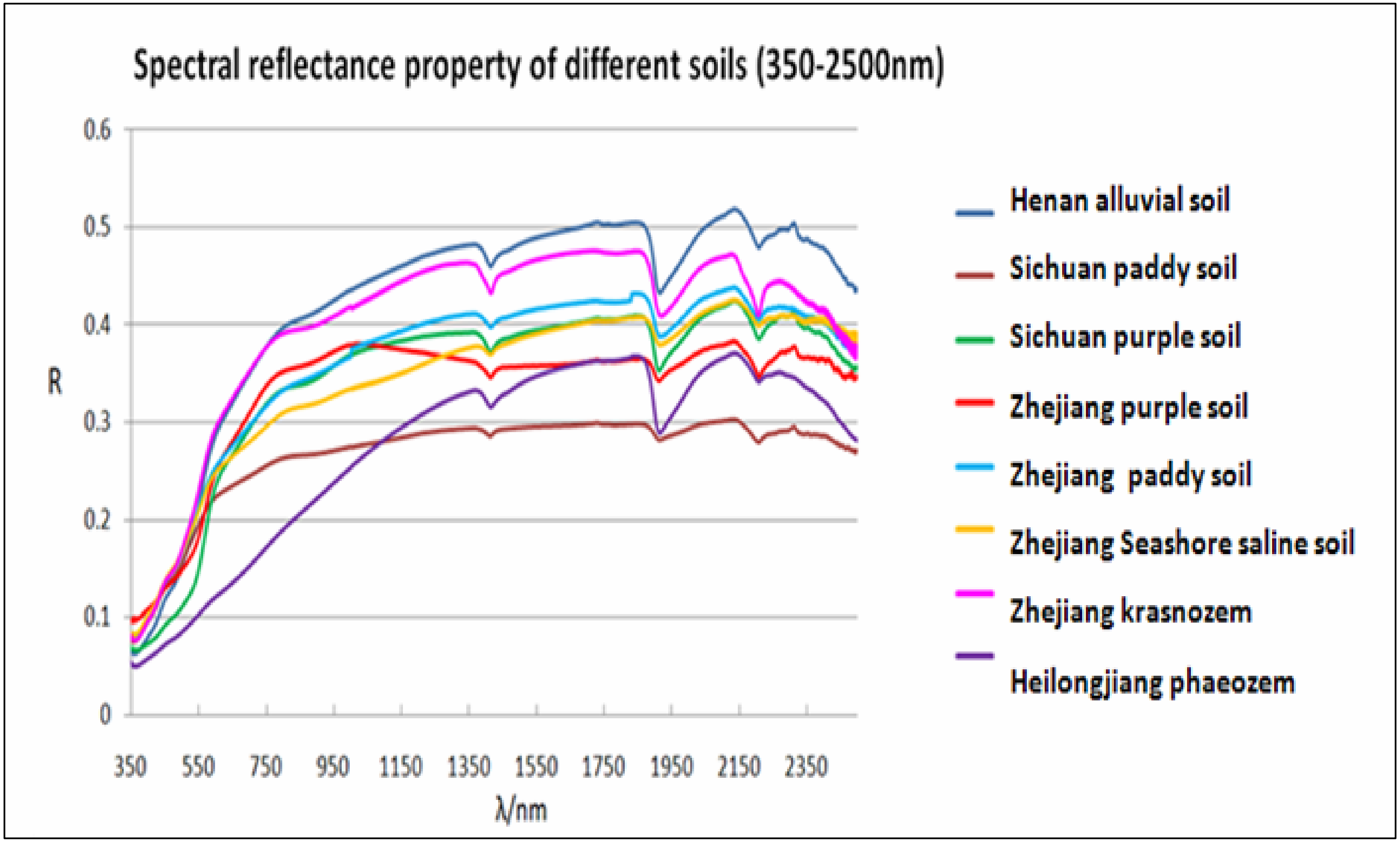
4439米海拔，高山草甸(alpine meadow)

4161米海拔，中大试验站，灌木(shrub)

3893米海拔，高山冷杉(alpine fir)

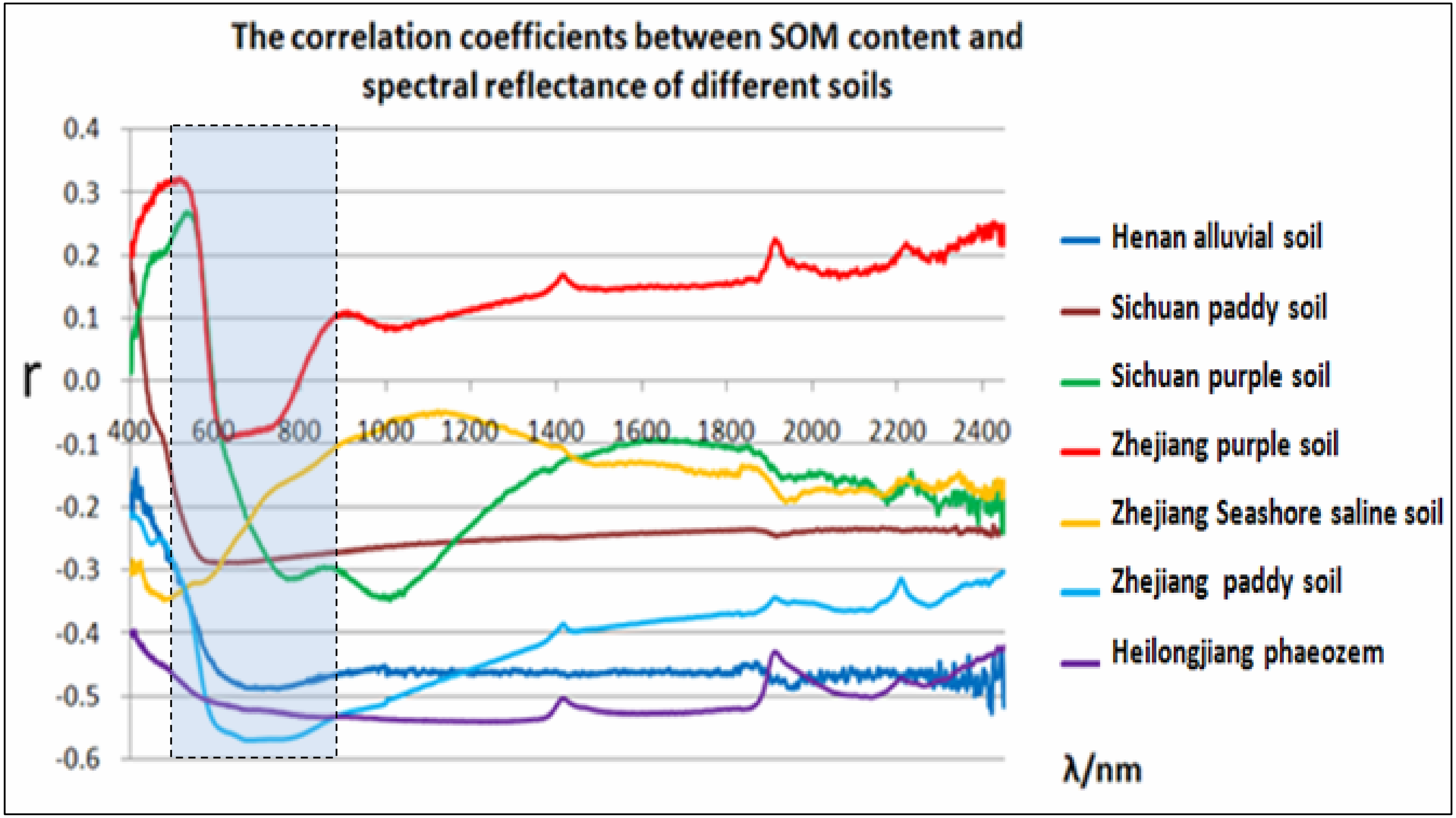
3426米海拔，青稞田(hullessbarley)

◻ The soil spectral library of China (SSLC)



Spectral reflectance of some selected soils in China

The soil spectral library of China (SSLC)



Relationship between Soil OM and spectral reflectance

Data analysis & model calibration

Multivariate calibrations

(1) Linear regressions

•Partial least squares regression (PLSR)

•Multiple linear stepwise regression (MSLR)

•Principal component regression (PCR)

(2) Data mining techniques

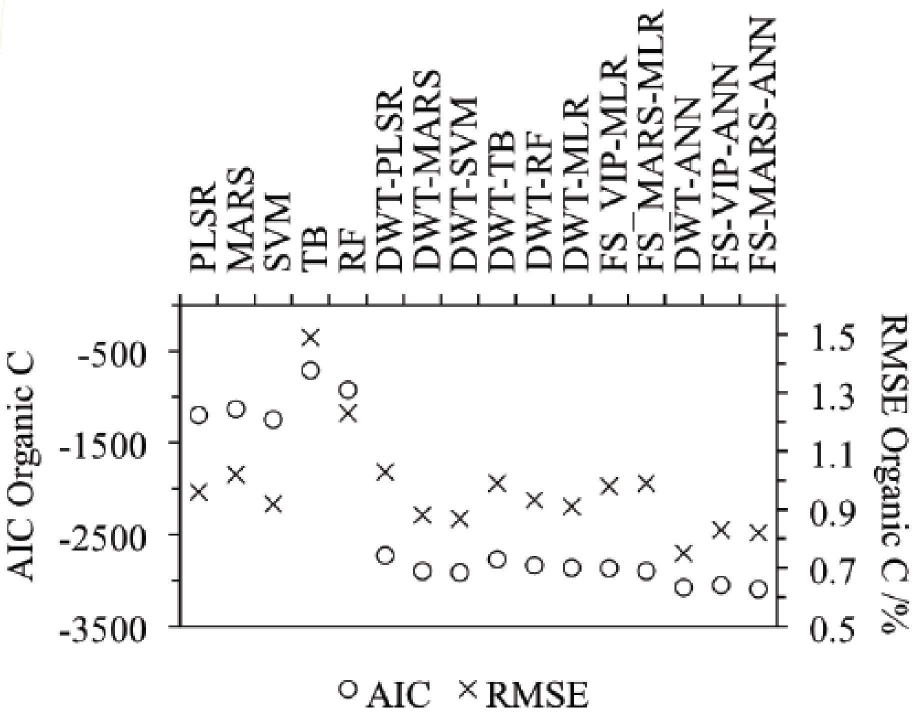
•Multivariate adaptive regression splines (MARS)

•Boosted regression trees (BT)

•Random forest (RF)

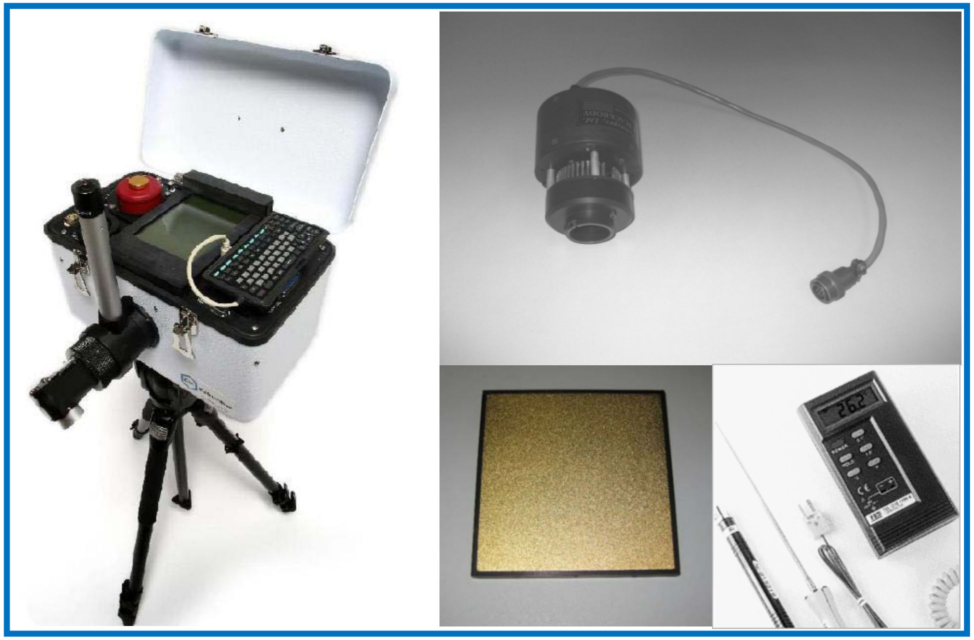
•Support vector machines (SVM)

•Artificial neural networks (ANN)

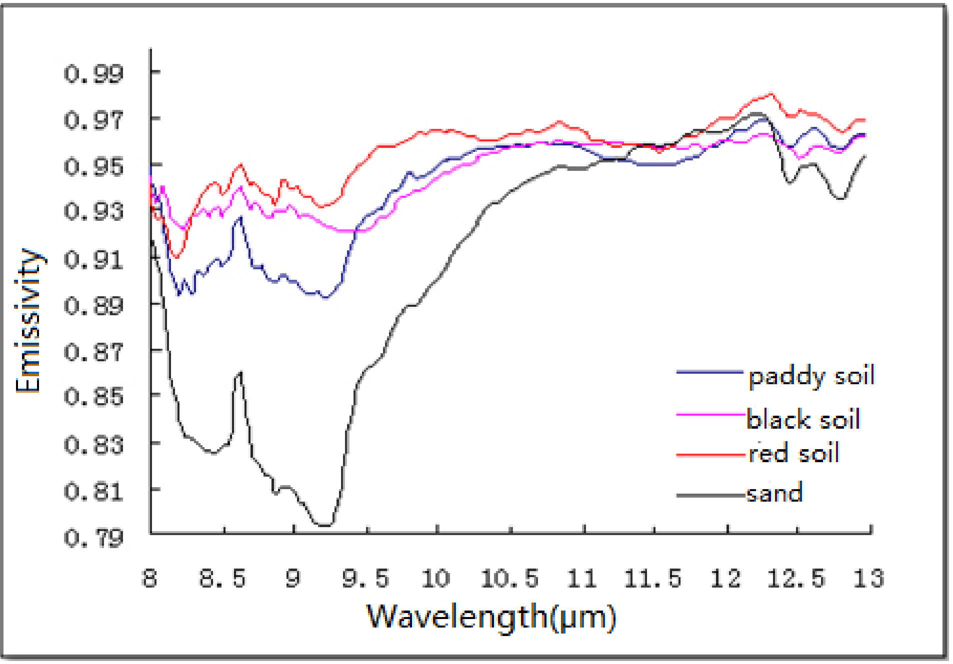


□ Thermal Infrared Spectral Property of Soil (土壤TIR特性)

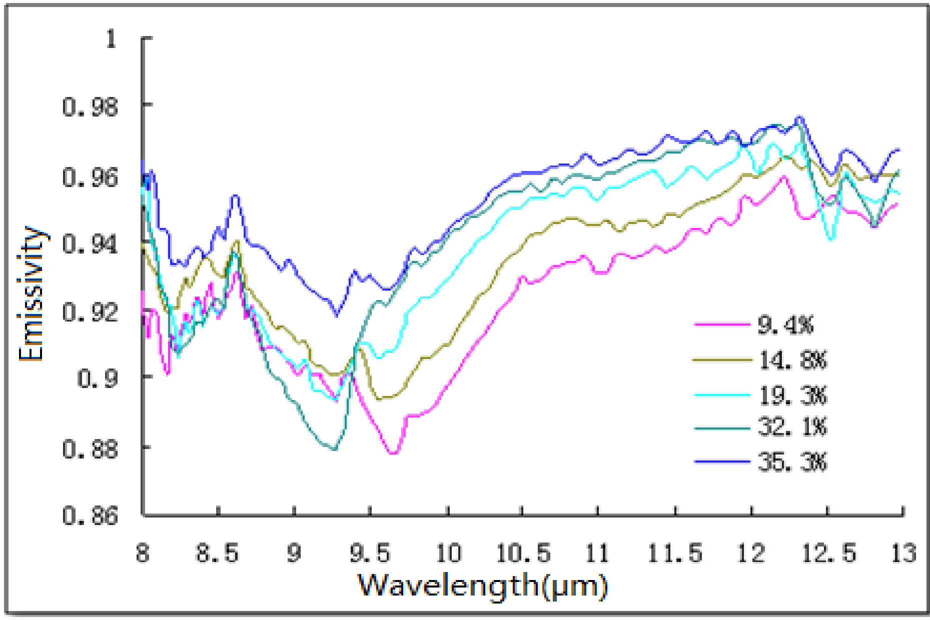
A hand portable, remote sensing FTIR spectrometer (Model 102F) is a type of Fourier transformed infrared spectrometers produced by Design& Prototypes company.(Design for *in situ* measurements)
美国Design& Prototypes公司便携式傅立叶变换红外光谱仪（102F型现场及工业用FT-IR光谱仪）



Relationship between the emissive spectral and soil property

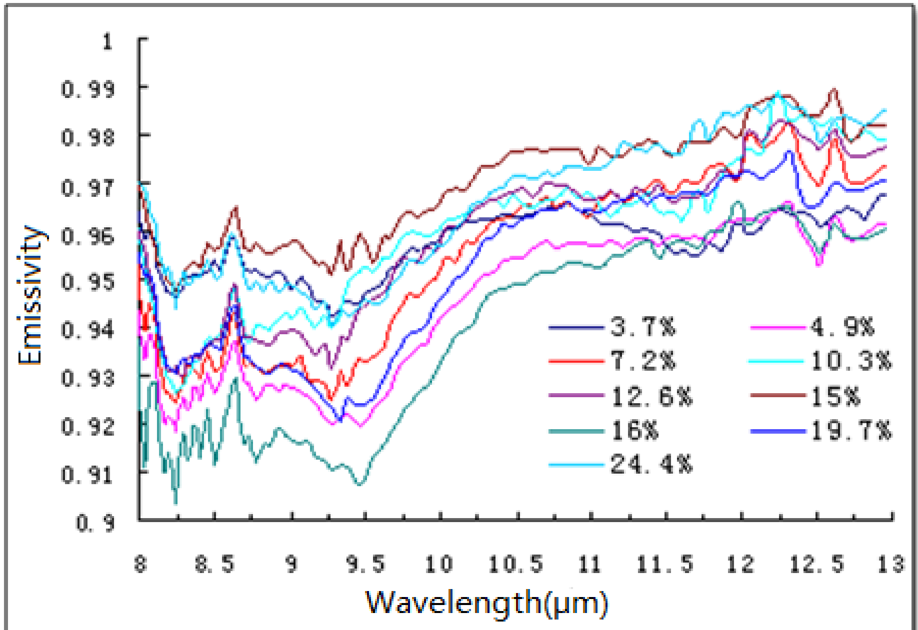


Emissive spectra feature for different soil types
不同类型土壤的发射光谱特征



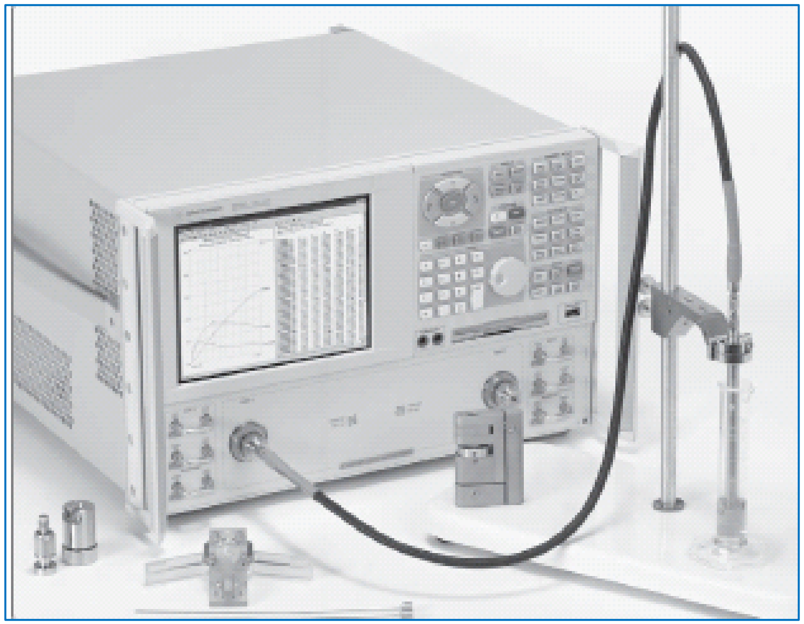
Emissive spectra feature for different soil water
不同含水量土壤的发射光谱特征

Emissive spectra feature for different soil's OM contents
不同有机质含量土壤的发射光谱特征



☐ Soil microwave dielectric properties

Soil dielectric constant was measured and analyzed using Vector Net Analyzer at different conditions



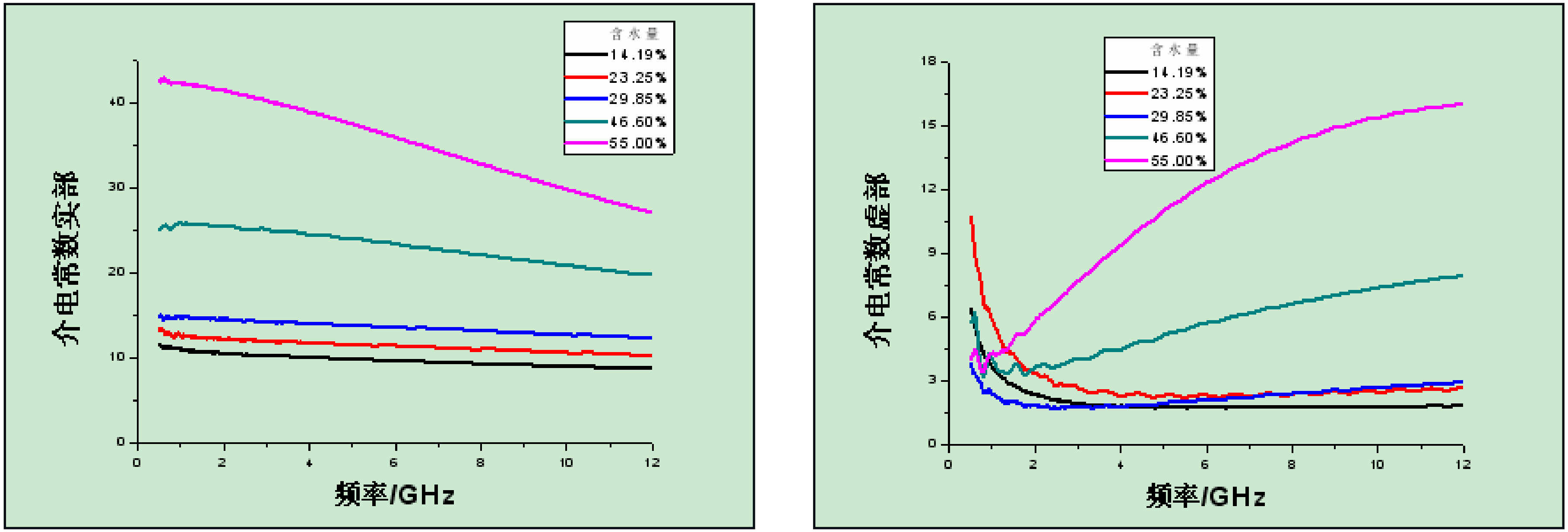
Coaxial probe method directly calculates the microwave complex permittivity of a medium by measuring the reflection coefficient of the probe terminal

Soil samples preparation

Set parameters:
Frequerency:500MHz-12GHz,concluding L S X C bands
Bands: 800
Probe pressure: according the drying condition of the samples

Install the test-bed

Measure the dielectric constant

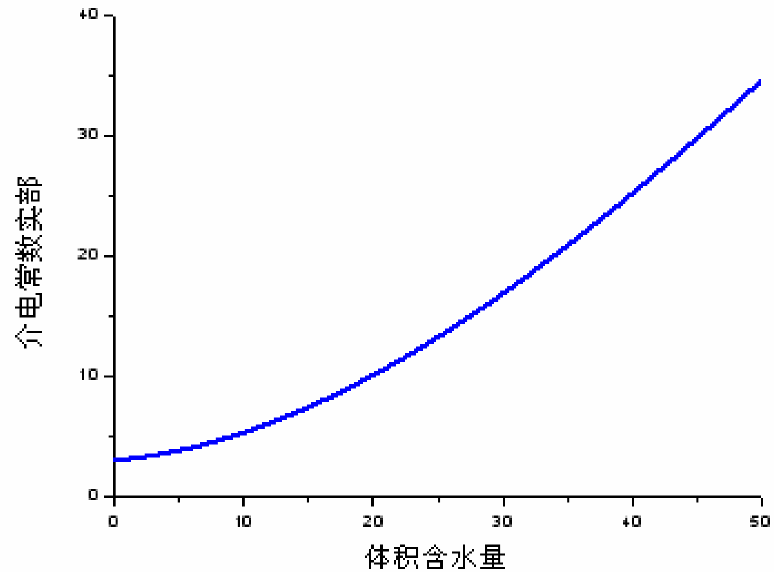


（a） （b）

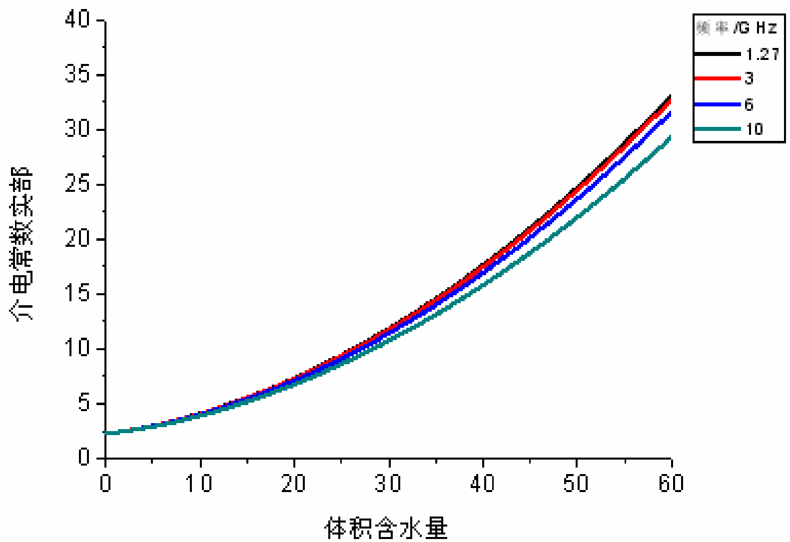
The relationship of the soil dielectric constant and the frequency

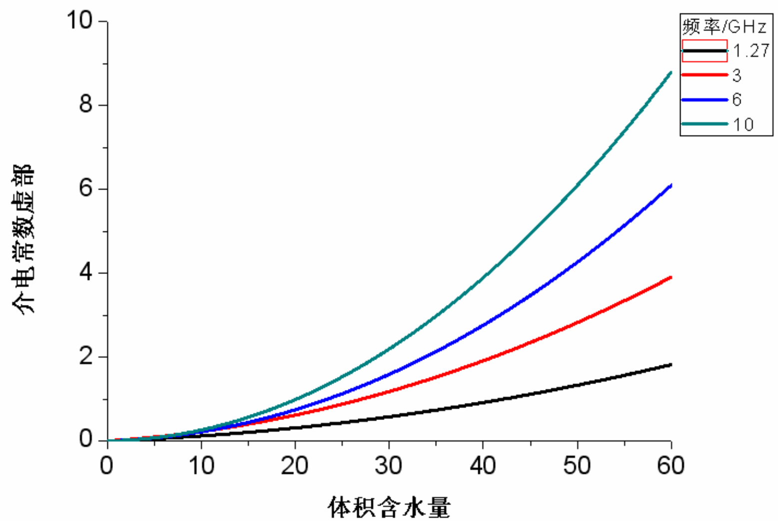
◆ The real part of the dielectric constant is increasing with the increase of the soil water content and decreasing with the decrease of the frequency. This trend is obvious at high water content but hardly changing at low water content.

◆ The imaginary part of the dielectric constant increase with the increase of the water content at higher frequency.



The relationship of the dielectric and soil volumetric water content simulated by Topp model.





The relationship of soil dielectric constant and soil volumetric water content by Dobson model at different frequencies.

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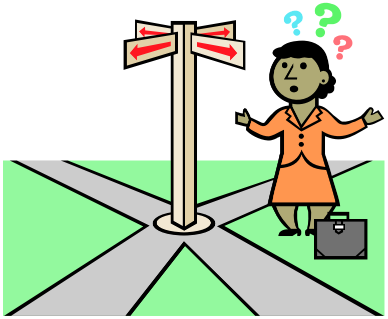


□ Application of field DRS technology

田间反射光谱技术应用

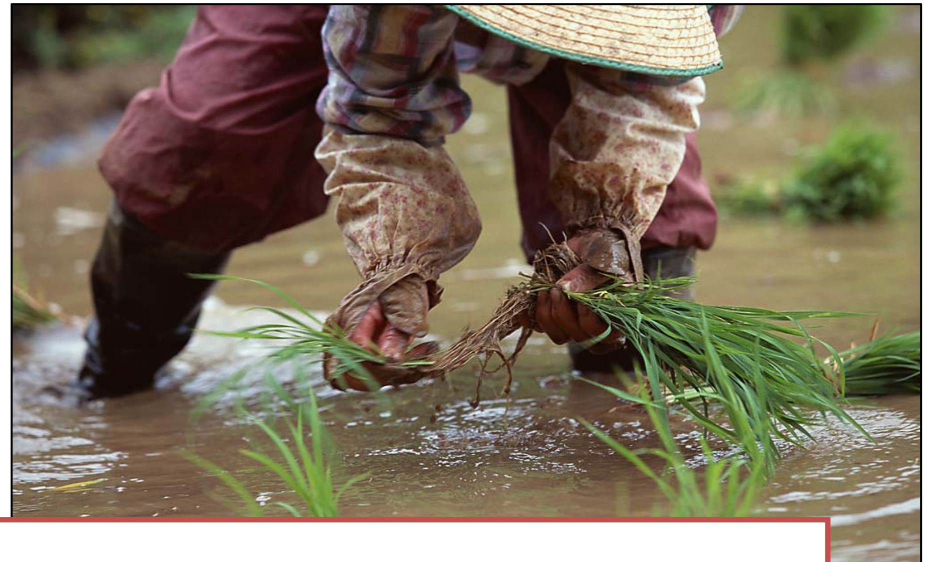
Program:

In situ Characterization of SOM of Paddy Soil with vis-NIR Diffuse Reflectance Spectroscopy (DRS)

Objective:

To evaluate the feasibility of VNIR-DRS for *in situ* quantification of organic matter content of paddy soil

Paddy soil in China



China is the largest producer of rice in the world

In situ Characterization of SOM of Paddy Soil with vis-NIR Diffuse Reflectance Spectroscopy (DRS)

1. 20cm-deep-transect

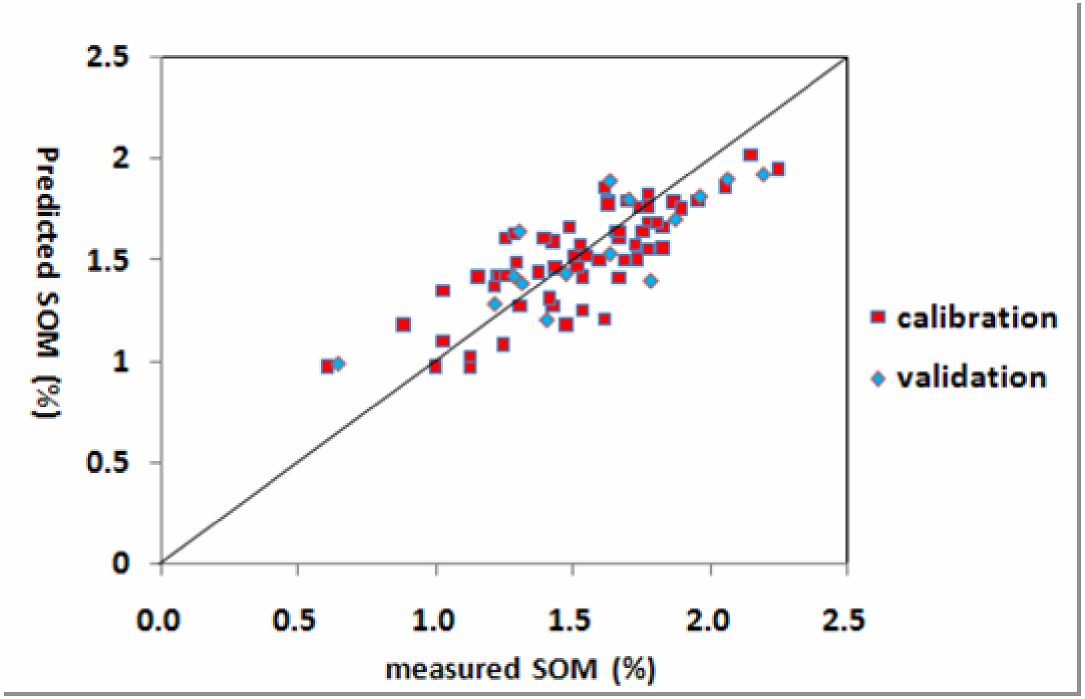
2. optimize by spectralon panel

3. scanned by spectrometer

5.Soil collection

4. Moisture measurement

In situ Characterization of SOM of Paddy Soil with vis-NIR Diffuse Reflectance Spectroscopy (DRS)



Predicted model by MLSR method, Selected bands （454,469,404nm)

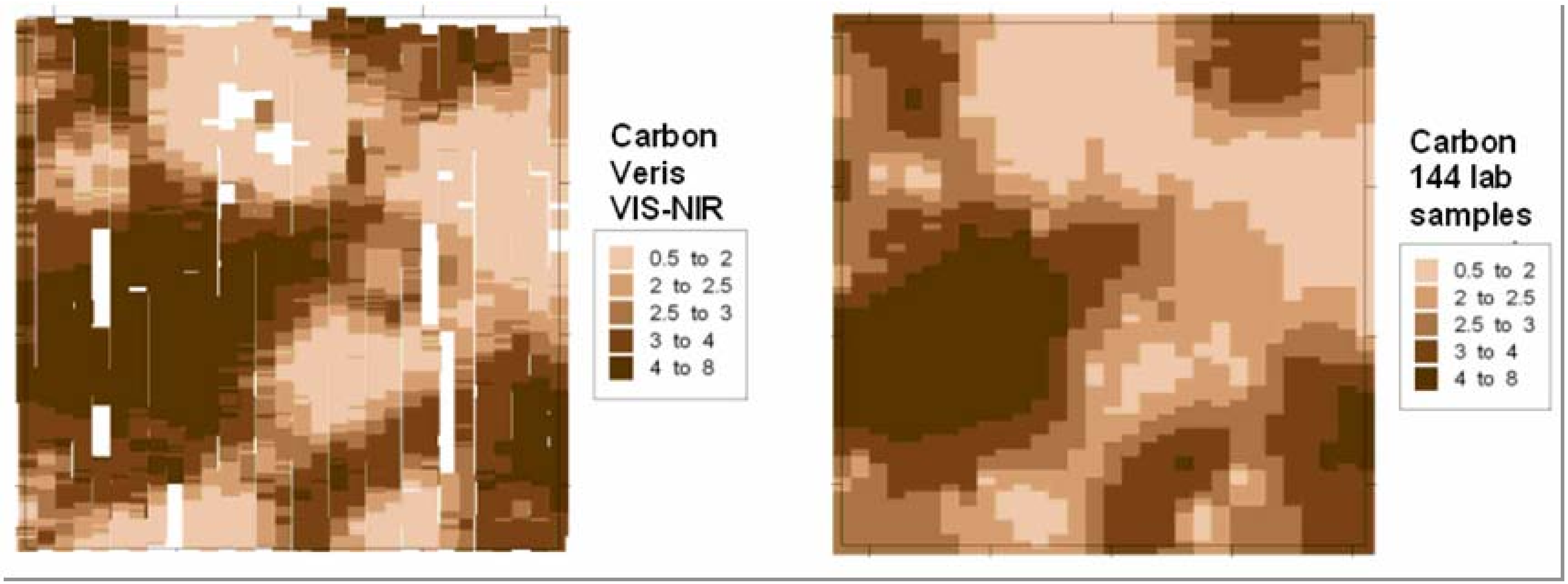
n=75, R^2=0.701, RMSE=0.215

Soil OM Range [6.02-22.4 g/kg]

On-the-go measurement by vis-NIR DRS

Vis-NIR DRS probe module(Veris P4000)

Vis-NIR DRS shank module (Veris)



☐ Soil proximal technology and sensors

National Program for Science and Technology Development in China (2006-2020)

Key fields:

- ☐ Precision agriculture, Agricultural IT
- ☐ Sensors and intelligent information processing

Area of priority:

- ☐ Agricultural Internet of things (IOT)
- ☐ Intelligent equipment or sensors

National High Technology Research and Development Program of China (*863 Program*) ------- “**Digital Agriculture**”

Agricultural sensors

- For laboratory, *in situ* field, on-the-go measurement
- Static and dynamic observation
- Robust, low power consumption, wireless communication

Plant

- Nutrient index: Chlorophyll , water, N, P, K, trace element etc.
- Physiology : Protein, amino acid, enzyme etc.
- Ecology : LAI, VI, shape, Leaf temperature, stem flow etc.

Soil

- Physics : moisture, water potential, temperature、tension, compaction, EC, salinity
- Chemistry: pH, organic matter, N, P, K, heavy metal

Environment

- Temperature, humidity, Solar radiation , CO_2

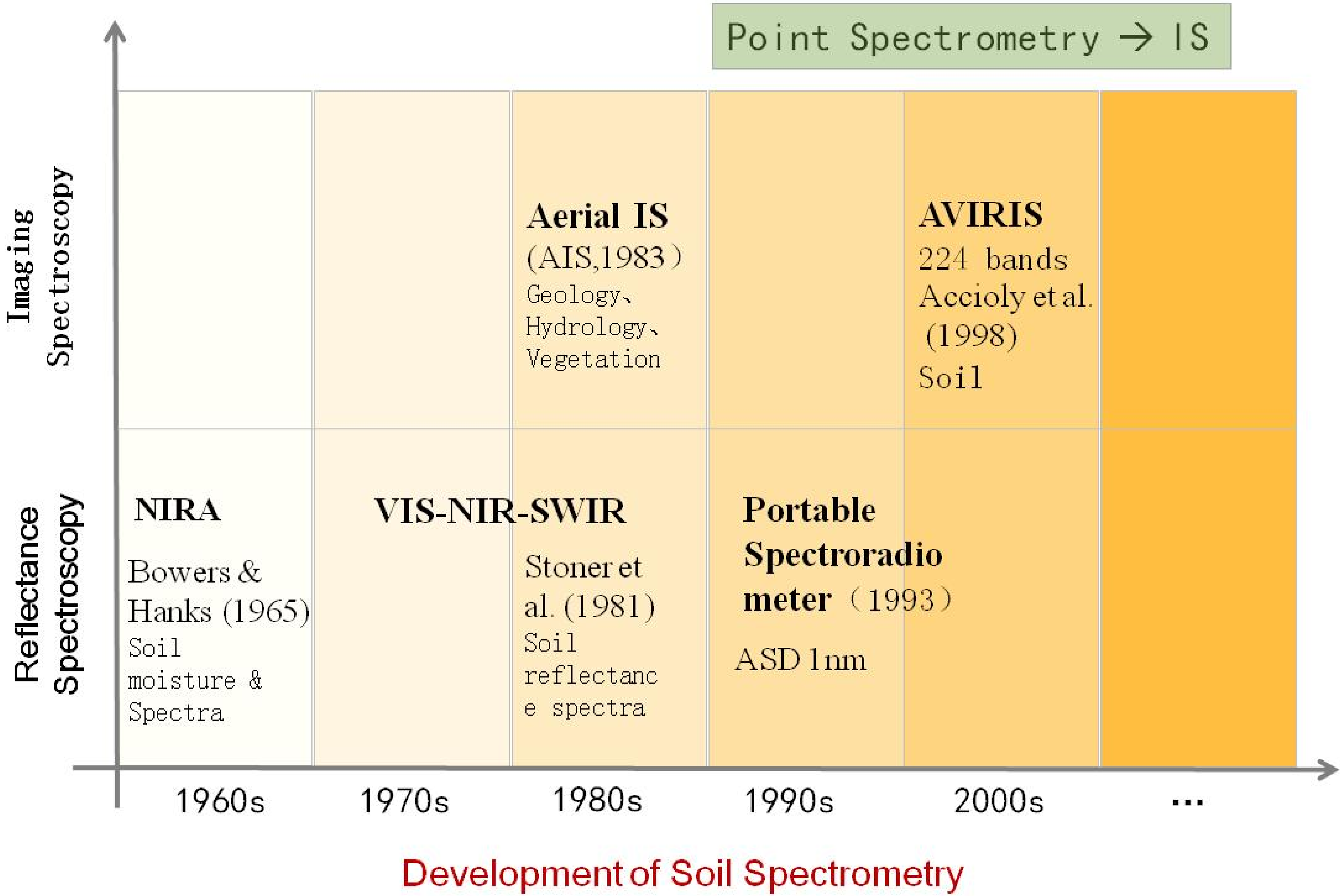
••••••••••••

Outlines

1、Introduction

2、Soil Proximal Sensors

3、Soil Remote Sensing ✓


Point Spectrometry → IS
Imaging Spectroscopy
Reflectance Spectroscopy
Aerial IS
(AIS,1983)
Geology、Hydrology、Vegetation
AVIRIS
224 bands
Accioly et al. (1998)
Soil
NIRA
Bowers & Hanks (1965)
Soil moisture & Spectra
VIS-NIR-SWIR
Stoner et al. (1981)
Soil reflectance spectra
Portable Spectroradio meter (1993)
ASD 1nm
1960s
1970s
1980s
1990s
2000s
...
Development of Soil Spectrometry

□ Problems to soil remote sensing

Going from point (spectrometer) to image spectrometry (remote sensing) is not only a journey from micro- to macro-scales but also a long stage that encounters problems such as dealing with data having a ***low signal-to-noise level***, ***atmospheric interference***, shade and shadow effects, ***mixtures*** of materials within pixels, the ***BRDF*** effect, variation in soil ***moisture*** content, and more.

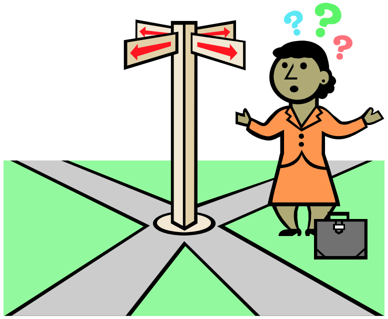
(大气干涉、地面覆盖物阴影、粗糙地表的二向反射影响、混合像元、表土水分空间异质性等)

Shepherd. Development of reflectance spectral libraries for characterization of soil properties. SSSAJ 66 (2002) 988–998

3.1 Soil OM/Carbon remote sensing

3.2 Soil moisture remote sensing

3.3 Application of soil remote sensing



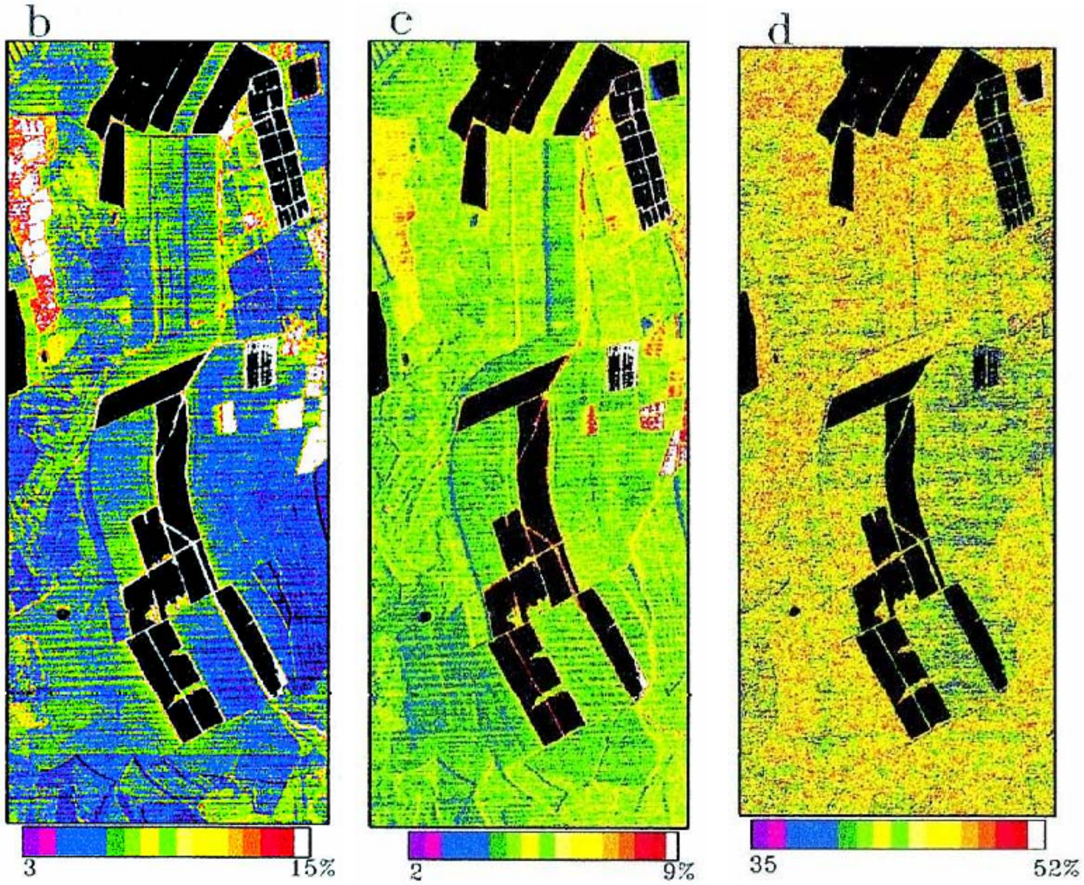
□ Soil OM/Carbon remote sensing
土壤有机质/碳遥感获取

Source image	Wavelengths	R^2
SPOT	R–G	0.22
Aerial photograph	B–G–NIR	0.22–0.28
AVIRIS	VIS–NIR	0.72
Arial photograph	B–G–R	0.92
Color slide	B–G–R	0.93
ATLAS	R–NIR	0.95
ATLAS	G–R–NIR	0.89
Landsat TM	G–R–NIR	0.51
IKONOS	B–G–R	0.06
Digital orthophotograph	B–G–R	0.08–0.16
Hyperspectral image	VIS–IR	0.74

*ATLAS： digital aerial images by NASA ATLAS sensor
* AVIRIS: Airborne Visible / Infrared Imaging Spectrometer

◘ Hyper-spectral aerial remote sensing 高光谱航空遥感

DAIS-7915
0.4-12.6 μm
79 bands

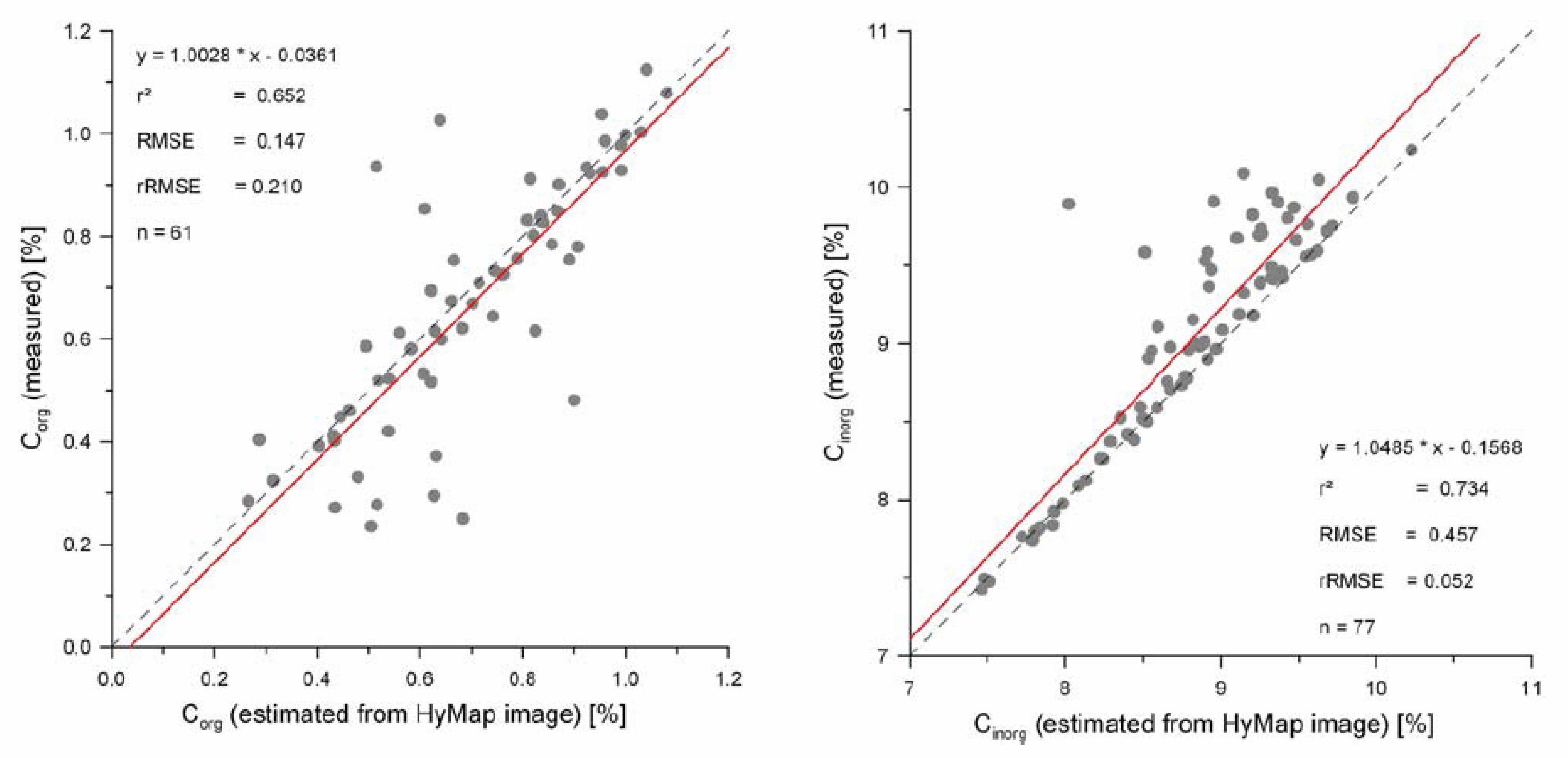


b)田间水分(Filed moisture,FM), (c)有机质(OM), (d) 饱和含水量(Saturated moisture, SM)

Ben-Dor,E. *et al*. l. Int. J. Remote Sens. 2002, 23, 1043–1062.

☐ Detecting soil OC and IC
土壤有机和无机碳提取

Hymap, 0.45-2.5 μm
128 bands



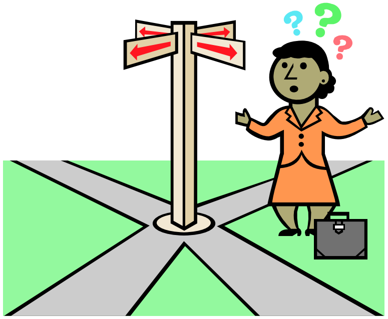
Validation results for the organic (left side) and inorganic (right side) carbon contents estimated from the HyMap image data. The red lines show the linear regression between the modelled and measured values. The dashed lines indicate a linear 1:1-relationship.

Thomas, J. *et al*. 2007. *Proceedings of 5th EARSeL Workshop*

3.1 Soil OM/Carbon remote sensing

3.2 Soil moisture remote sensing ✓

3.3 Application of soil remote sensing



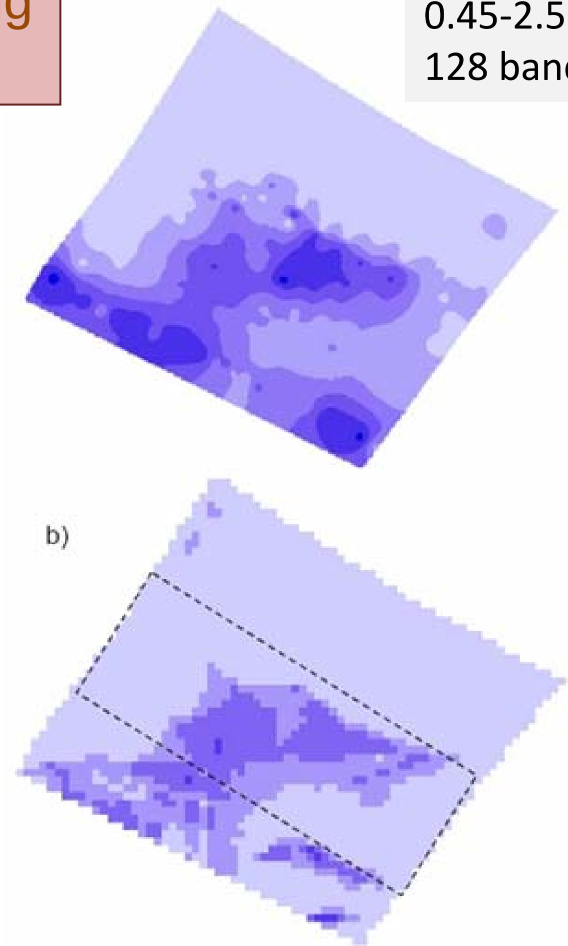
Soil Moisture Retrieving by Remote Sensing

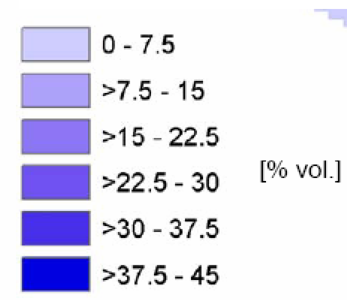
Sensor types	Methods	Advantages and disadvantages
Optical remote sensing	Statistical relational model-based	The relationship with the soil moisture spectral characteristics is not closely. interfered by vegetation layer ,weak ability to penetrate the surface , seriously affected by atmosphere and clouds , rarely applied in soil moisture detection
Thermal infrared remote sensing	(1)Bare soil or low vegetation coverage areas：Thermal inertia (2)High vegetation coverage areas：TVDI,CWSI	With the advantages of **macro and high time resolution**, it has superiorities in the large range of soil moisture detection and river basin drought early warning.
Passive microwave remote sensing	(1)Empirical model: Inversion soil moisture by using brightness temperature and establish a linear relationship (2)Theoretical model based on radiative transfer equation	With the definite rationale, **high time resolution** and relatively-low spatial resolution(about 10-50km)，it fits soil moisture monitoring by remote sensing on **the regional even global scales**.
Active microwave remote sensing	(1) Theoretical model：Kirchhoff ,SPM,IEM (2) Semi-empirical model & Empirical model： Oh Model, Dubois Model, Shi Model (3) The model of the high vegetation coverage areas ：Water-Cloud Model, MIMICS Model	It has the quality of **all-day and all-weather** resistance to mist and weather, and high spatial resolution relative to passive microwave sensor , making the advantage on Soil moisture detection.

→Hyper-spectral aerial remote sensing 高光谱航空遥感

Hymap
0.45-2.5 μm
128 bands

HyMap image from July 30th 2004 (RGB from bands 13/7/2). The red line depicts the boundaries of soil moisture measurements in the field



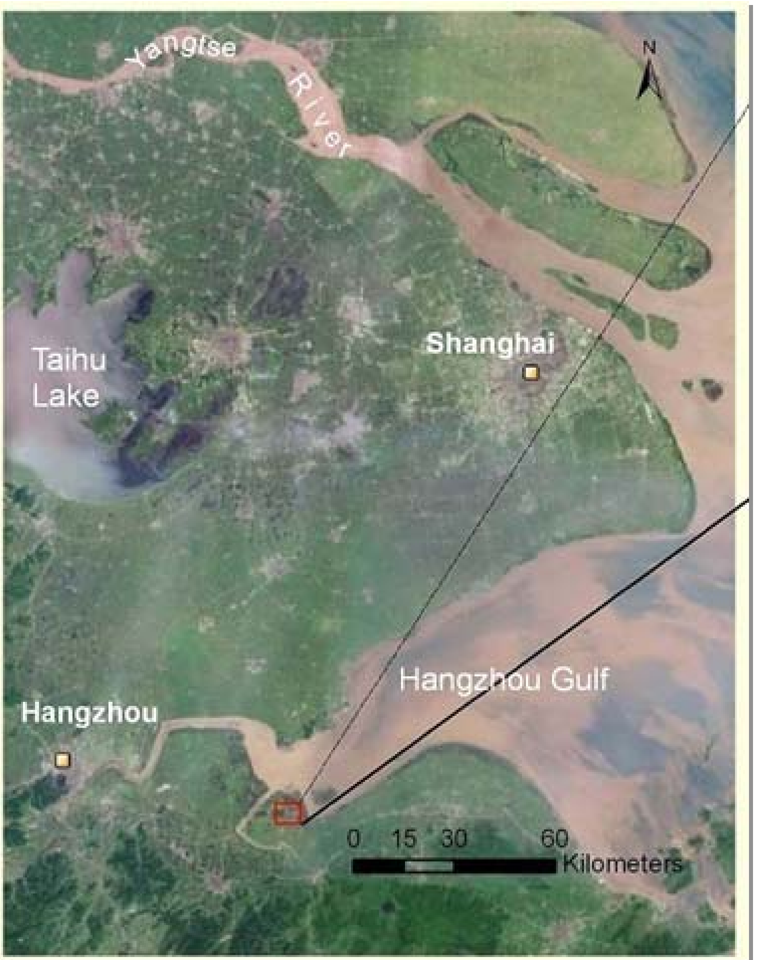


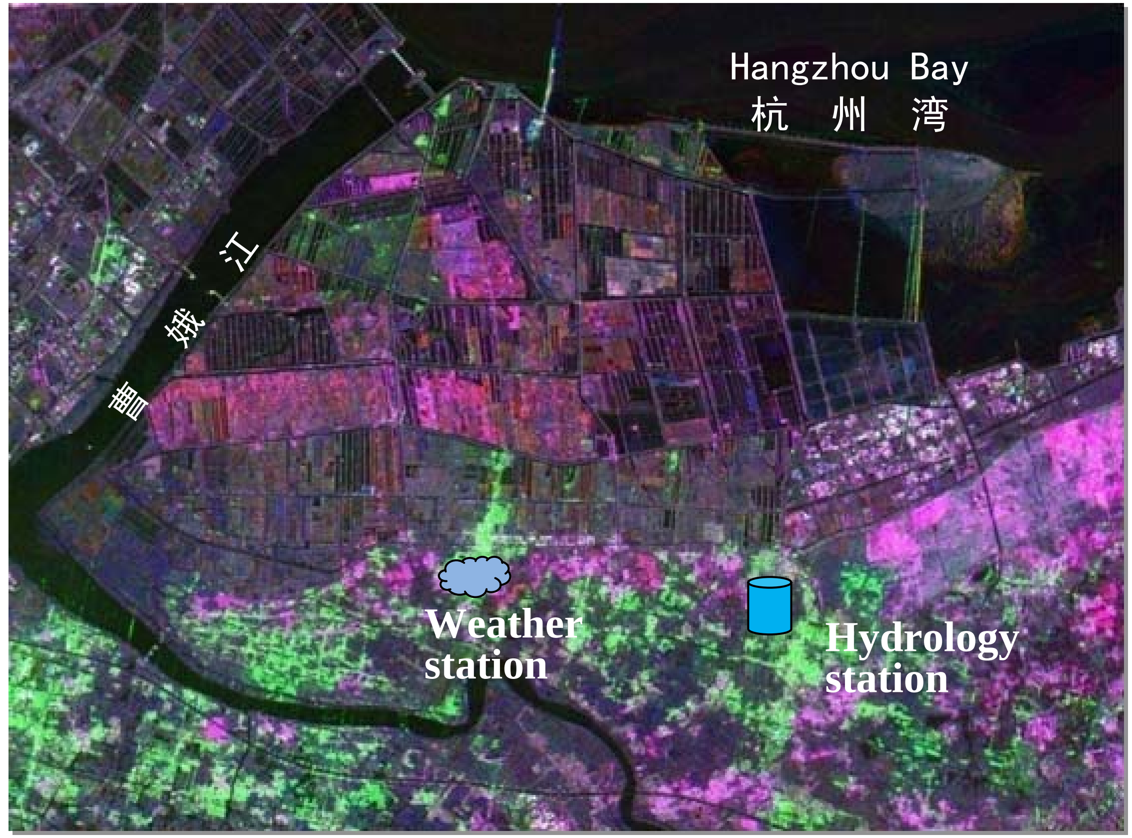
Surface soil moisture from July 30th 2004 determined from (a) FDR（频域反射仪）*field measurements and (b) HyMap-based ratio calculation (**1288 vs. 1515 nm**) based on the regression function for quaternary sand. The dashed line shows the part of the area being covered with quaternary sand*

Haubrock, S. *et al*. 2005. *Proceedings of 4th EARSeL Workshop*

→Active microwave remote sensing
主动微波遥感

Detecting soil moisture based on ALOS/PALSAR





Multi-temporal SAR images - False color compostie

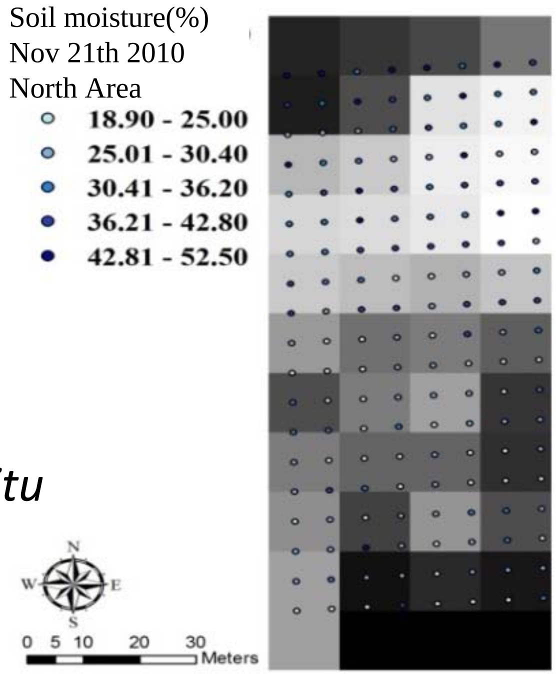
R:2009-2-15 PALSAR HH G:2009-5-14 PALSAR HH

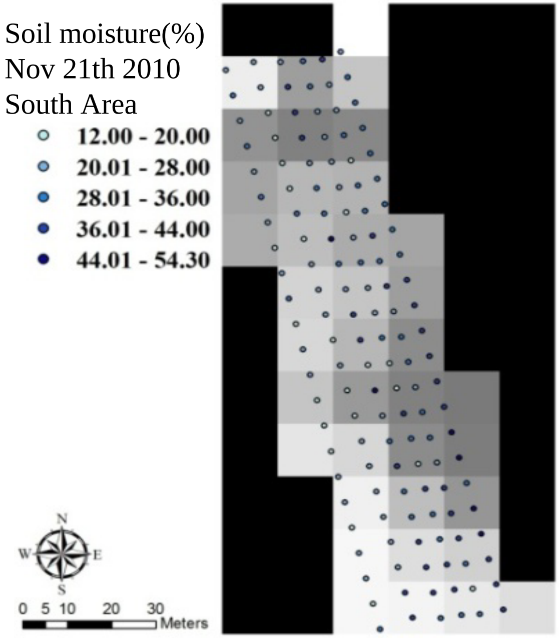
B: 2009-8-18 PALSAR HH (Polarization)

Supported by NSFC(40871100), 2009-2011

Synchronous field experiment

Ground measurement *in situ*





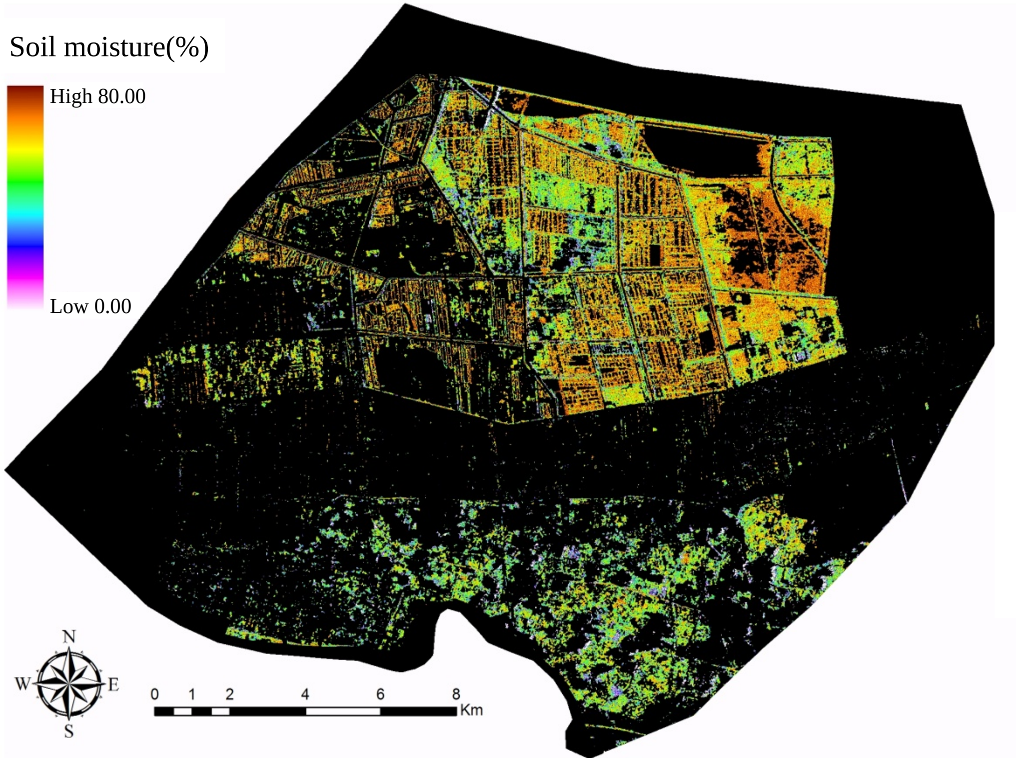
Equipments:
TDR300 (USA, ST)
W.E.T Sensor (UK, Delta-T)
MiniTrase (USA, SEC)
eKo PRO (USA, XBOW)

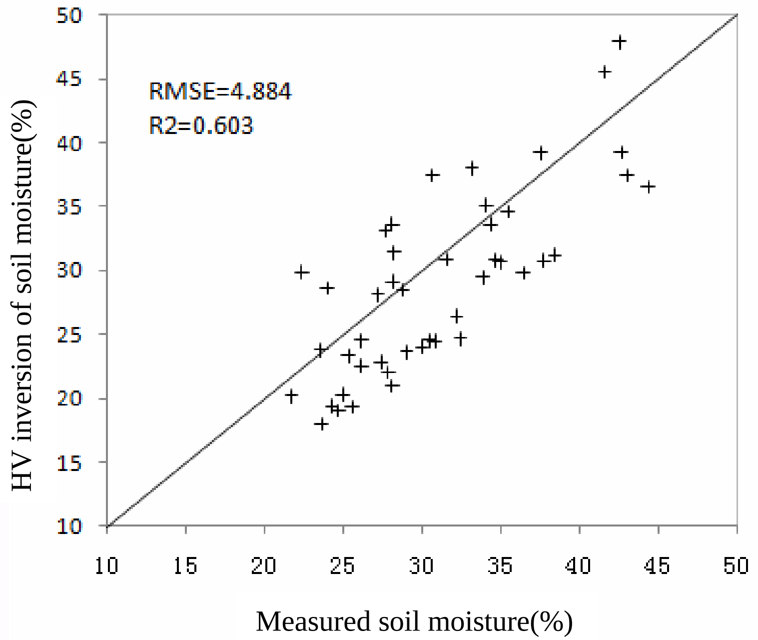
Supported by NSFC(40871100), 2009-2011

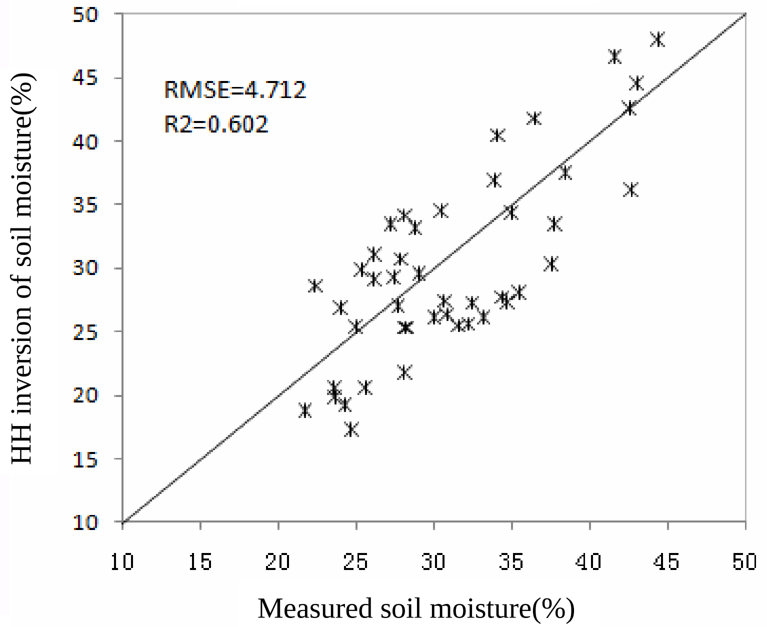
Inversion model 反演模型

Oh model

$$\frac{\sigma^o_{HH}}{\sigma^o_{VV}} = \left[1-\left(\frac{2m_v}{\pi}\right)^{\frac{1}{3\Gamma_o}}\exp(-ks)\right]^2$$



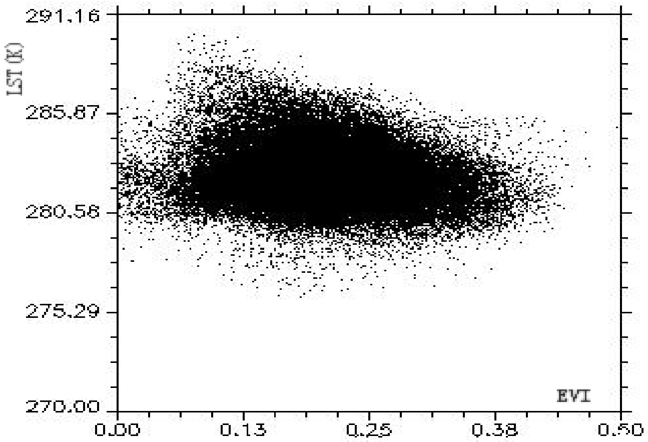


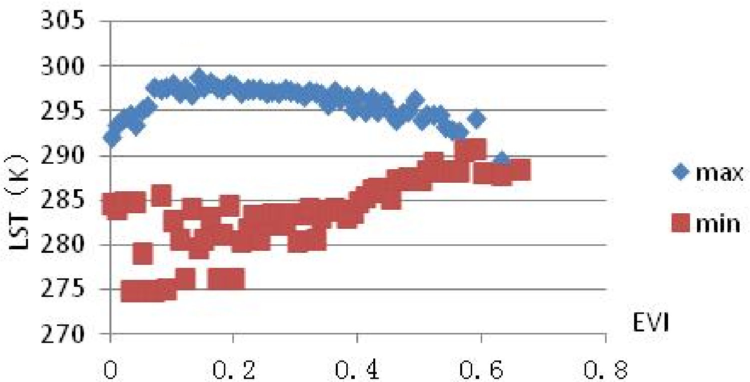


Supported by NSFC(40871100), 2009-2011

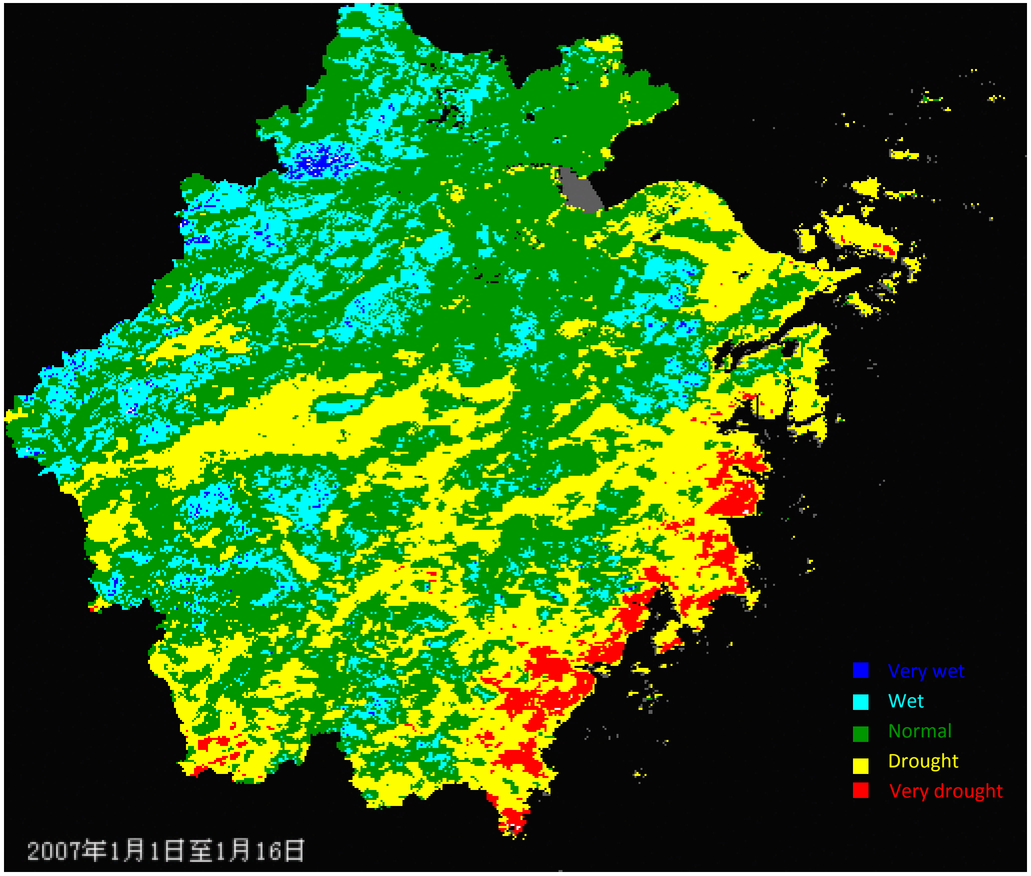
→ Thermal infrared remote sensing 热红外遥感

Detecting soil moisture based on MODIS data





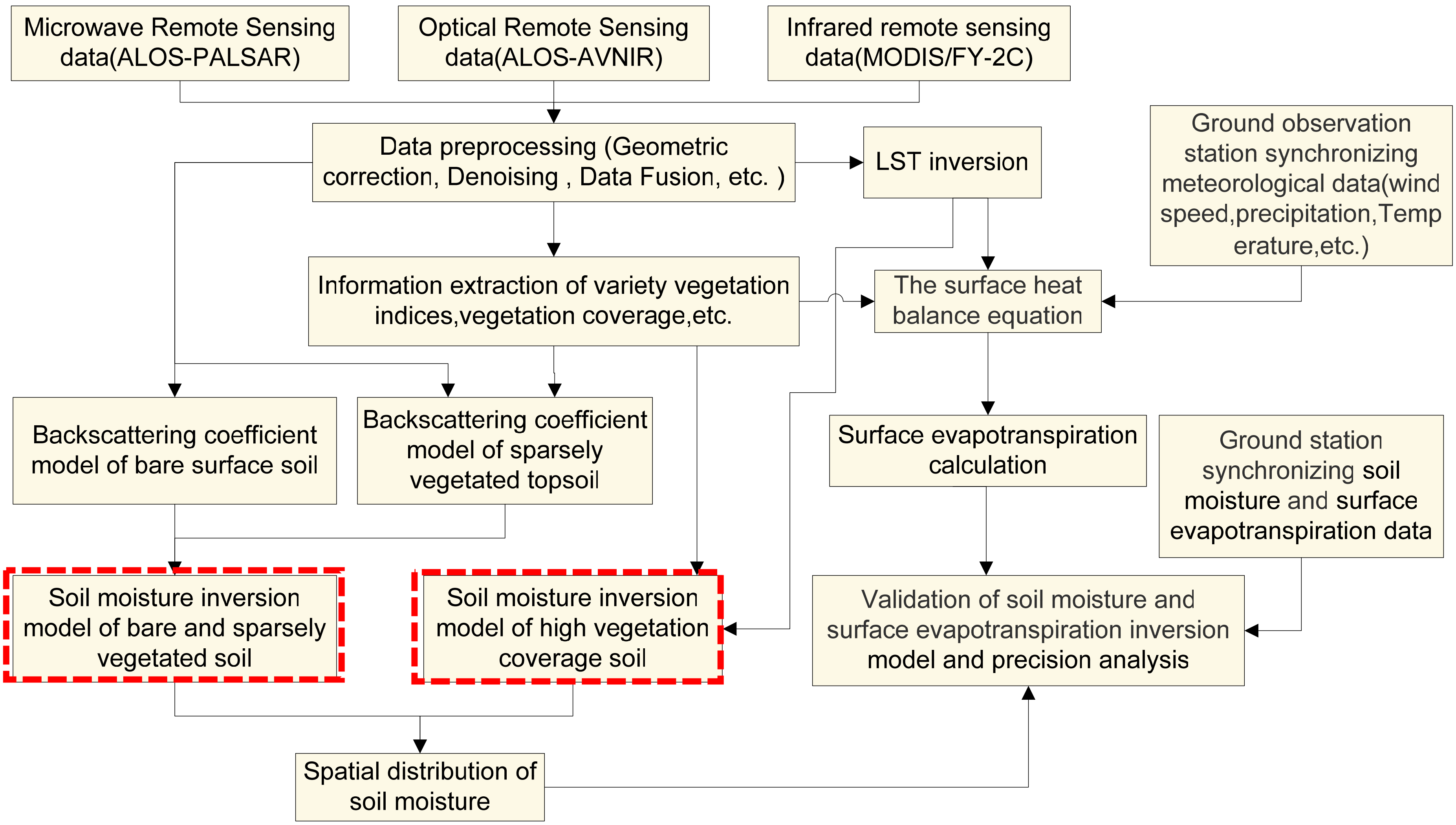
LST_EVI scatter diagram
Eigenspace
散点图、特征空间



Time-series maps of soil moisture covered the whole Zhejiang province land in 2007

浙江省2007年1月、2月土壤相对含水量分布图

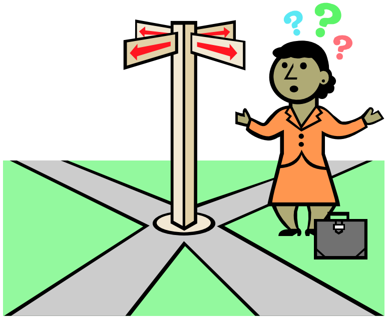
→Detecting soil moisture based on multi-resource remote sensing



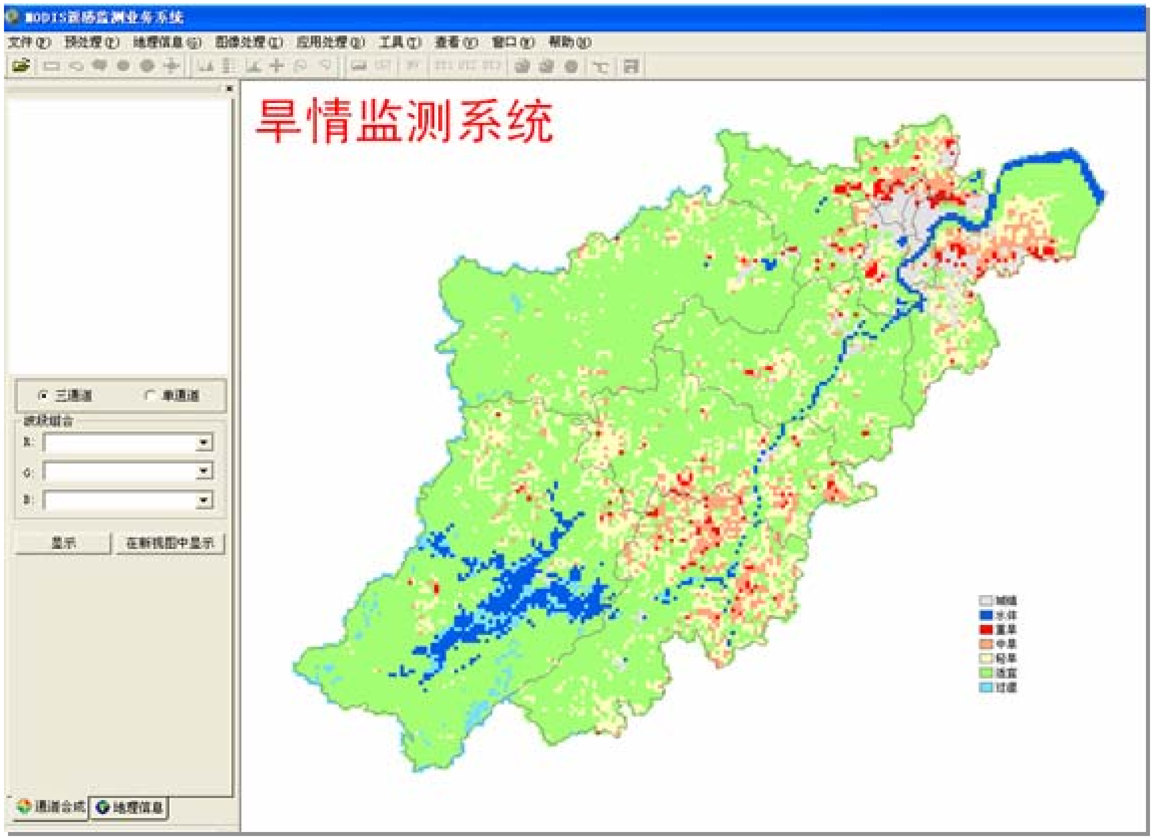
3.1 Soil OM/Carbon remote sensing

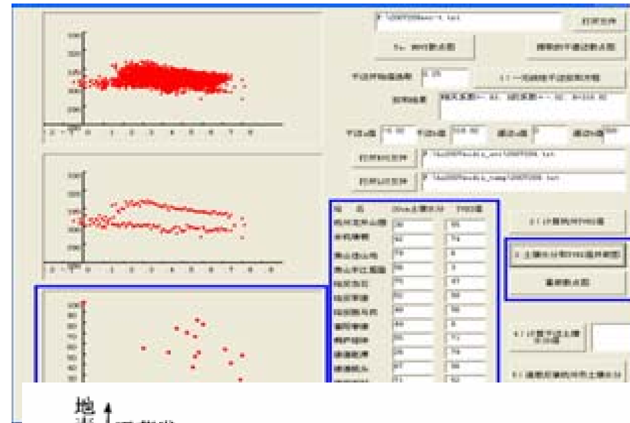
3.2 Soil moisture remote sensing

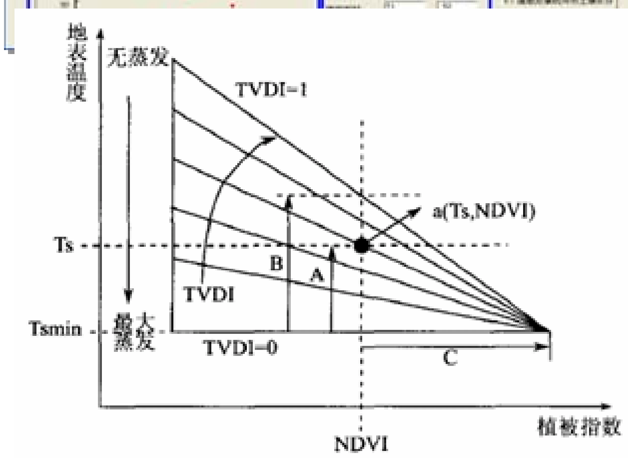
3.3 Application of soil remote sensing ✓



Application I：Monitoring drought



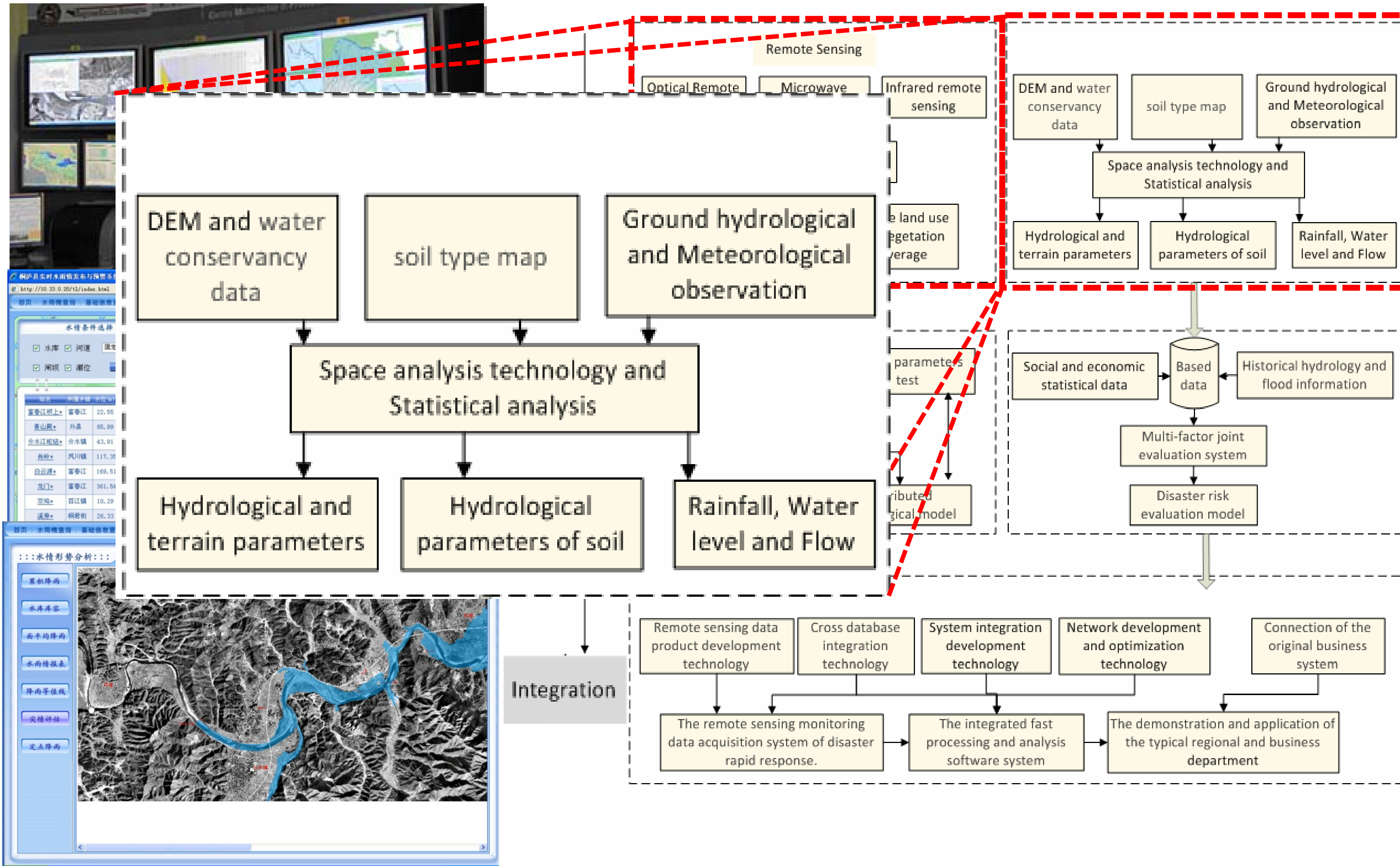




Using Temperature—Vegetation Dryness Index (TVDI) to predict the soil surface moisture. The remote sensing data include LST and EVI from MODIS data , also containing measured soil moisture over the same period.

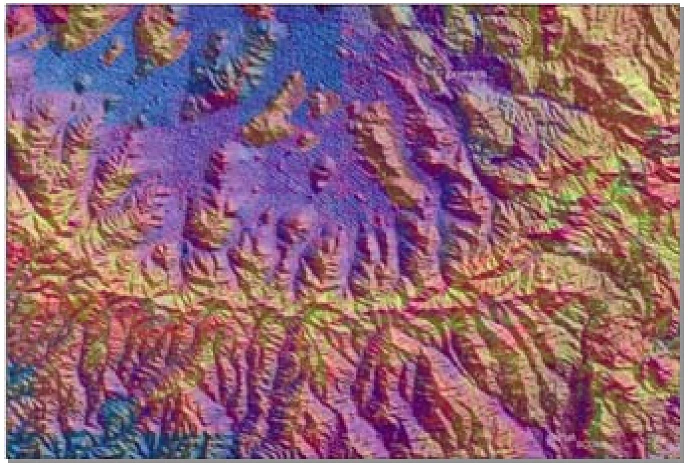
The study of the integration system of flood forecasting

Application II：Flooding forecast

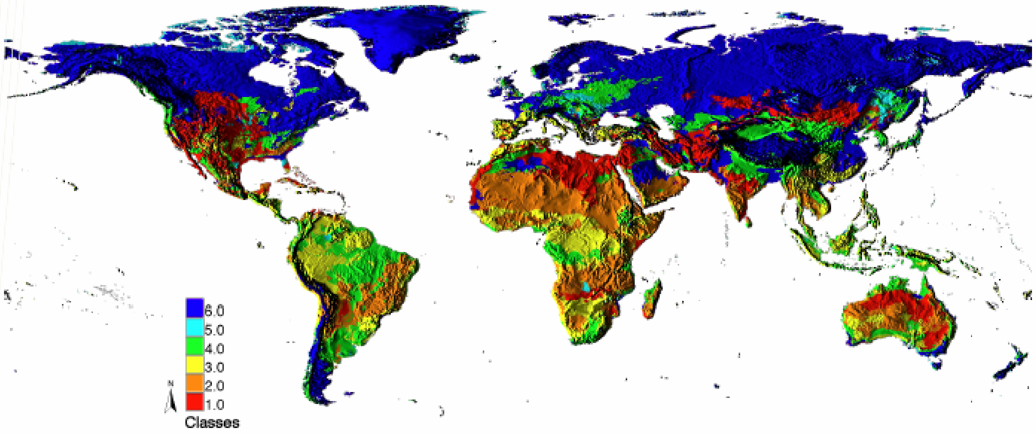


Application III：DSM

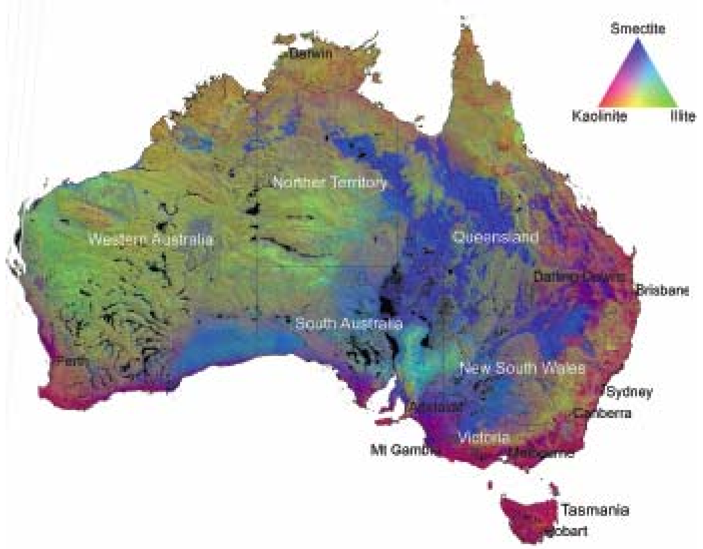
combine soil spectral libraries, and other geo-referenced information, such as from digital terrain models and field observations, with information from multi- and hyper-spectral remote sensing imagery



Preliminary results!



Mapping with Random
Climate and DEM predictors
on a 1 km grid



Application III：DSM

County Level Digital Soil Mapping (1:50,000) Using Decision Tree Model

<u>SCOPAN approach</u>
(McBratney et al., 2003)

$$S=f(s,c,o,r,p,a,n)$$

DT algorithm

ID3

CART

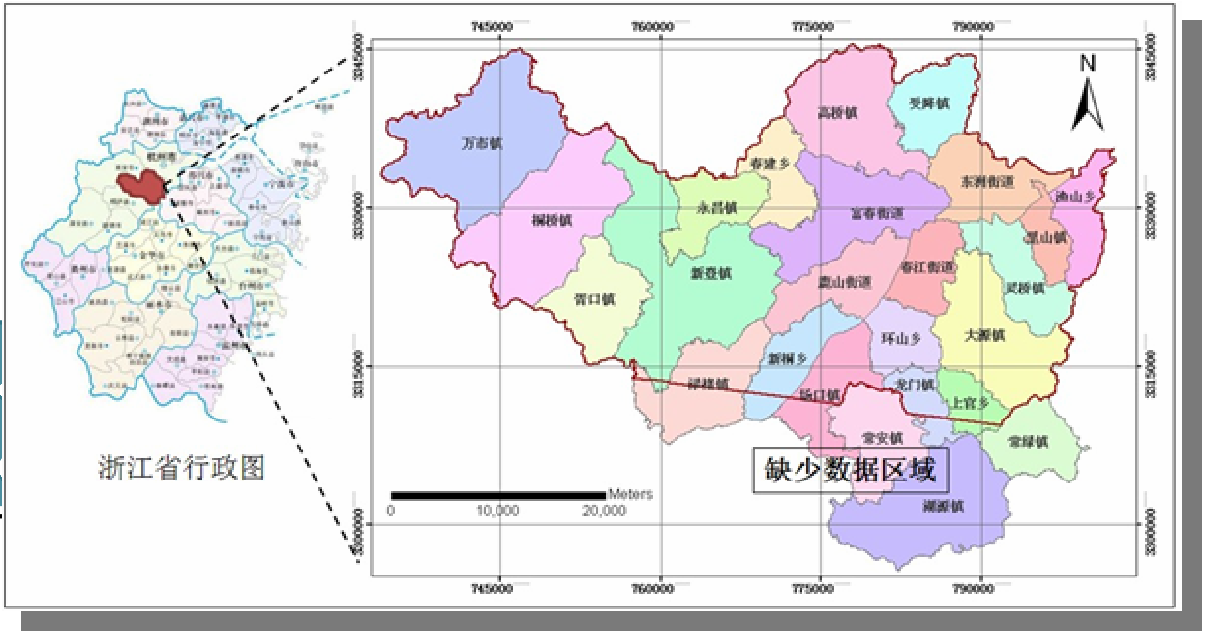
C4.5

SLIQ

SPRINT

◆E

◆L

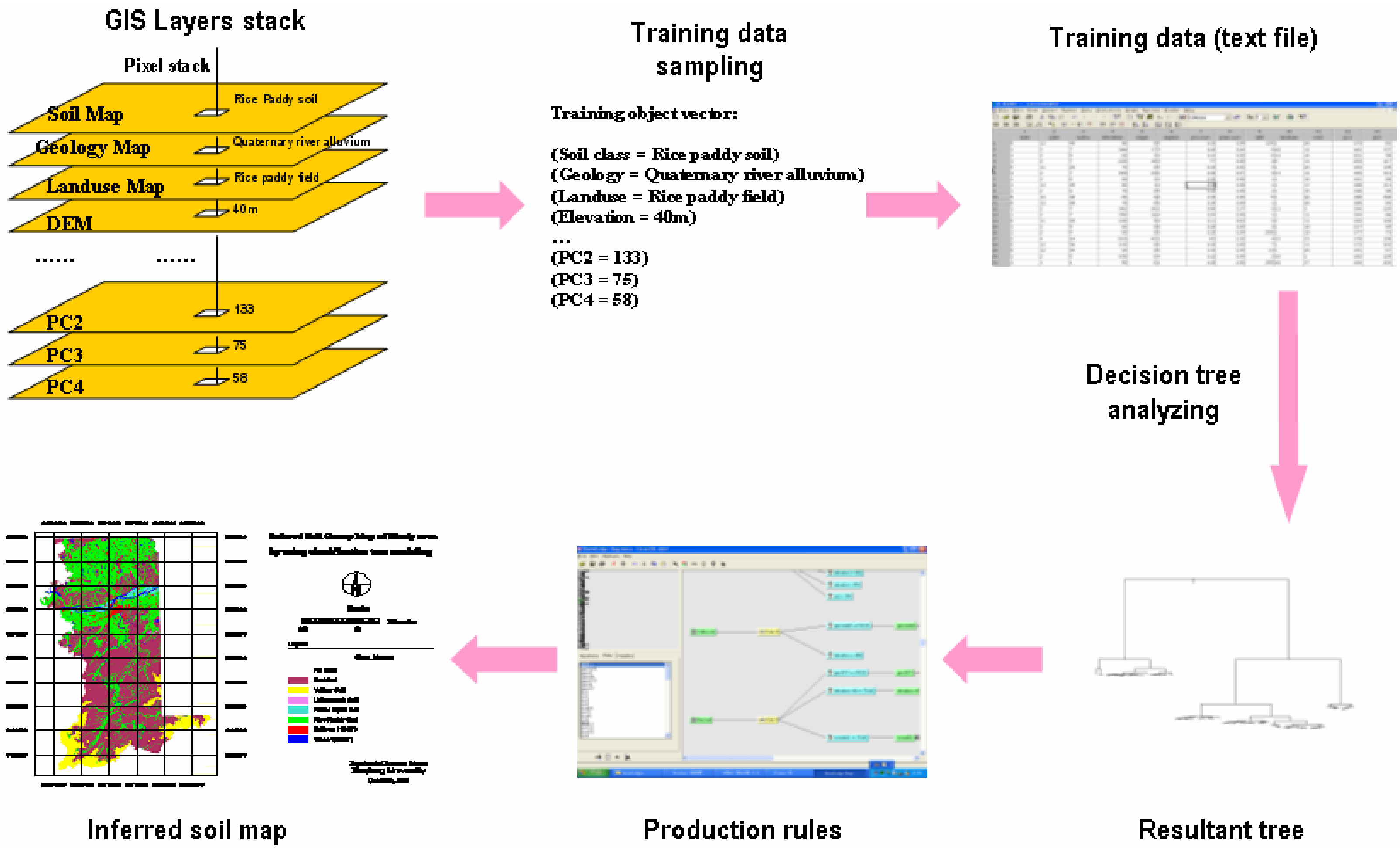


Study area – Fuyang county

Zhou Y and Shi Z. Digital soil mapping technology. 2010

Application III：DSM

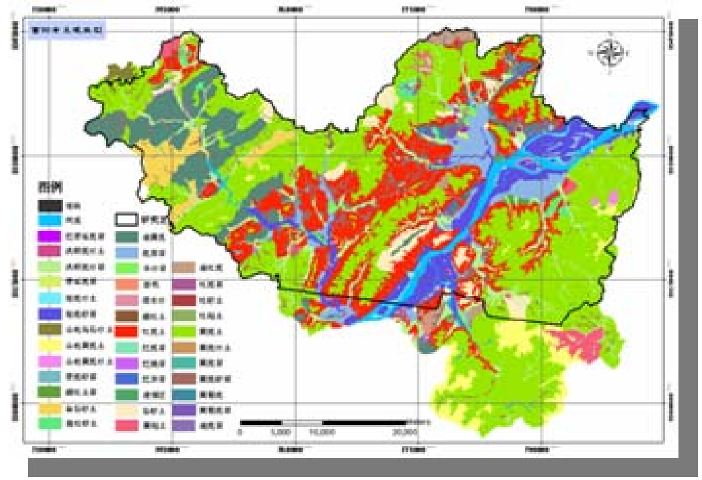
County Level Digital Soil Mapping (1:50,000) Using Decision Tree Model



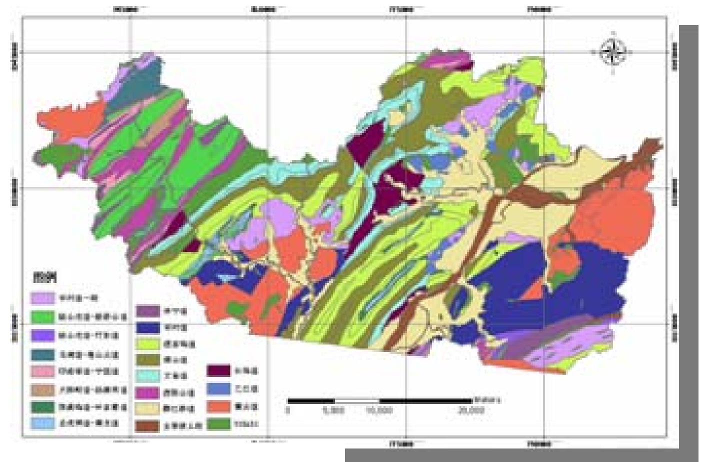
Application III：DSM

County Level Digital Soil Mapping Using Decision Tree Model

Predictor variables
Soil (s)
Soil classification map (categorical)
Landsat ETM band 1,3,6,7
Soil spectral data
Climate (c)
Mean annual rainfall (mm)
Mean annual temperature (° C)
Organisms(o)
Landsat ETM band 2,4,5
Vegetation cover, NDVI, Wetness
Relief (r)
DEM, slope, relief, aspect
Parent materials (p) and age(a)
Geology
Land use



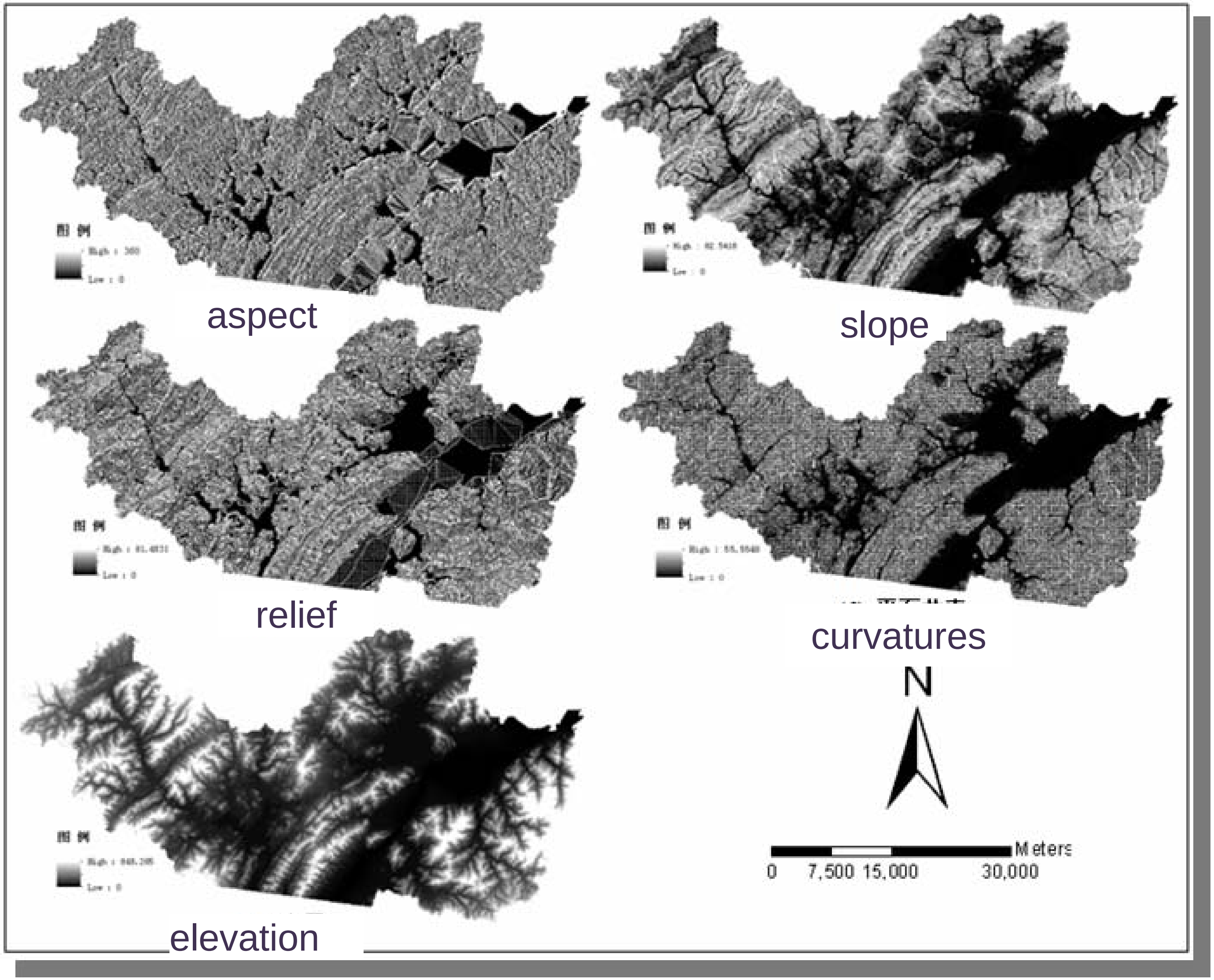
soil type map (1:50,000)



Geology map

Application III：DSM

County Level Digital Soil Mapping Using Decision Tree Model

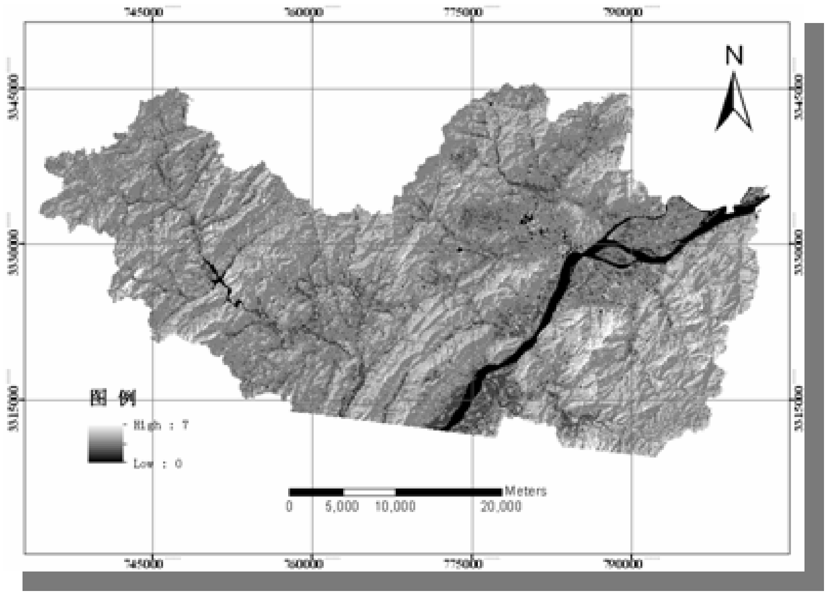


Predictors data from DEM

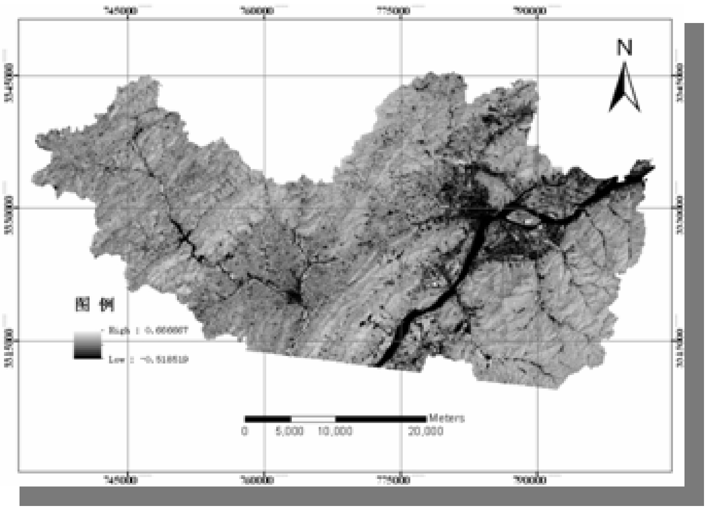
Application III：DSM

County Level Digital Soil Mapping Using Decision Tree Model

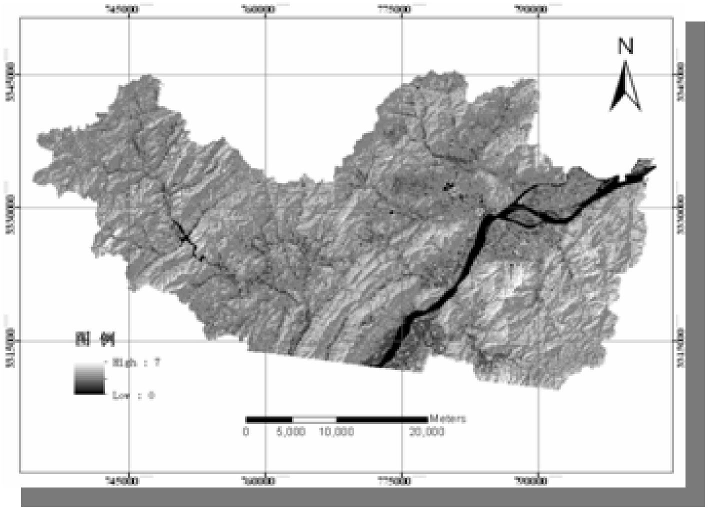
Predictors data from Landsat image (optical remote sensing)



Normalized difference water index (NDWI)



Normalized difference vegetation index(NDVI)

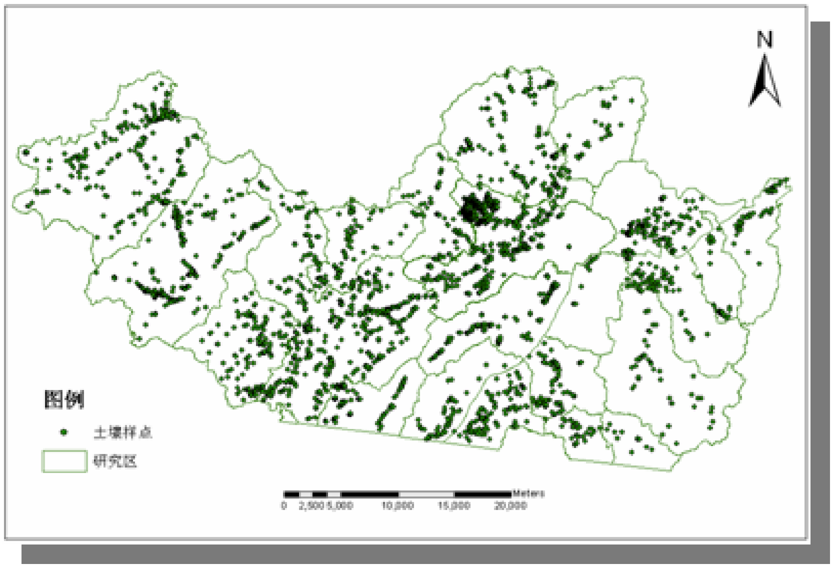


Soil color index (SCI)

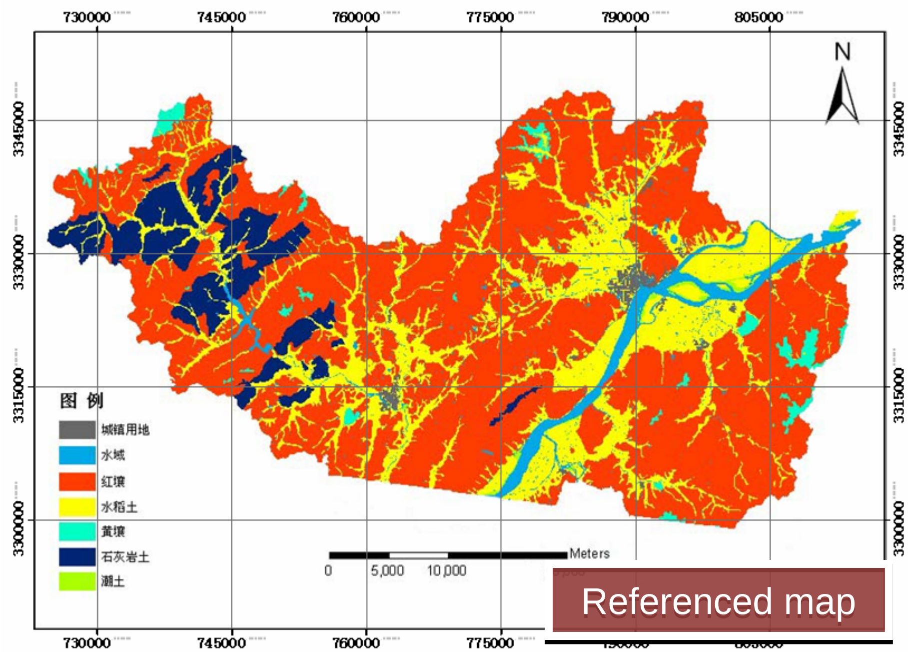
Application III：DSM

County Level Digital Soil Mapping Using Decision Tree Model

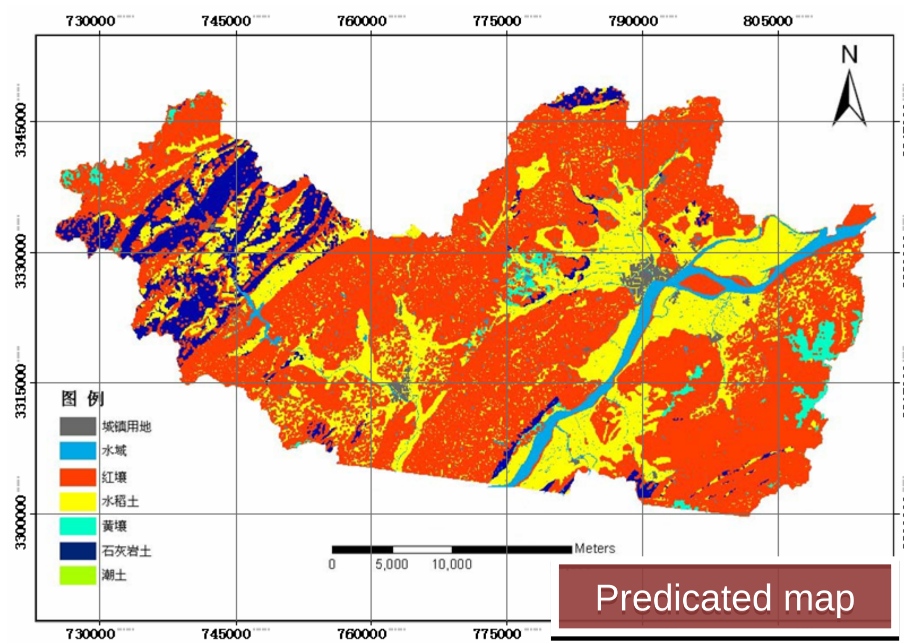
Predictors data from soil sampling and spectral measurement



Soil samples (n=3682) and spectral measurement in Lab (n=347)



Referenced map



Predicated map

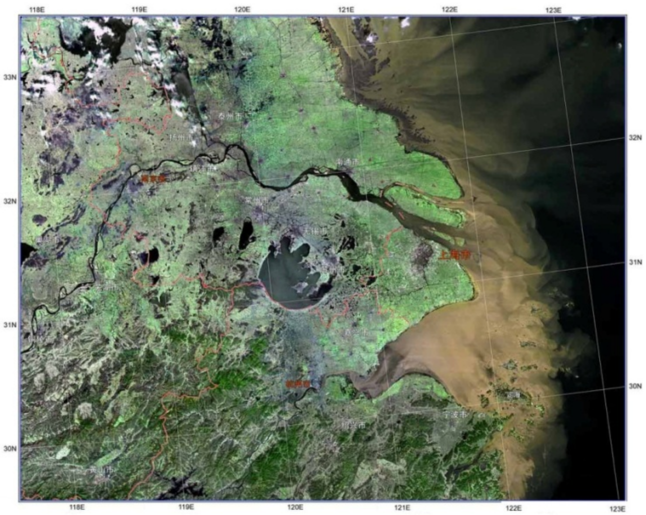
Zhou Y and Shi Z. Digital soil mapping technology. 2010

Summary and discussion

The increasing number of new satellite or sensors now available and the higher spatial/spectral resolution along with shorter revisit intervals offers greater potential than ever improve the digital mapping of soil type and some functional soil properties.

- But, the knowledge of classical mapping is not replaced by the new digital technologies including remote sensing(RS) and proximal sensors(PS) which mostly provide the auxiliary information for DM nowadays.
- In spite of recent advances, development of robust methods for estimating soil properties using RS/PS has to be extremely complicated. We should further to research the theory behind of new technologies / modeling approaches, and do more extensive field calibration working in different soils under different agricultural practice.

Equipment



Acknowledgement

National scientific foundation of China(NSFC)

（1）土壤空间变异与景观模型支持下的土壤遥感解译技术研究（40001008），2001-2003

（2）滨海盐土高光谱特性和二向反射模型研究 （40571066），2006-2008

（3）基于高精雷达卫星的滨海盐土水盐含量遥感监测建模研究（40871100），2009-2011

Ministry of education of China, National scientific foundation of Zhejiang Province

教育部新世纪人才计划、浙江省自然科学杰出青年基金、浙江省科技计划重大项目等

（1）区域典型土壤光谱标准数据库和有机质预测模型研究. 教育部新世纪优秀人才. 2010－2012年.

（2）星陆双基遥感土壤表层含水量同化反演方法研究.浙江省自然科学杰出青年基金.2011-2013.

（3）流域汛旱情遥感监测与防减灾辅助分析系统研究.浙江省重大科技计划.2011-2013年

Thanks and questions?

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