Soil Quality of Rice Paddy:

Concerns of Greenhouse Gas Mitigation and Farm Productivity

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Introduction

- Soil quality：A critical issue of Soil Science
- Soil quality: A focus of soil of common interest
- Soil quality: A target for soil management

Integrated soil management (ISM)

Soil quality

- **What is soil quality?**
- **What are the criteria for soil quality?**
- **Soil quality of rice paddys:**

GHGs production and global warming

From soil fertility to soil quality

Soil fertility	Soil quality (Soil health)
Agro-production	Ecological services
Productivity	Sustainability
Crop-supporting	Life-supporting

New demand for soil quality

- Soil health → Ecosystem functioning
- Local service → Global service
- Farm sustainability → Earth sustainability
- ? Capacity building?

Soil quality of rice paddys

- Concerns of rice productivity
- Concerns of food security
- GHGs mitigation in context of global change
- ....?

Examing Soil quality from a Case study

The studied paddy farm

- Ferric Accumulic Stagnic Anthrosols;
- A high-yielding paddy soil in the Tai Lake region, Jiangsu With a average rice yield around 9 t/ha;
- Located in Wujiang County, Jiangsu Province, China (NL: 31 ° 05’900’’; EL: 120 ° 46’924’’);

Site and Farm situation

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Soil and the profile

The soil has been cultivated with rice rape rotation since 1987.

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Fertilization Treatments

4 treatments as:

(1) no fertilizer application (**NF**);

(2) chemical fertilizer only (**CF**);

(3) chemical fertilizer plus rice straw return (**CSF**)

(4) chemical fertilizer plus pig manure (**CMF**).

Chemical fertilizers per year is:

N as urea 427.5 kg/ha, P_2O_5 as super phosphate 45 kg/ha, KCl 84 kg/ha;

Rice straw return at 300 kg FW/ha/yr and

Manure application at 1,120 kg FW/ha/yr

Basic property of the topsoil

As sampled and measured in 1987

- pH, 5.6;
- (<2μm) clay content: 30.3 %;
- Bulk density: 1.2 g/cm^3;
- Organic C: 1.43 %;
- CEC: 20.5 cmol(+)/kg.

Soil quality changes under different fertilization treatments

1 Pool Change of Major Nutrients

Sampled and measured in 2003

Treatment	pH (H_2O)	OC (g/kg)	DOC (mg/kg)	Total N (g/kg)	Total P (g/kg)	Avail. K (mg/kg)
NF	6.13	16.43 c	64.3 b	1.72 b	0.24 c	82
CF	5.93	16.75 bc	45.5 c	1.80 b	0.37 b	105
CMF	5.74	17.22 b	79.9 a	2.05 a	0.72 a	98
CSF	5.88	17.93 a	81.4 a	2.06 a	0.37 b	88

焦少俊等,土壤肥料,2005

Change of Aggregation(%)

Treatments	200-2000μm	20-200μm	2-20μm	<2μm
CFM	37.8±2.5a	30.1±1.7a	26.7±1.6a	5.3±0.3a
CF	33.7±0.5b	28.3±0.3b	28.9±0.3a	5.9±0.5a
NF	29.7±0.7c	29.1±0.5b	35.1±0.5b	6.1±0.4a

Li et al., 2007, JSFA

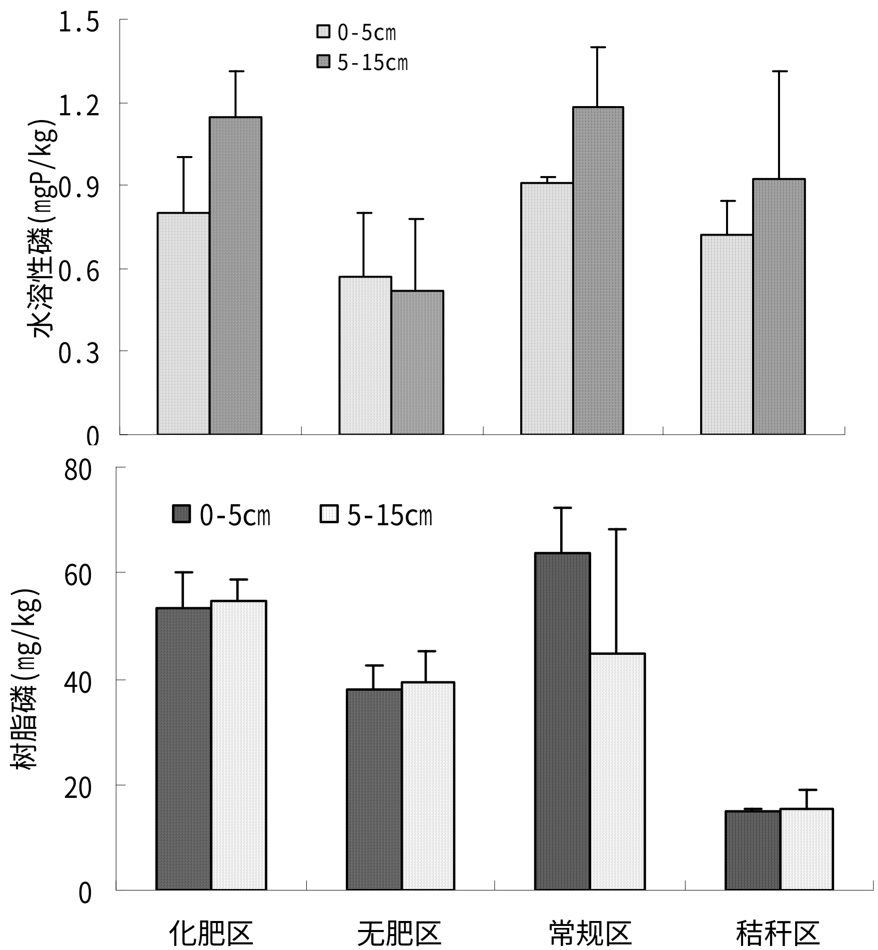
Budget of soil P / kg.(hm^2.a)$^{-1}$

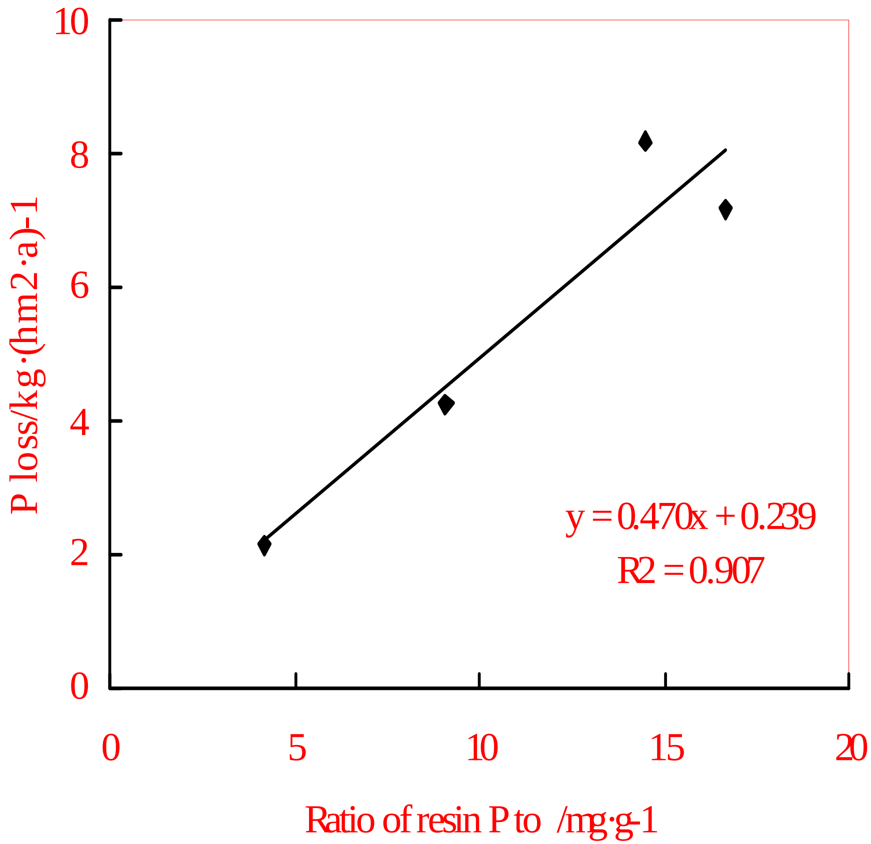
潘根兴等,环境科学,2003

Treatment	Present TP /g·kg^{-1}	Added P	Soil provided P	Crop consumed P	P loss
NF	0.29	0.0	27.2	20.3	7.2
CF	0.32	19.7	23.1	34.9	8.2
CFS	0.36	27.3	17.7	43.2	2.1
CFM	0.53	53.3	-6.81	42.5	4.3

Calculated according to mass balance

P pools





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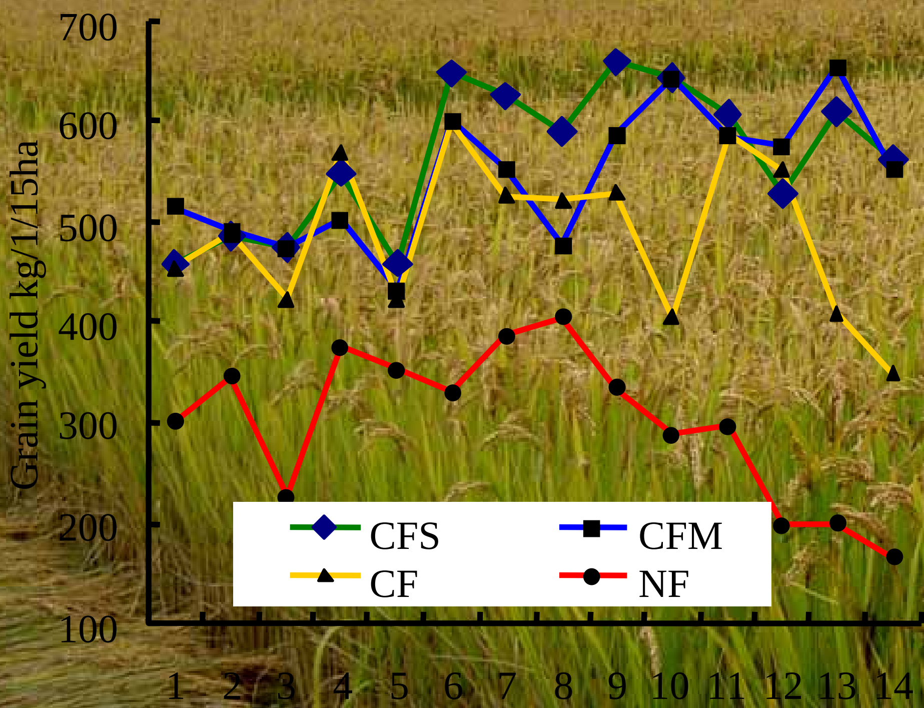
2 Farm Productivity:rice and rape seed



	Rice t/ha/a	Rape seed t/ha/a
NF	3.84a	0.37a
CF	6.47b	2.21b
CFS	8.88c	2.56c
CFM	8.60c	2.45c

张平究等.生态学报,2004

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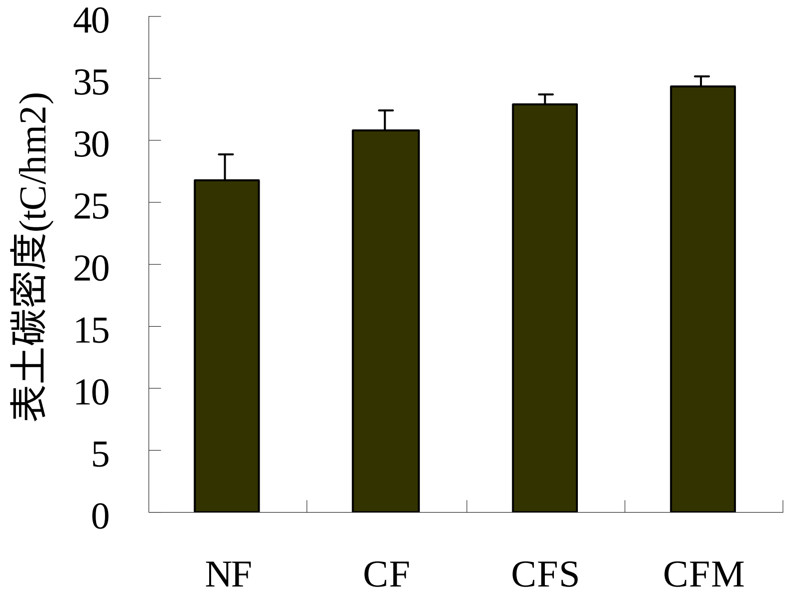
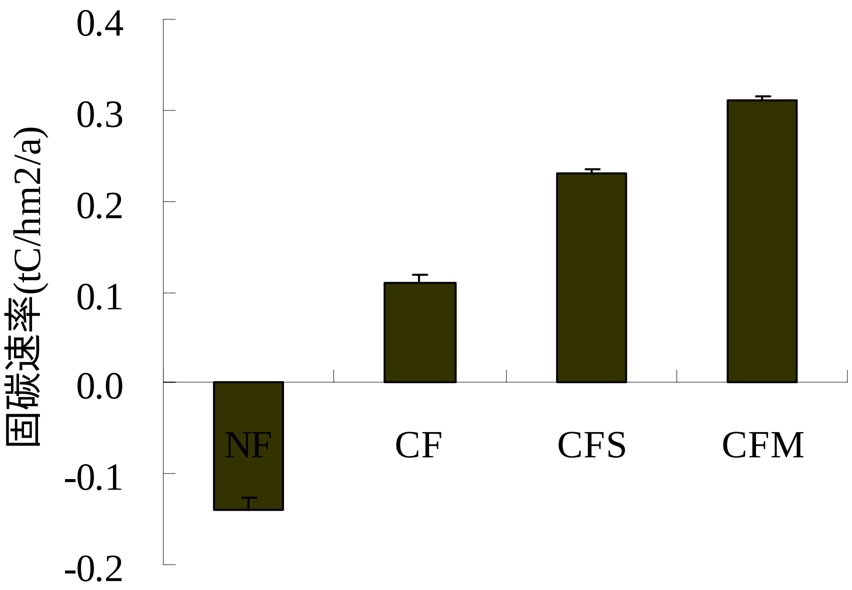
3 GHGs production and mitigation potential

Higher SOC storage and SCS rate under CFS and CFM



Topsoil SOC storage



SOC sequester. Rate

ZhouP,G Pan et al., Ecol. Sinica,2006

Flux of CO_2(mgCO2/m2/d): much higher under CF than under CFM and CFS

处理	Daytime 白天排放量	Night 夜晚排放	Daily 日排放量
5/11/2003-6/11/2003			
常规区CFM	777.0±55.6	643.3±46.1	1420.2±90.1
化肥区CF	1225.5±149.5	1056.6±144.7	2282.1±289.7
秸秆区CFS	703.6±77.9	633.1±92.9	1336.7±160.7
6/11/2003-7/11/2003			
常规区CFM	744.8±52.5	681.9±56.9	1426.7±100.8
化肥区CF	1163.3±139.5	985.4±59.1	2148.7±187.0
秸秆区CFS	556.7±91.6	506.1±62.4	1062.8±119.7

Temperature sensitivity of soil CO_2 flux

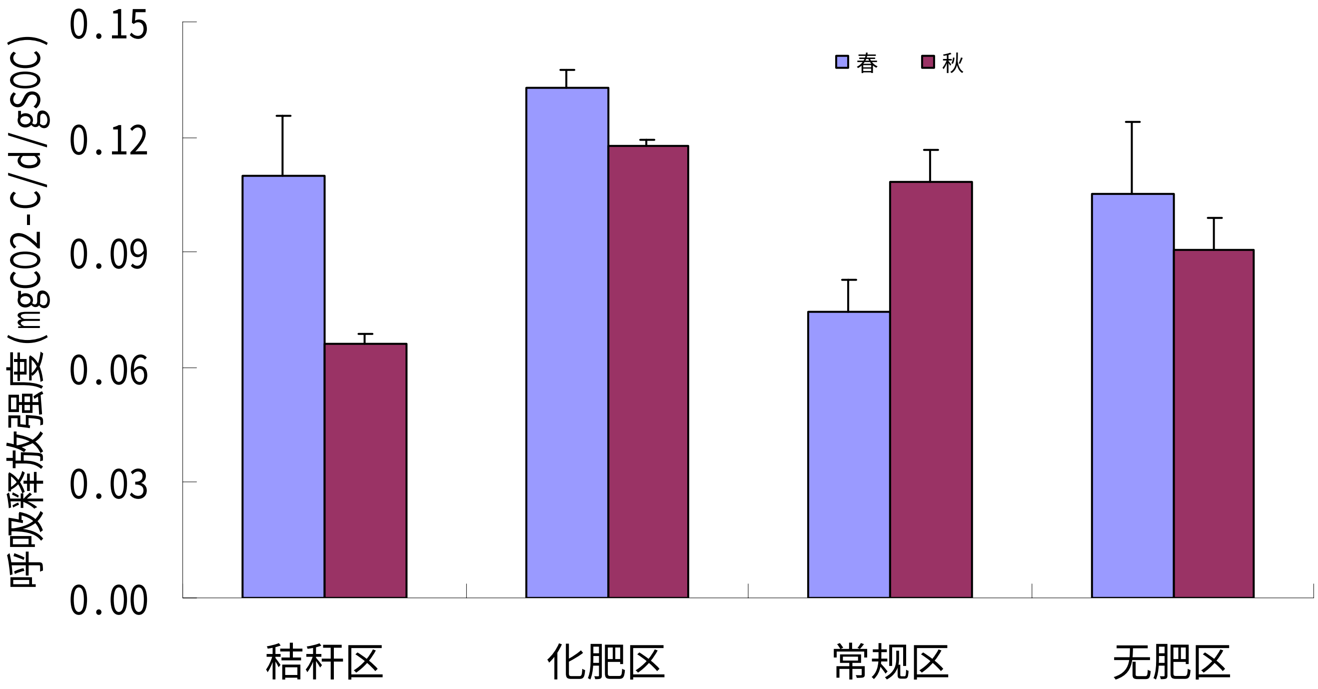
Soil Tem. (5cm)		Air temp.
$Y=-0.5048x^2+22.555x-179.21$		$Y=-0.2301x^2+12.962x-105.37$
$R^2=0.7865^{**}$	FM	$R^2=0.9677^{**}$
$Y=-1.847x^2+74.147x-632$		$Y=-0.3268x^2+17.282x-115.52$
$R^2=0.9136^{**}$	CF	$R^2=0.8608^{**}$
$Y=-1.1654x^2+48.987x-438$		$Y=-0.1421x^2+8.1573x-45.075$
$R^2=0.9627^{**}$	CS	$R^2=0.8333^{**}$

Potential of CO_2 and CH_4 Production

Treatm	GHG production (μg g^{-1} soil)-		GWP		Total GWP	CH_4 to total GWP (%)
	CH_4	CO_2-C	CH_4	CO_2		
CFM	46.3±3.5B	470.4±15.8A	179.4B	39.2A	218.6B	82.1B
CF	136.4±15.3A	465.3±44.8A	528.5A	38.8A	567.3A	93.2A
NF	5.2±0.6C	240.5±23.3B	20.2C	20.0B	40.2C	50.1C

注：不同字母表示不同施肥处理间在p<0.01水平上存在显著差异

Higher respiration ratio under CF



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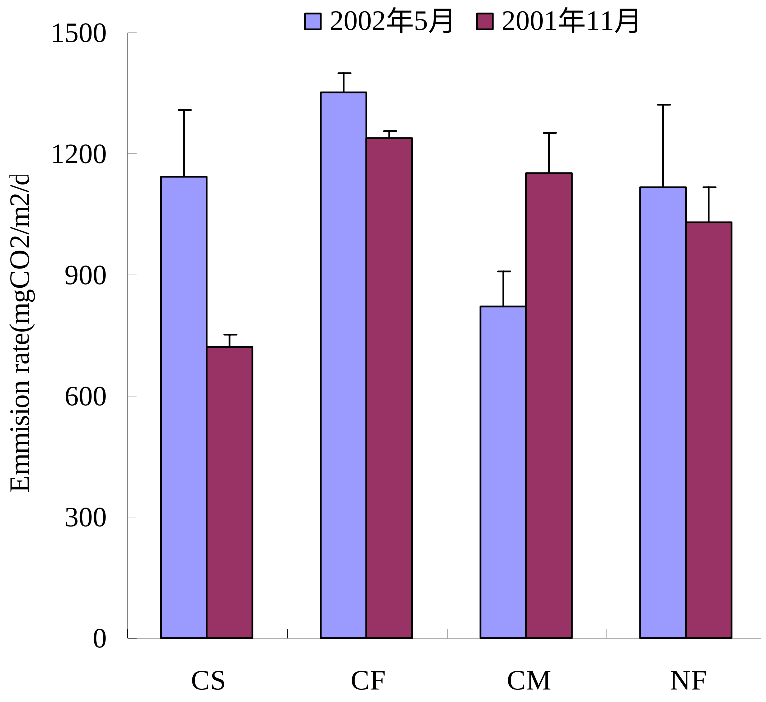
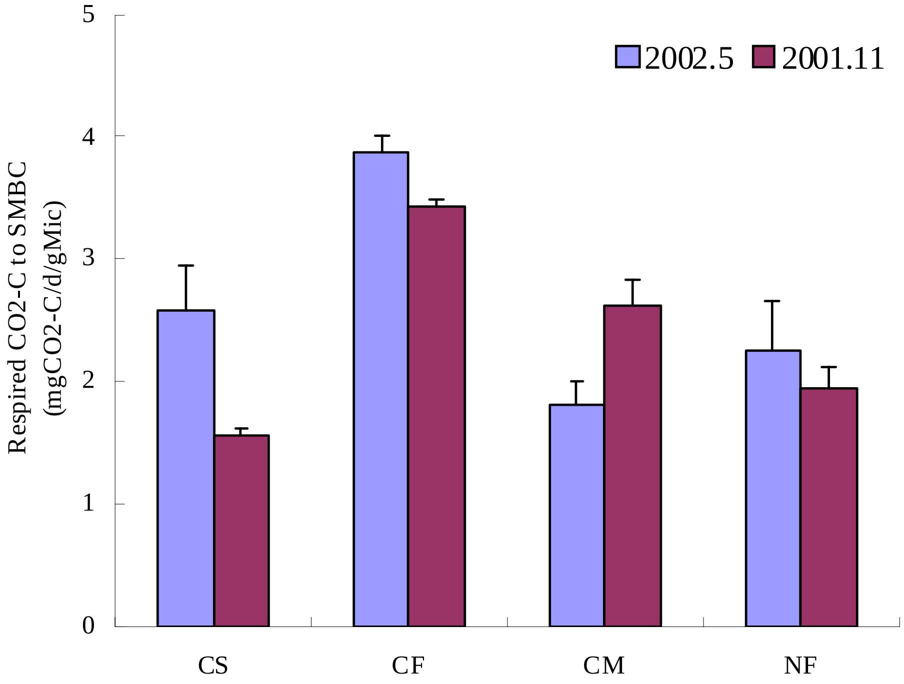
Higher respiration intensity and metabolic quotient under CF





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4 Soil health, bio-diversity

Microbial, soil fauna, seed bank, …

Change in microbial community

小区	Fungi (10^4/g)	Actinomycetes (10^6/g)	Bacteria (10^6/g)	Anaerobic bacteria(10^5/g)
无 肥 区 NF	3.63±0.55A	1.04±0.04A	4.13±2.93A	1.38±0.14A
化 肥 区 CF	6.74±0.30B	1.54±0.05B	8.23±1.00B	1.43±0.05A
秸 秆 区 CFS	5.58±0.46C	1.58±0.18B	2.14±0.93A	2.69±0.06B
常 规 区 CFM	3.78±0.20A	1.52±0.04B	2.90±0.46A	0.98±0.04C

李玉祥，潘根兴等,2006.未投

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Molecular Fingerprints of microbes

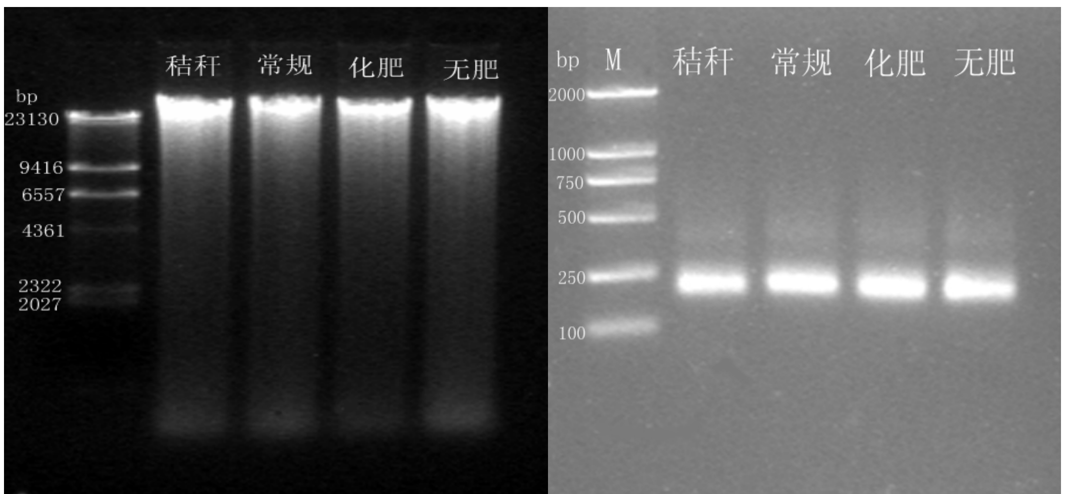
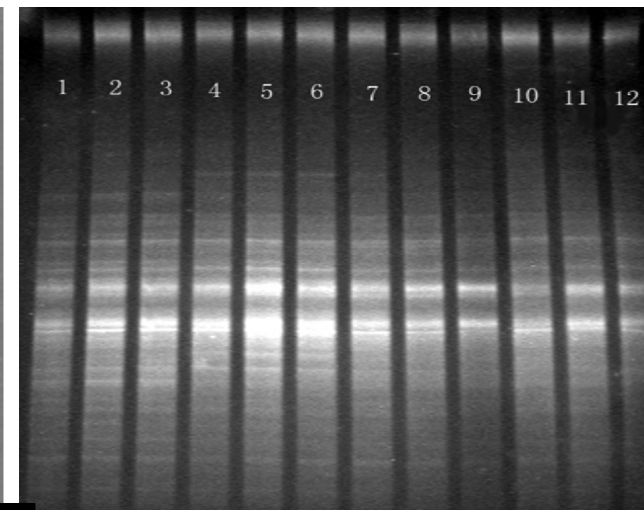


图 1 土壤基因组　土壤16SrRNA基因



不同施肥措施的DGGE图谱(秸秆区:1-3;常规区:4-6;化肥区：7-9;无肥区：10-12)

张平究等,生态学报,2004

Changes in Methane-oxidizing bacterial community

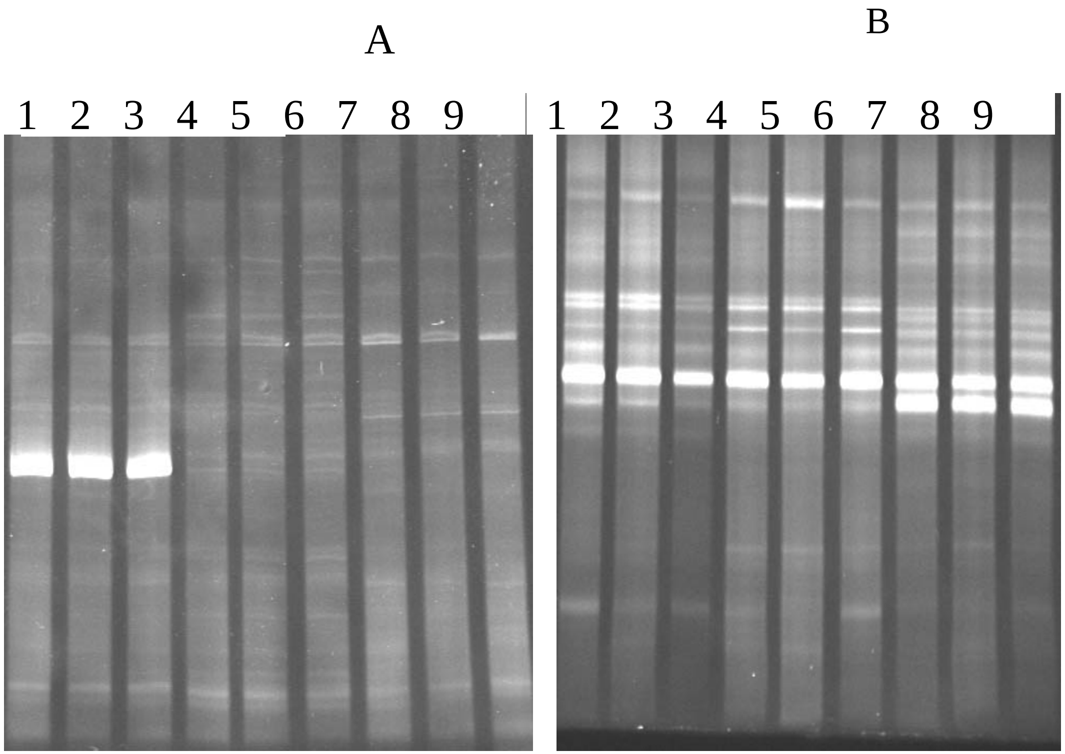
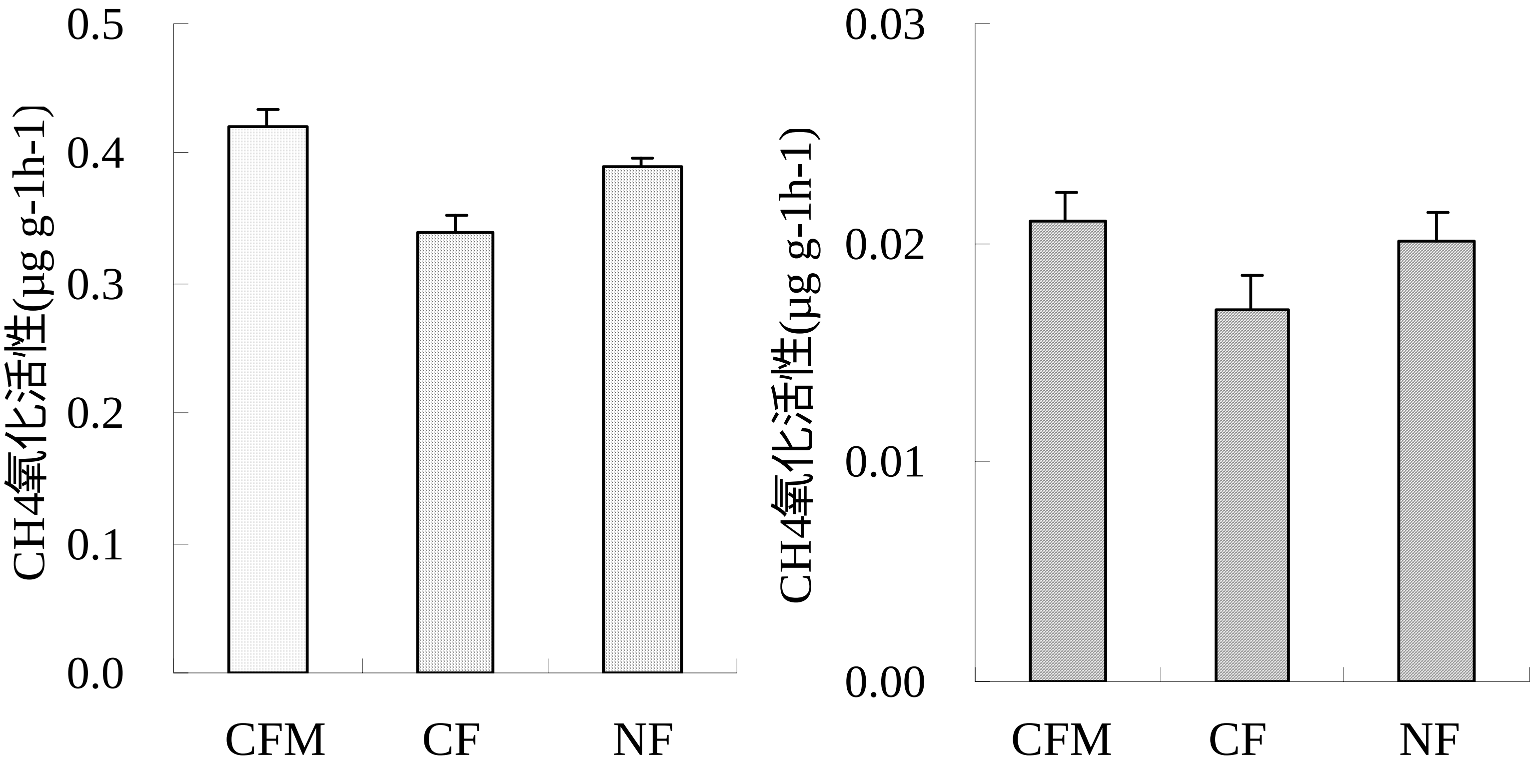


图4-3.不同施肥措施下的MOB1和MOB2的DGGE图谱（A：MOB1；B：MOB2）化肥区：1~3；常规区：4~6；无肥区：7~9

Lower activity of methane-oxidizing bacteria under CF than under CFM and CFS



不同施肥处理下土壤氧化活性对CH_4浓度的响应（A: CH_4起始浓度为7000μl l^{-1}；B: CH_4起始浓度为400μl l^{-1}）

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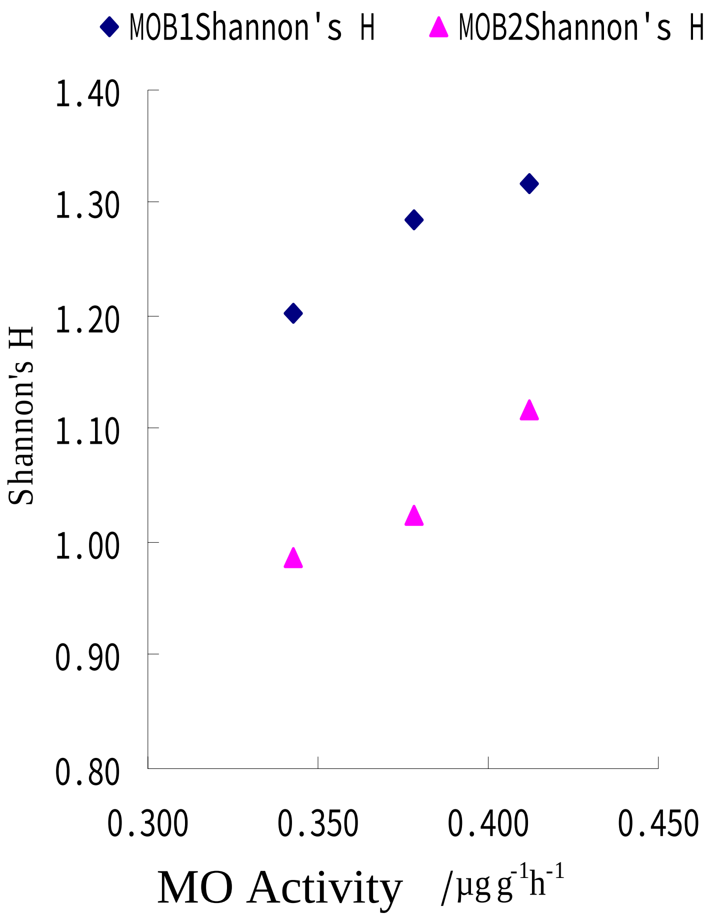
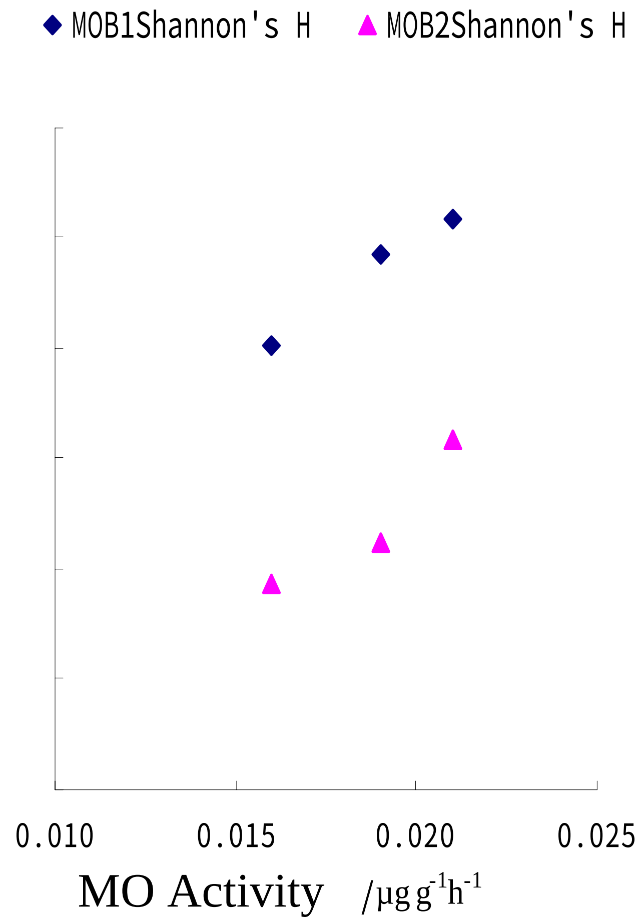
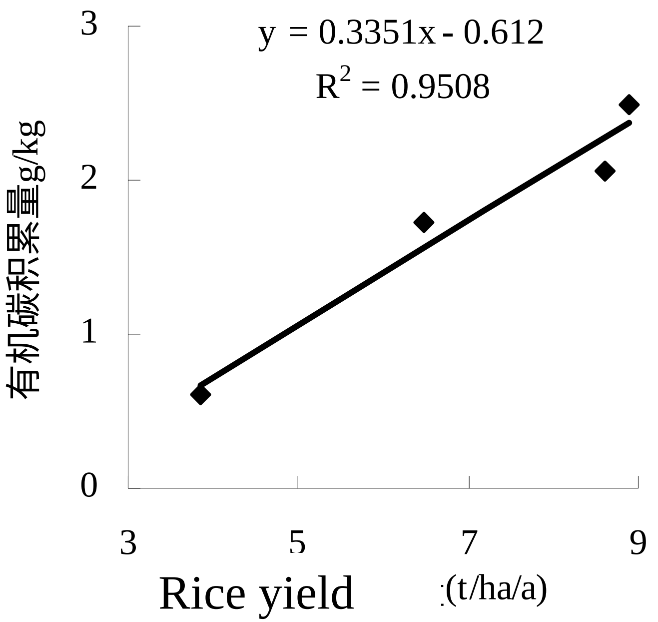
Diversity and Redundancy as a potential control on MO activity

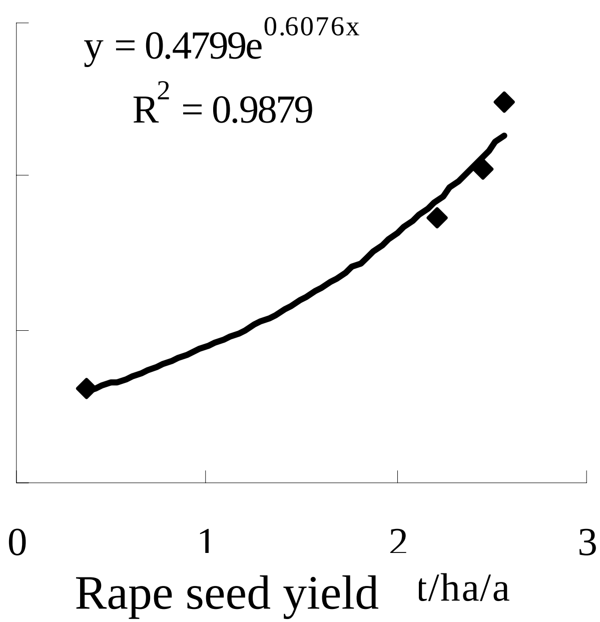


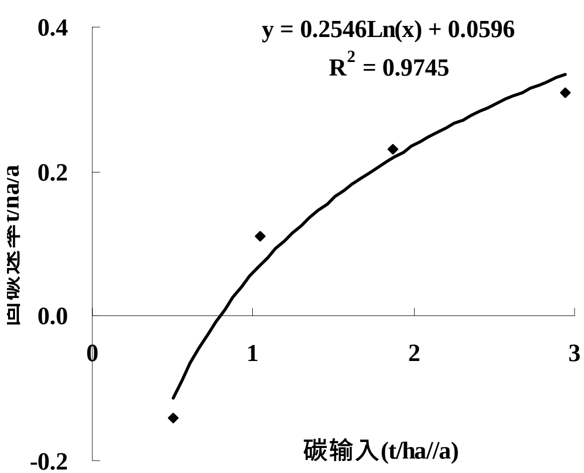


5 Coupling of productivity with GHGs mitigation potential

SOC enhancement and rice yield:
a possible coupling of productivity and GHG mitigation







SCS in relation to C input

From biomass C to Soil C: as an route for C capture

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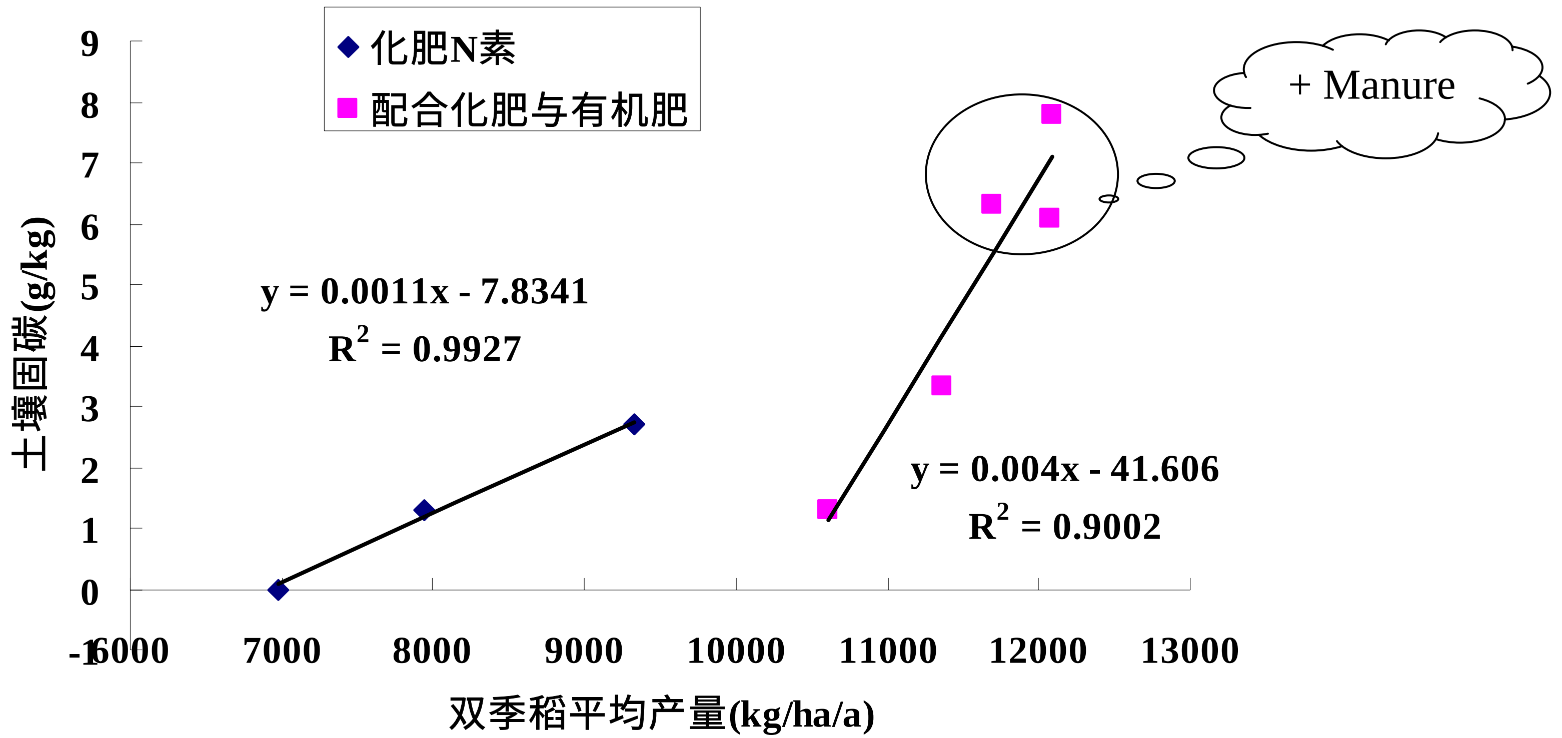
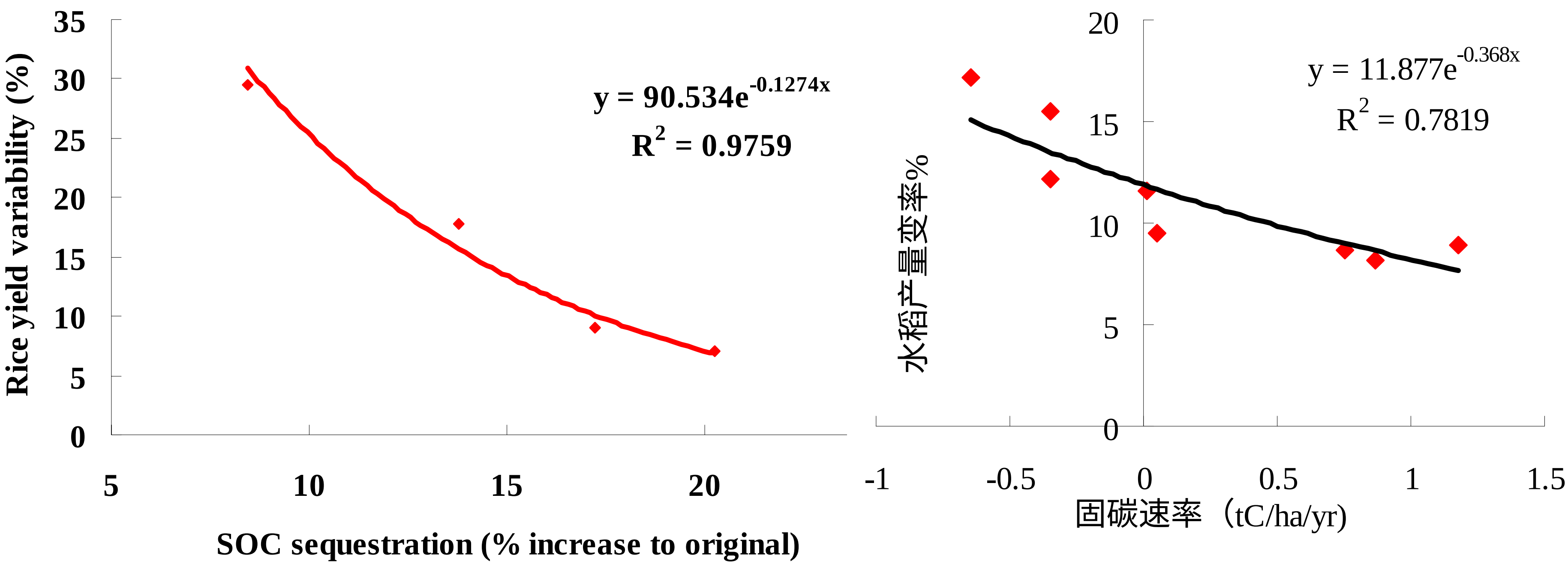
Manure application enhanced productivity and SOC sequestration

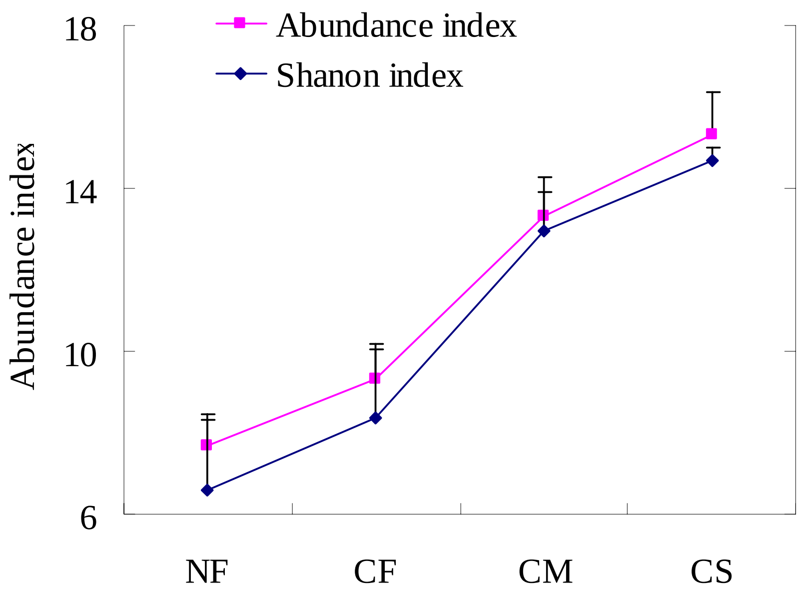


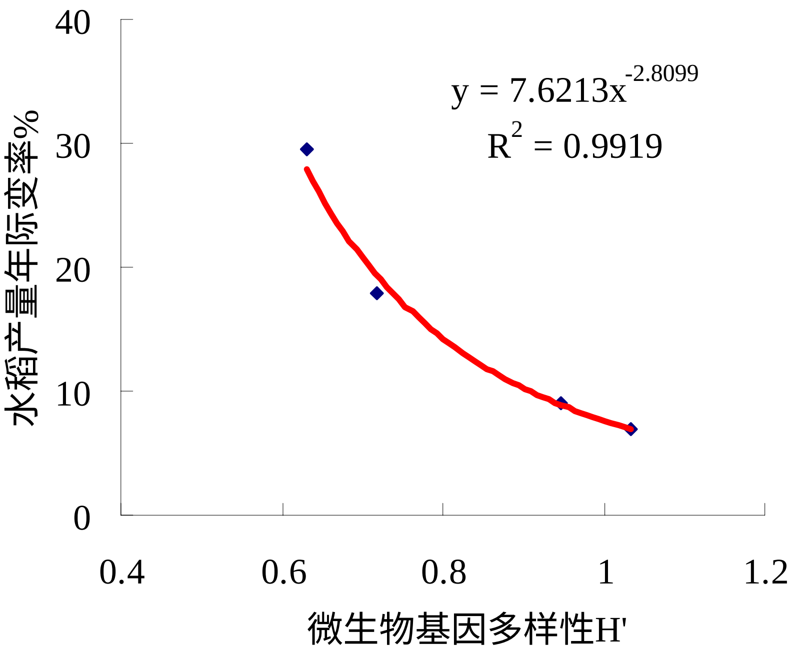
Linkage of SCS to productivity



SCS and rice yield variability(a, our case;b,red soil paddy case)

MB diversity: a possible control





张平究等,生态学报,2004

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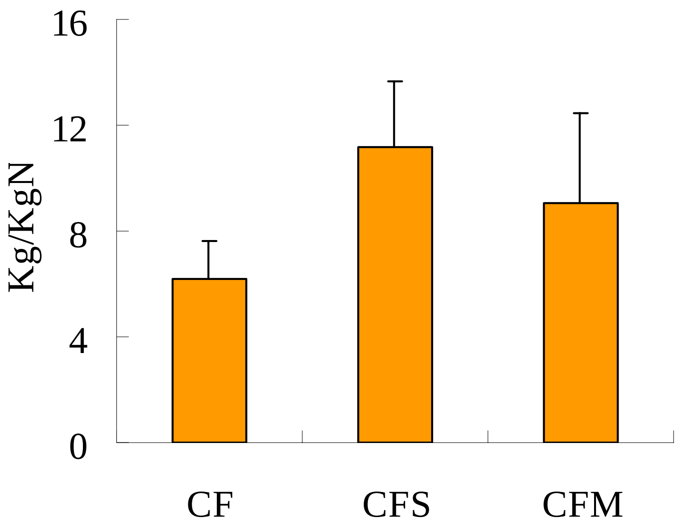
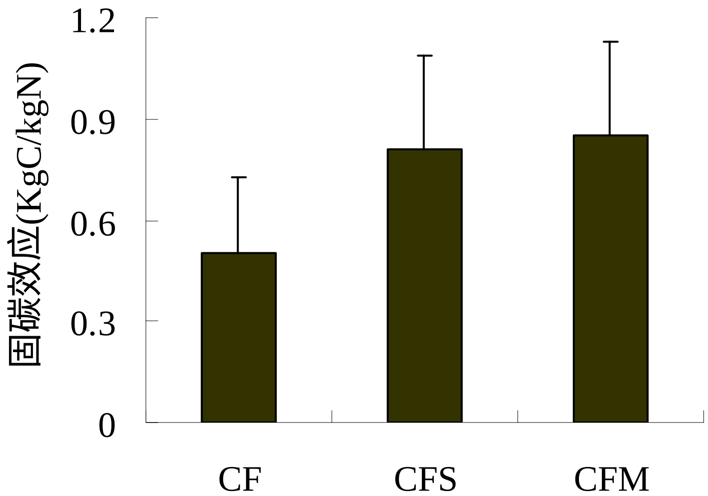
Efficiency of nutrient utilization and SCS



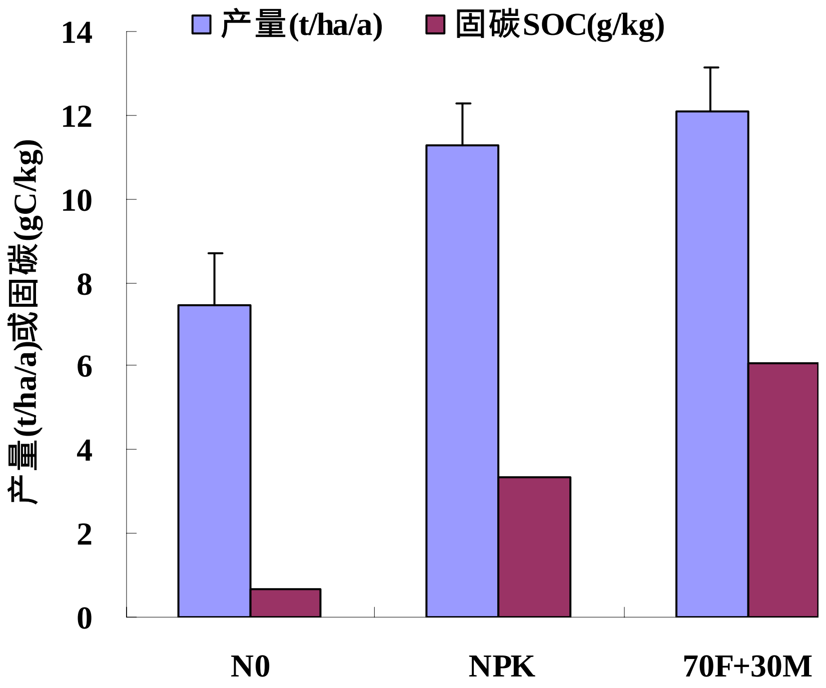
N efficiency: yield

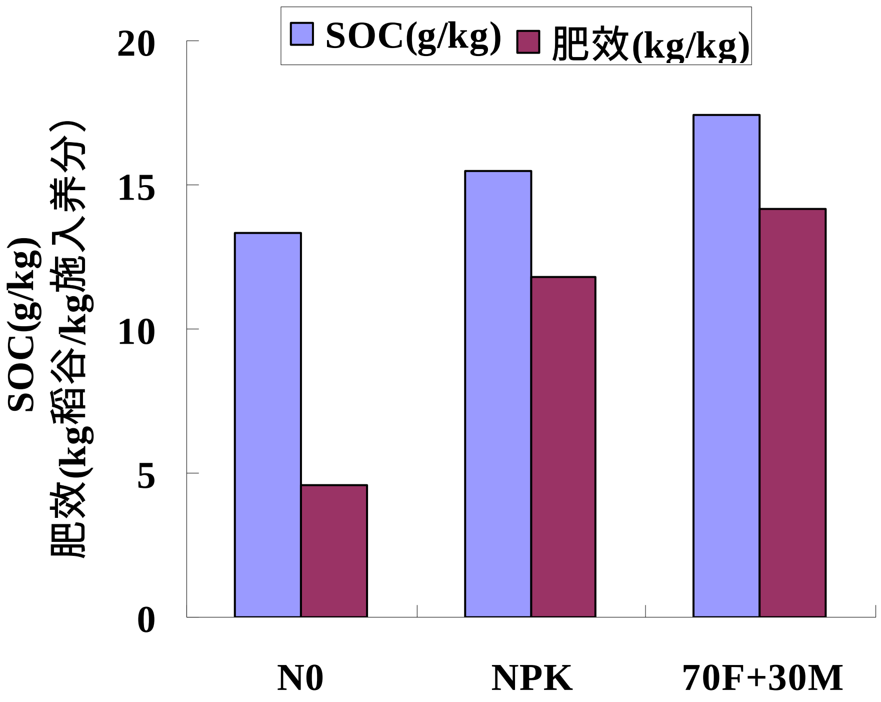


N efficiency: SCS

Zhou P,Pan G,et al.,Ecol. Sinica,2006

Supplements from red soil paddy





Suggestions for understanding Soil Quality

- **Soil quality: Capacity to support productivity and sustainability in harmony**
- **Soil quality: Coupling of productivity with ecological functioning**
- **Soil quality: New criteria input, major concerns of biota diversity and ecological redundancy**

Rice Paddy Soil Quality

- **Rice productivity: yield, variability,**
- **GHGs mitigation capability: SCS potential, GHG production potential,**
- **Key Parameters of soil quality: parameters for indicating the coupling capacity**

1, Nutrient Efficiency;

2, Soil respiration ratio and metabolic quotient;

3, Biological diversity?

4, SCS capacity……?

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Thanks You!

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