Important Response and Feedback of Asian Terrestrial Ecosystems Carbon Cycle to Global Warming

MOE NIES
CGER LAC

梁乃申 (Naishen Liang)
日本国立環境研究所

[2]Yiping Zhang, [3]Po-Neng Chiang, [4]Derrick Y.F. Lai, [1]Munemasa Teramoto, [5]Kentaro Takagi, [6, 13]Toshiaki Kondo, [7]Jun Koarashi, [3]Yanan Wang, [8]Shenggong Li, [9]Jingyun Fang, [9]Shilong Piao, [10]Masahiro Takagi, [11]Sachinobu Ishida, [5]Takashi Hirano, [1]Jiye Zeng, [1]Yoshiyuki Takahashi, [7]Mariko Ando, [12]Samsudin Musa

[2] XTBG, CAS; /// [5] Hokkaido Uni.; // [7] Japan Atomic Energy Agency ///

Global Soil Organic Carbon (SOC) Stock

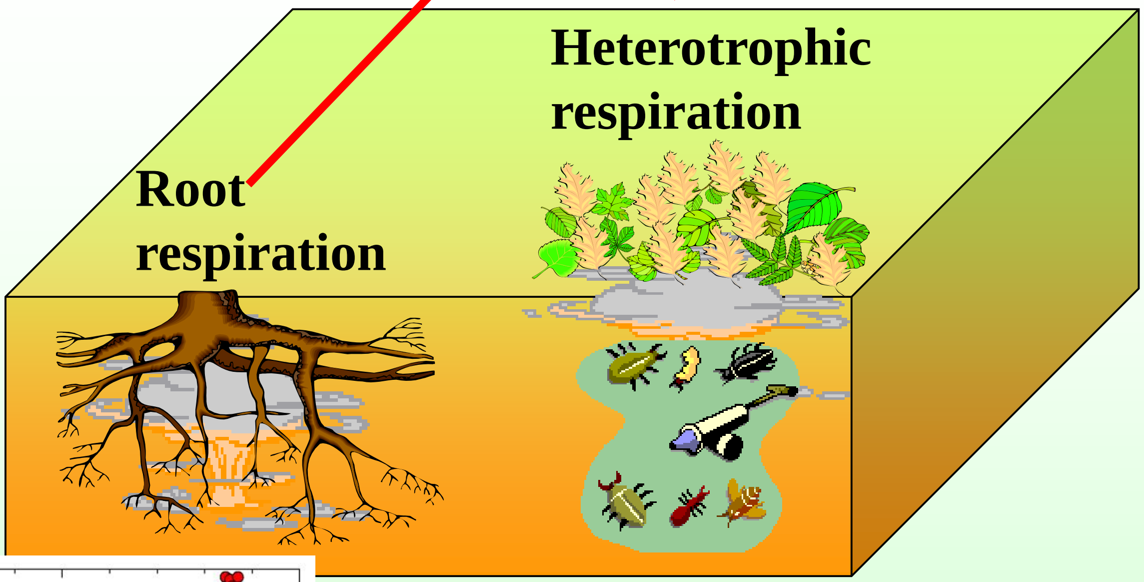
Global SOC pools (0-100cm) = 1550 Gt C

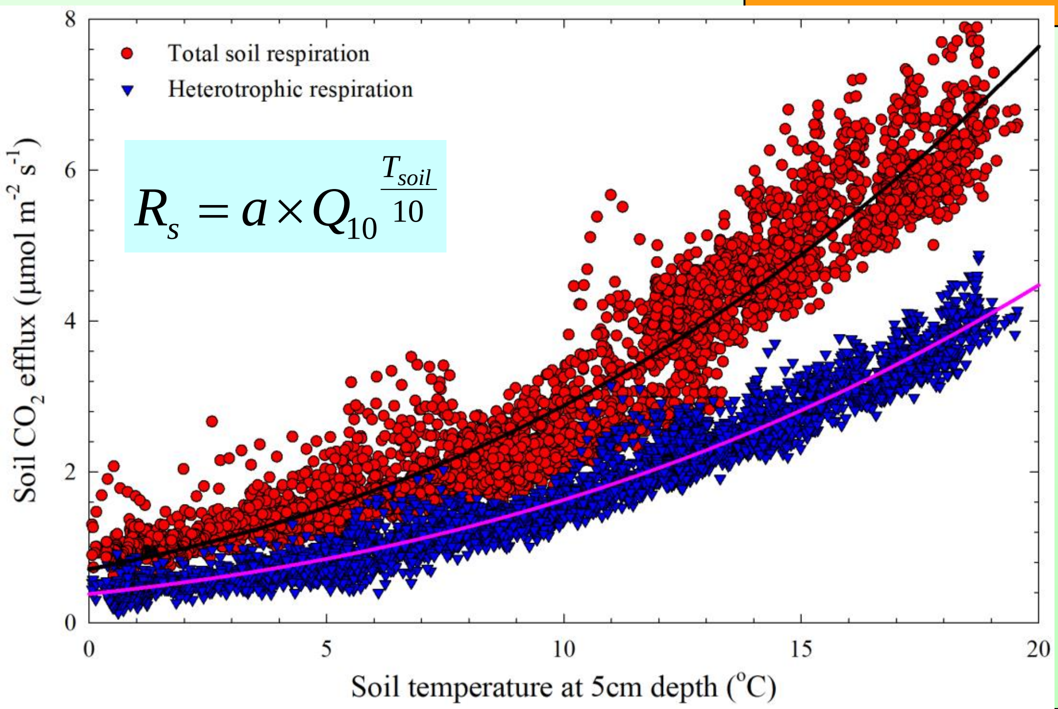
(Batjes 2014, *EJSS*)

Doubled the atmospheric carbon

Trebled the global vegetation biomass

Soil Respiration





Larch forest in Hokkaido
Liang *et al*. Biogeosciences, 2004

Global Soil Respiration

Raich & Potter 1995 (*GBC*)

$$Rs = 1.250 \times e^{0.05452 \times Ta} \times (W/(4.259 + W))$$

***T*a = monthly mean air temperature (°C),**

***W* =monthly mean precipitation (cm)**

Global Soil Respiration = 80 Gt C y^{-1}

Potter & Klooster 1998 (*GBC*); IPCC2001-2007

CASA model

Global Heterotrophic Re = 57 Gt C y^{-1}

9 times of fossil fuel emission (6.4 GtC y^{-1})

57 times of land sink (1.0 GtC y^{-1})

- **Important role of soil respiration in global carbon cycle**

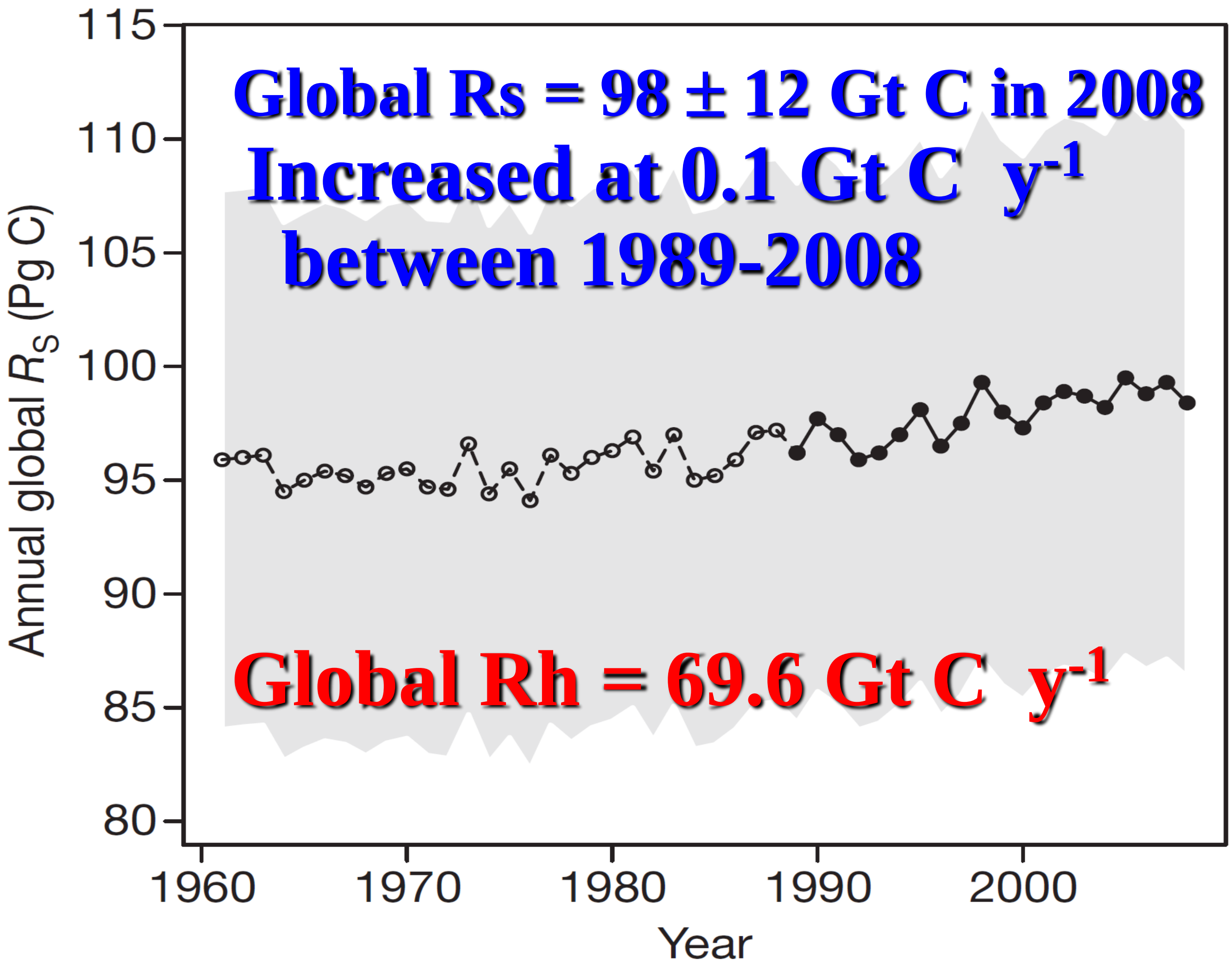
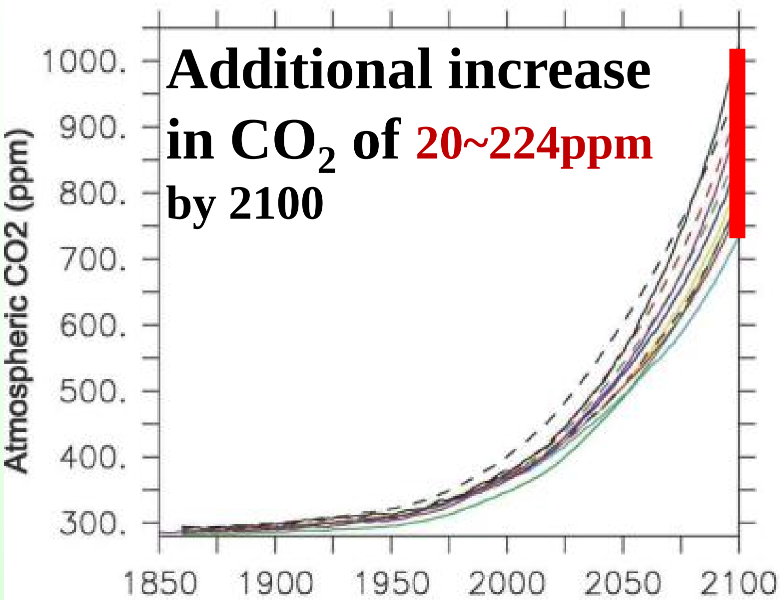


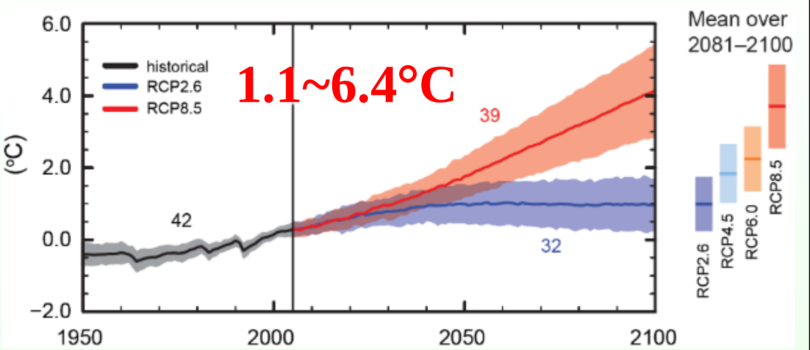
Figure 2 | Estimated annual global R_S. The dashed line indicates results outside the time period covered by main data set, S1 (1989–2008), but within the period covered by the entire R_S database, S0 (1961–2008), and should be considered speculative. The grey region shows the standard deviation of the Monte Carlo simulations ($N = 1,000$). Nature, 464: 579-582 (25 March 2010)

Feedback of SOC Decomposition to Global Warming
(IPCC AR4, AR5)



Vicious cycle

0.1~1.5°C



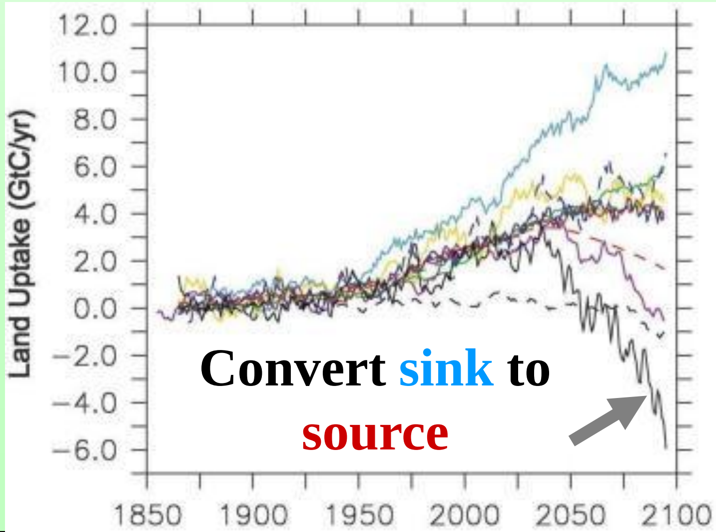
SOC decomposition

$C = \mathrm{NPP}/(k\ Q_{10}^{(T-15)/10})$ Eq. (2)

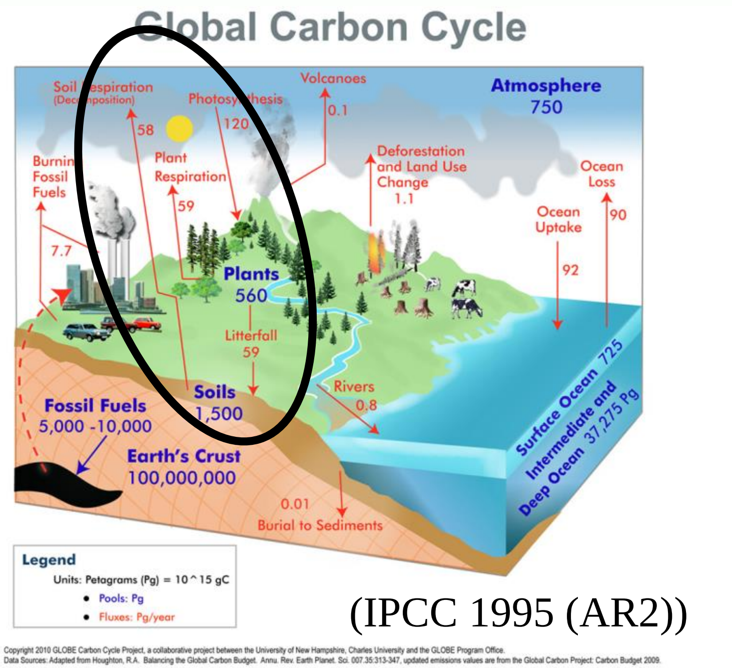
Model name	(yr)	Q_{10}
HWSD-MODIS-CRU	16.0	1.75
CCSM4	11.5	1.55
NorESM1	14.9	1.65
BCC-CSM1.1	16.8	2.05
HadGEM2	18.5	1.52
IPSL-CM5	13.2	1.61
GFDL-ESM2G	10.9	2.61
CanESM2	22.5	1.74
INM-CM4	20.7	2.19
GISS-E2	–	–
MIROC-ESM Asia	37.1 Japan	1.98
MPI-ESM-LR	29.8	1.45

6.2% °C^{-1} (4.0~8.1%)

Positive feedback



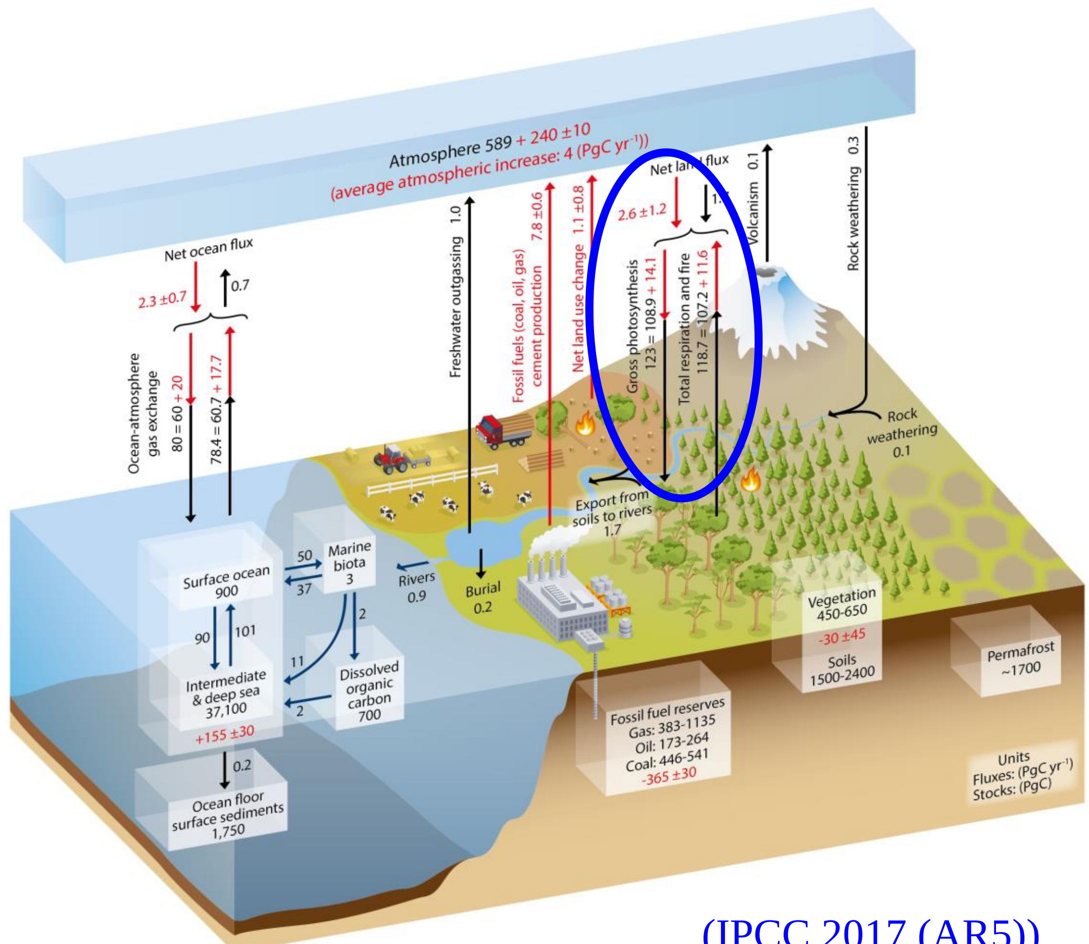
Global Soil respiration in Last 3 Decades



(IPCC 1995 (AR2))

Copyright 2010 GLOBE Carbon Cycle Project, a collaborative project between the University of New Hampshire, Charles University and the GLOBE Program Office.
Data Sources: Adapted from Houghton, R.A. Balancing the Global Carbon Budget. Annu. Rev. Earth Planet. Sci. 007.35:313-347, updated emissions values are from the Global Carbon Project: Carbon Budget 2009.

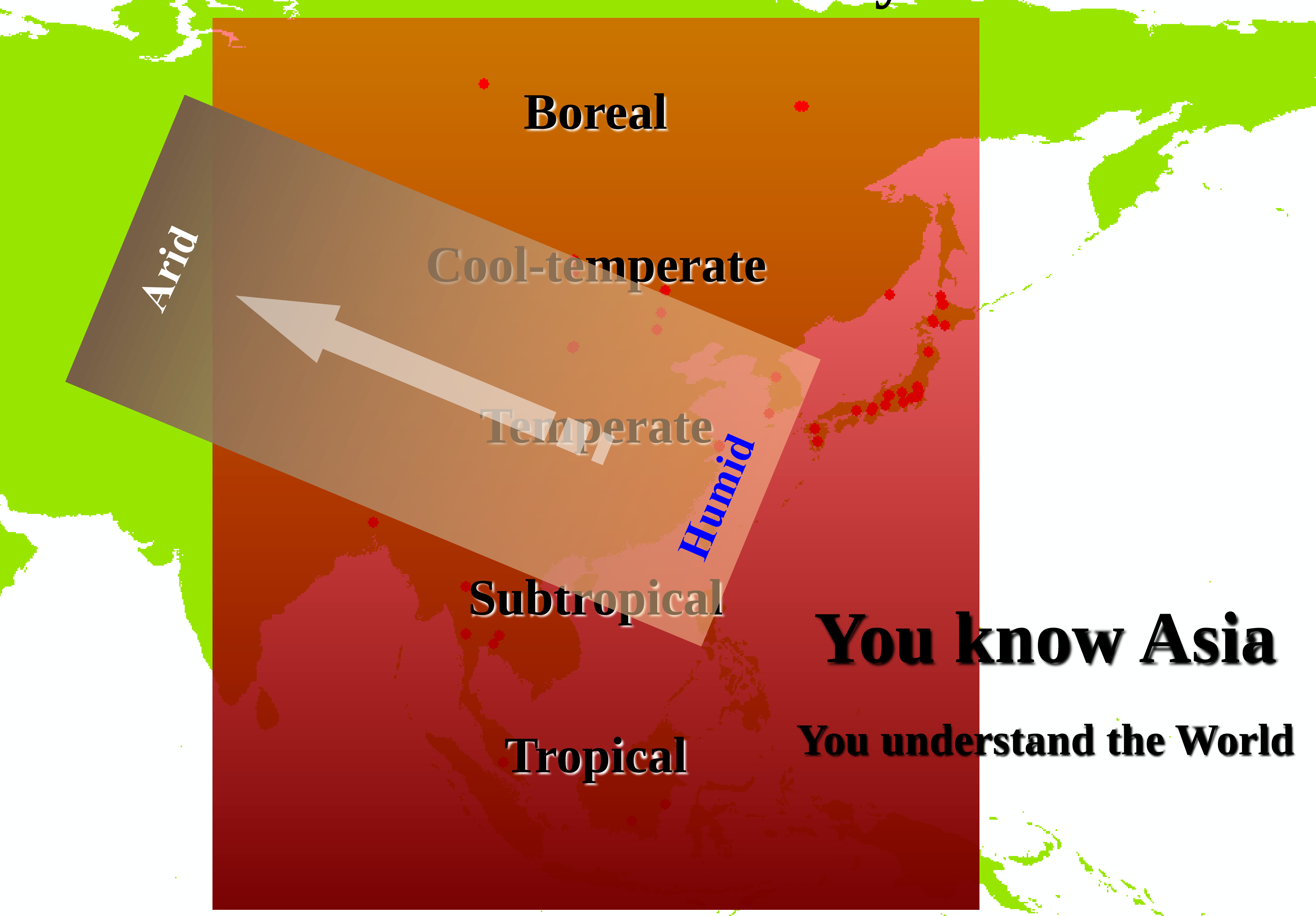
All processes have changed a lot



(IPCC 2017 (AR5))

But not soil carbon?

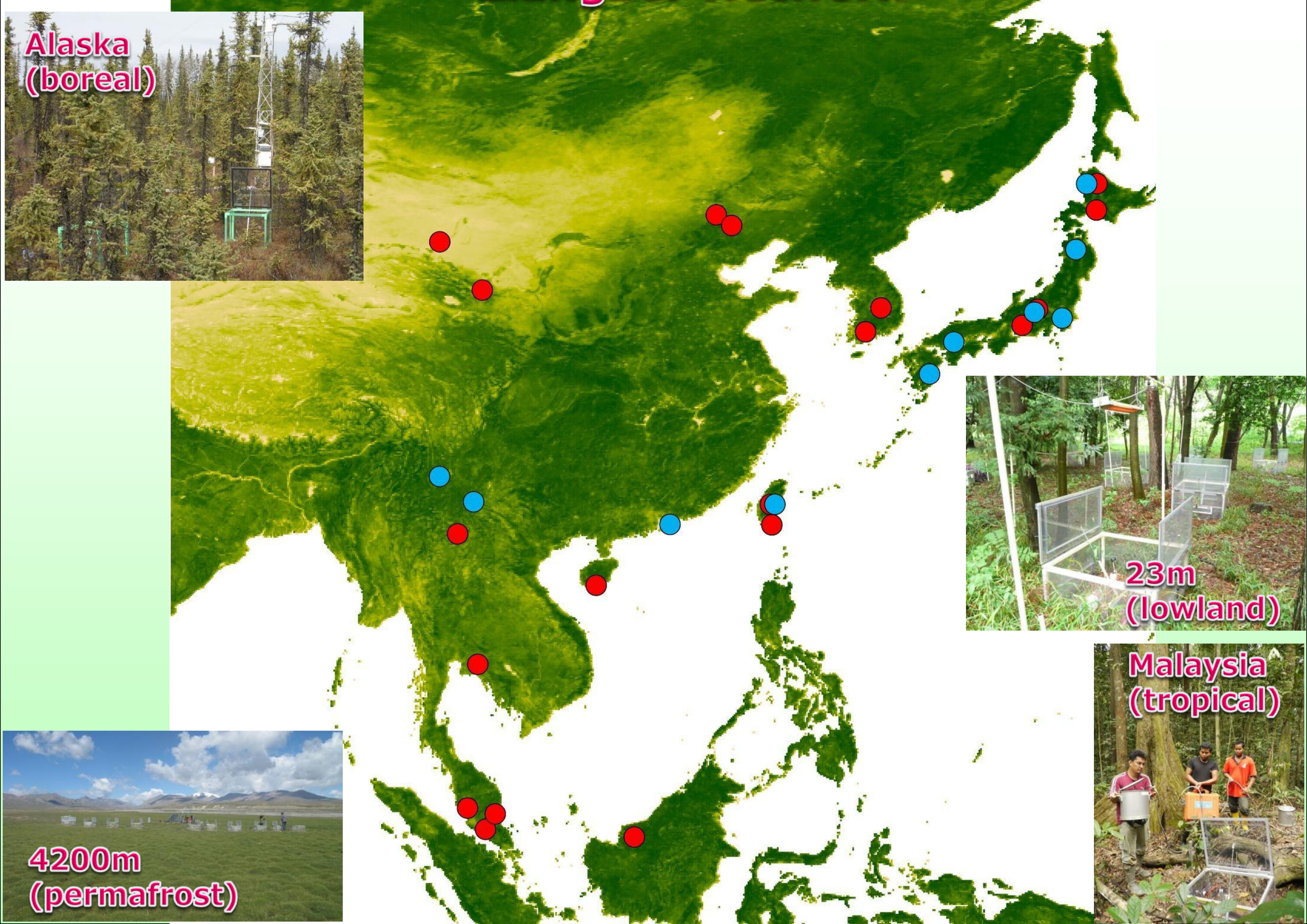
Asian Terrestrial Ecosystems



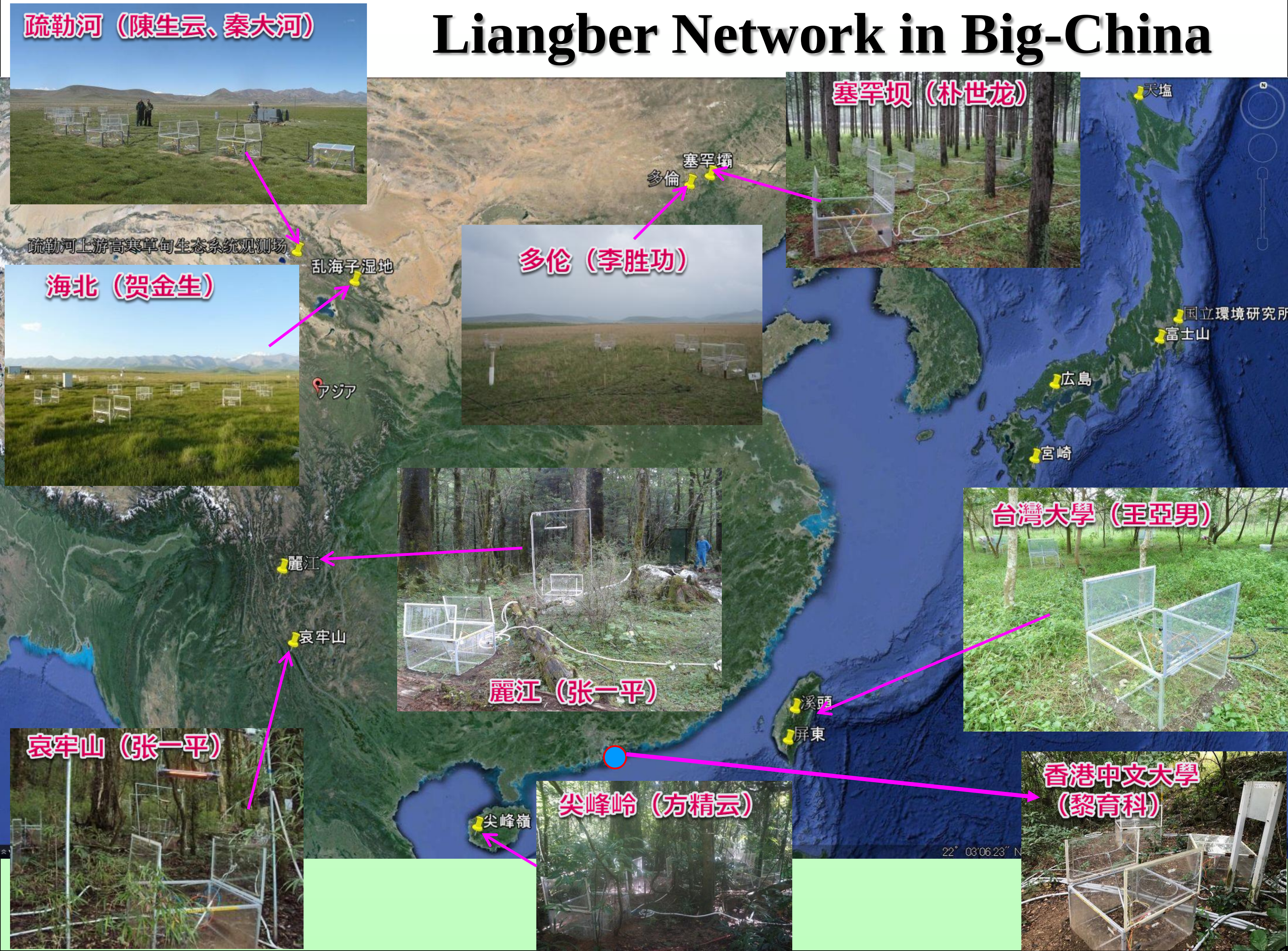
Open Questions

- **With global warming, will Asian (monsoon) terrestrial ecosystems continuous be carbon sink?**
- **or potentially convert to carbon source?**

Liangber Network



Liangber Network in Big-China

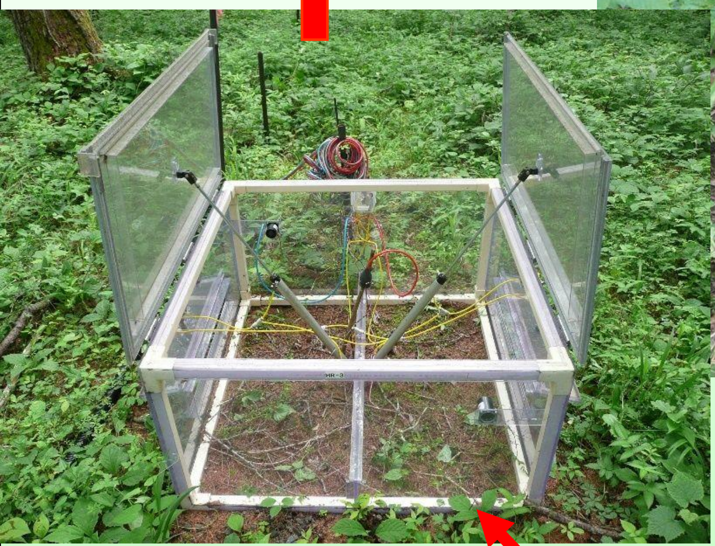


Partitioning Forest Understory Carbon Budget

Heterotrophic respiration (R_h)

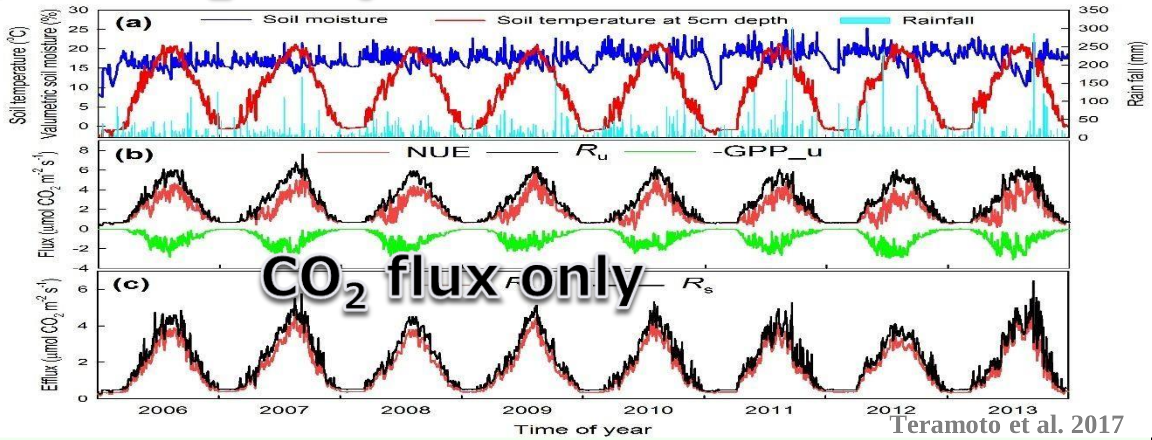
Soil efflux (R_s)

Soil efflux + Photosynthesis

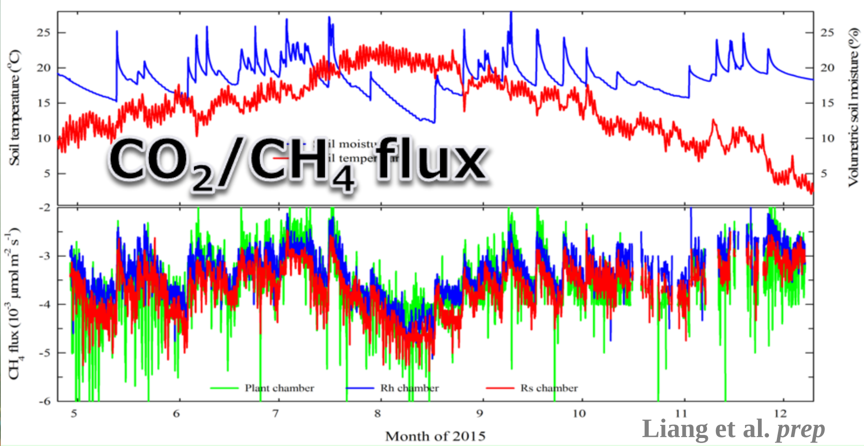


Multichannel gas sampler

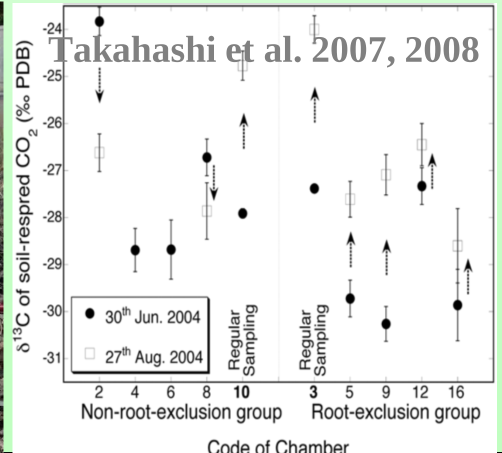
From CO_2 only to CO_2/CH_4 and to $^{13}C/^{18}O$



Teramoto et al. 2017



Liang et al. *prep*



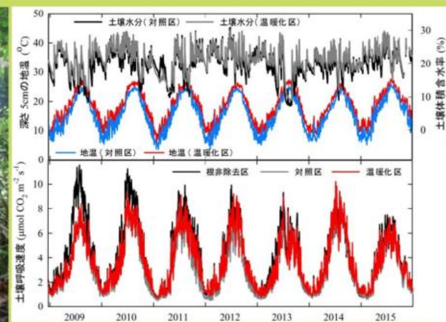
Takahashi et al. 2007, 2008

Stable isotope $^{13}C/^{18}O$

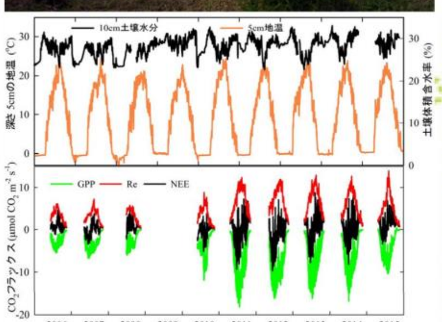
Funded by the Ministry of the Environment (2017~2020)

アジアの森林土壌有機炭素放出の温暖化影響とフィードバック効果に関する包括的研究

1. 温暖化操作実験で温暖化影響の定量的検出

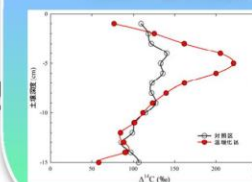


2. ネットワーク観測による撹乱影響の解明



プラットフォーム提供
結果フィードバック
情報共用
解析方法統一
プラットフォーム提供
結果フィードバック
広域トランセクト
情報共用
結果比較
● Fluxサイト
★ 温暖化サイト

^{14}Cで温暖化影響の解明



土壌有機物と土壌から放出されるCO_2の^{14}Cを分析し、温暖化影響を受けやすい有機炭素の"質"を鉛直的に解析

5,000万日元/年

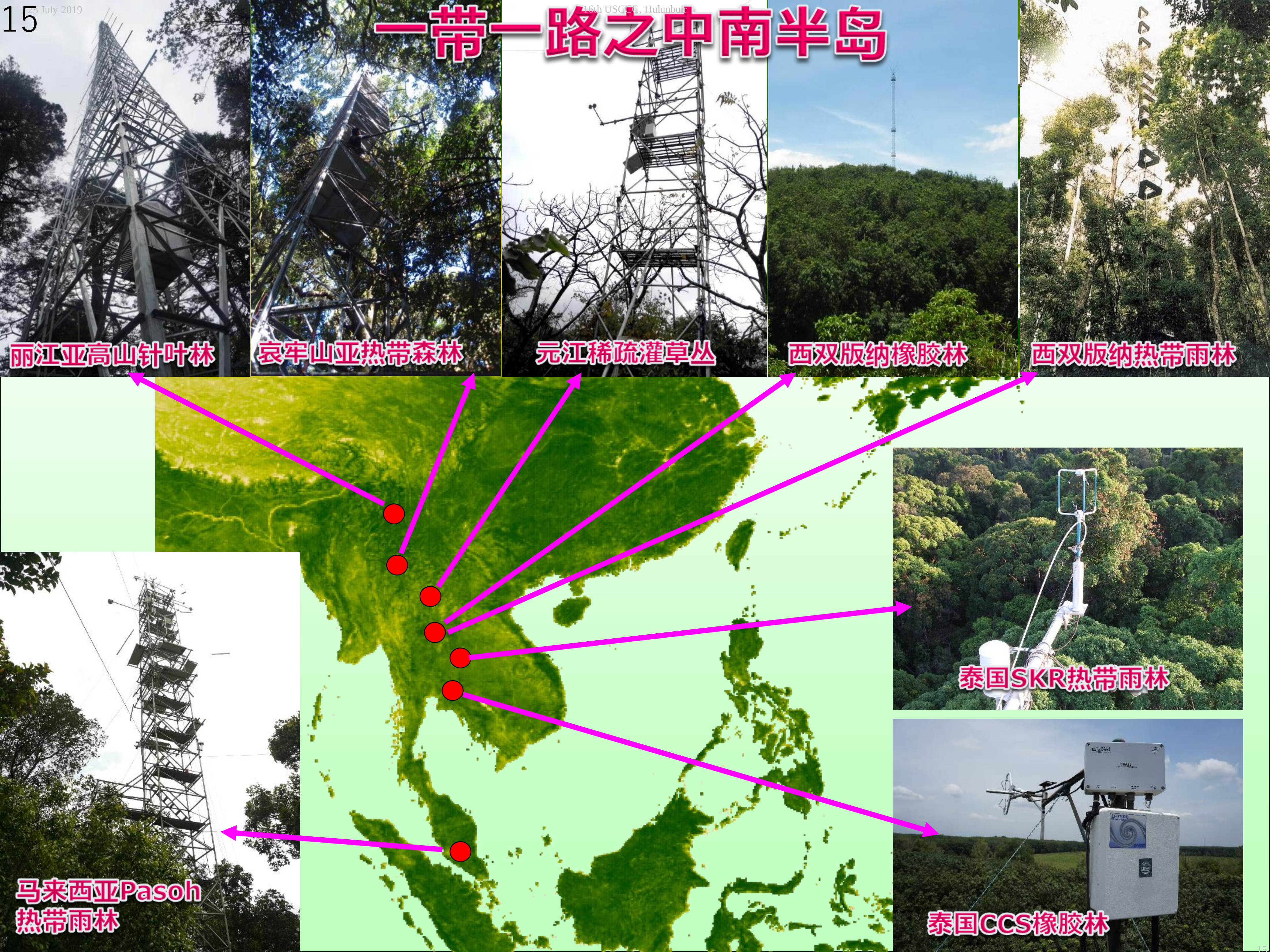
3. 微生物で温暖化効果の評価

次世代シーケンシング（NGS）で土壌微生物相の種組成、量、活性を分析し、温暖化効果の長期維持機構を評価

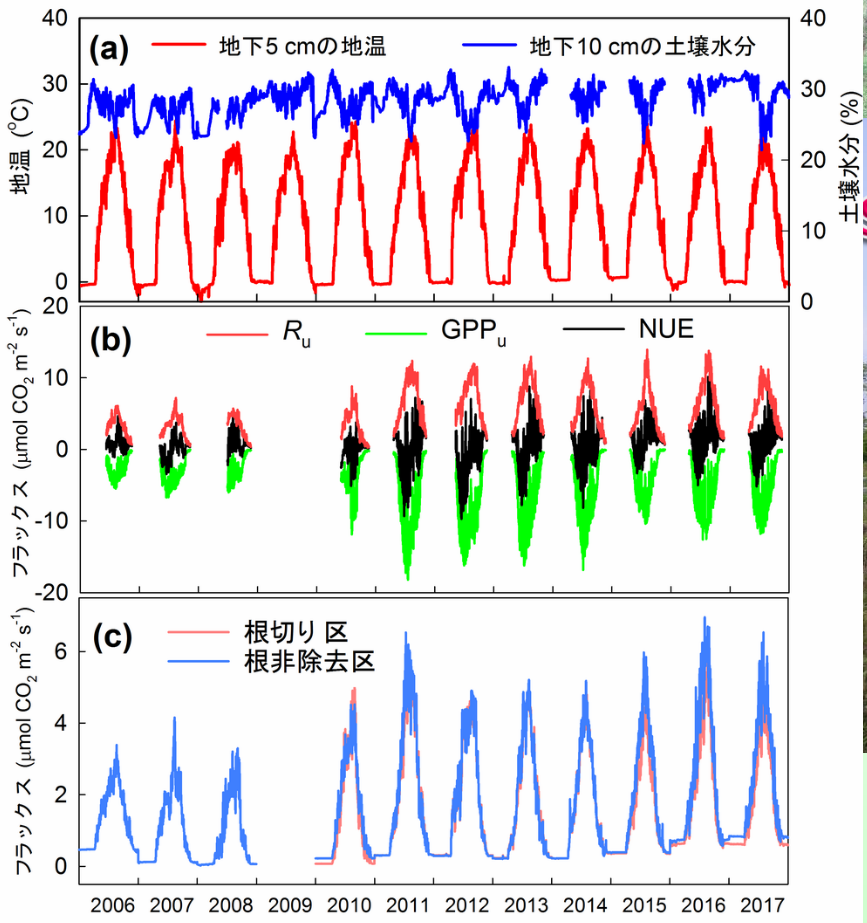
目標:

- 土壌炭素の長期変動メカニズムを地域毎に解明
- 炭素収支に与える気候変動・撹乱などの影響検出
- 温暖化条件下で森林が吸収源あるいは放出源となる可能性の広域的評価
- 途上国研究者のキャパシティ・ビルディングとともにアジア地域における日本のイニシアティブの発揮
- 適応策や緩和策、MRVなどの環境政策に提言

一带一路之中南半岛


丽江亚高山针叶林
哀牢山亚热带森林
元江稀疏灌草丛
西双版纳橡胶林
西双版纳热带雨林
泰国SKR热带雨林
泰国CCS橡胶林
马来西亚Pasoh
热带雨林

Mt. Fuji



Liang et al. 2004 (AFM), 2010 (BG)

Available online at www.sciencedirect.com

SCIENCE DIRECT

ELSEVIER

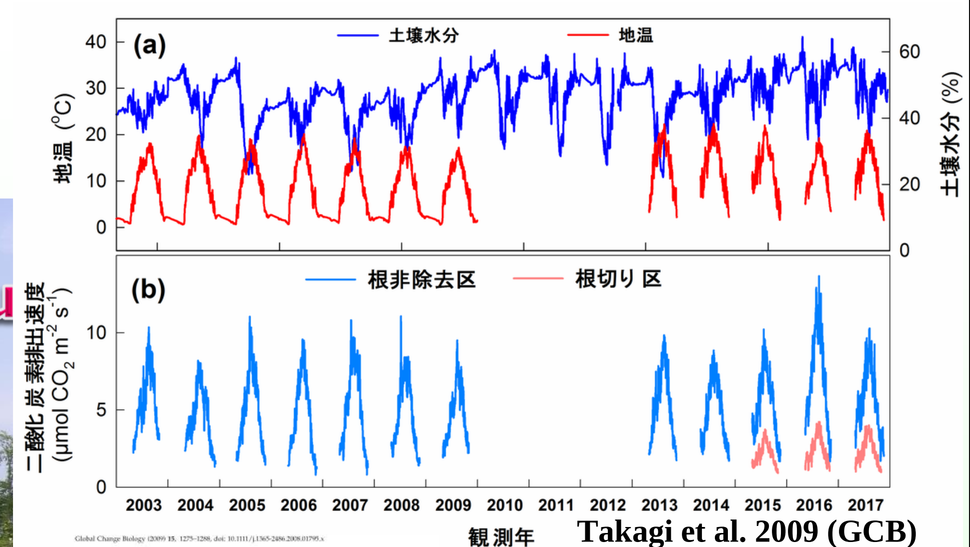
AGRICULTURAL AND FOREST METEOROLOGY

Agricultural and Forest Meteorology 123 (2004) 97–117
www.elsevier.com/locate/agrformet

In situ comparison of four approaches to estimating soil CO_2 efflux in a northern larch (*Larix kaempferi* Sarg.) forest

Naishen Liang[a,*], Toshie Nakadai[a], Takashi Hirano[b], Laiye Qu[b], Takayoshi Koike[c], Yasumi Fujinuma[a], Gen Inoue[a]
[a] Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba, Ibaraki 305-8506, Japan
[b] Graduate School of Agriculture, Hokkaido University, Sapporo, Japan
[c] Field Science Center for Northern Biosphere, Hokkaido University, Sapporo, Japan

Received 2 February 2003; received in revised form 20 August 2003; accepted 8 October 2003

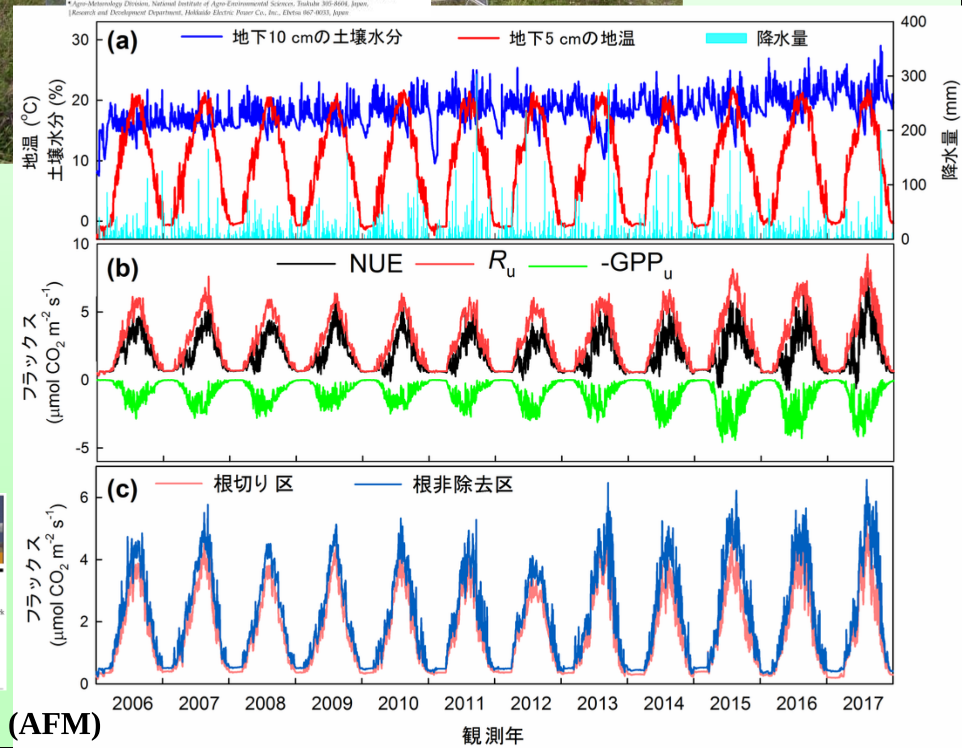


Takagi et al. 2009 (GCB)

Global Change Biology (2009) 15, 1275–1288, doi: 10.1111/j.1365-2486.2008.01795.x

Change in CO_2 balance under a series of forestry activities in a cool-temperate mixed forest with dense undergrowth

KENTARO TAKAGI*, KARIBU FUKUZAWA†, NAISHEN LIANG‡, MASAZUMI KAYAMA*, MUTSUMI NOMURA*, HAJIME HOJYO*, SADAO SUGATA*, HIDEAKI SHIBATA*, TATSUYA FUKAZAWA§, YOSHIYUKI TAKAHASHI‡, TATSURO NAKAJI‡, HIROYUKI OGUMA‡, MASAYOSHI MANO¶, YUKIO AKIBAYASHI*, TAKESHI MURAYAMA||, TAKAYOSHI KOIKE*, KAICHIRO SASA* and YASUMI FUJINUMA‡
*Field Science Center for Northern Biosphere, Hokkaido University, Sapporo 060-0809, Japan, †Graduate School of Agriculture, Hokkaido University, Nayoro 096-0071, Japan, ‡Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba 305-8506, Japan, §Graduate School of Engineering, Hokkaido University, Sapporo 060-8628, Japan, ¶Agro-Meteorology Division, National Institute of Agro-Environmental Sciences, Tsukuba 305-8604, Japan, ||Research and Development Department, Hokkaido Electric Power Co., Inc., Ebetsu 067-0033, Japan



Contents lists available at ScienceDirect

ELSEVIER

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

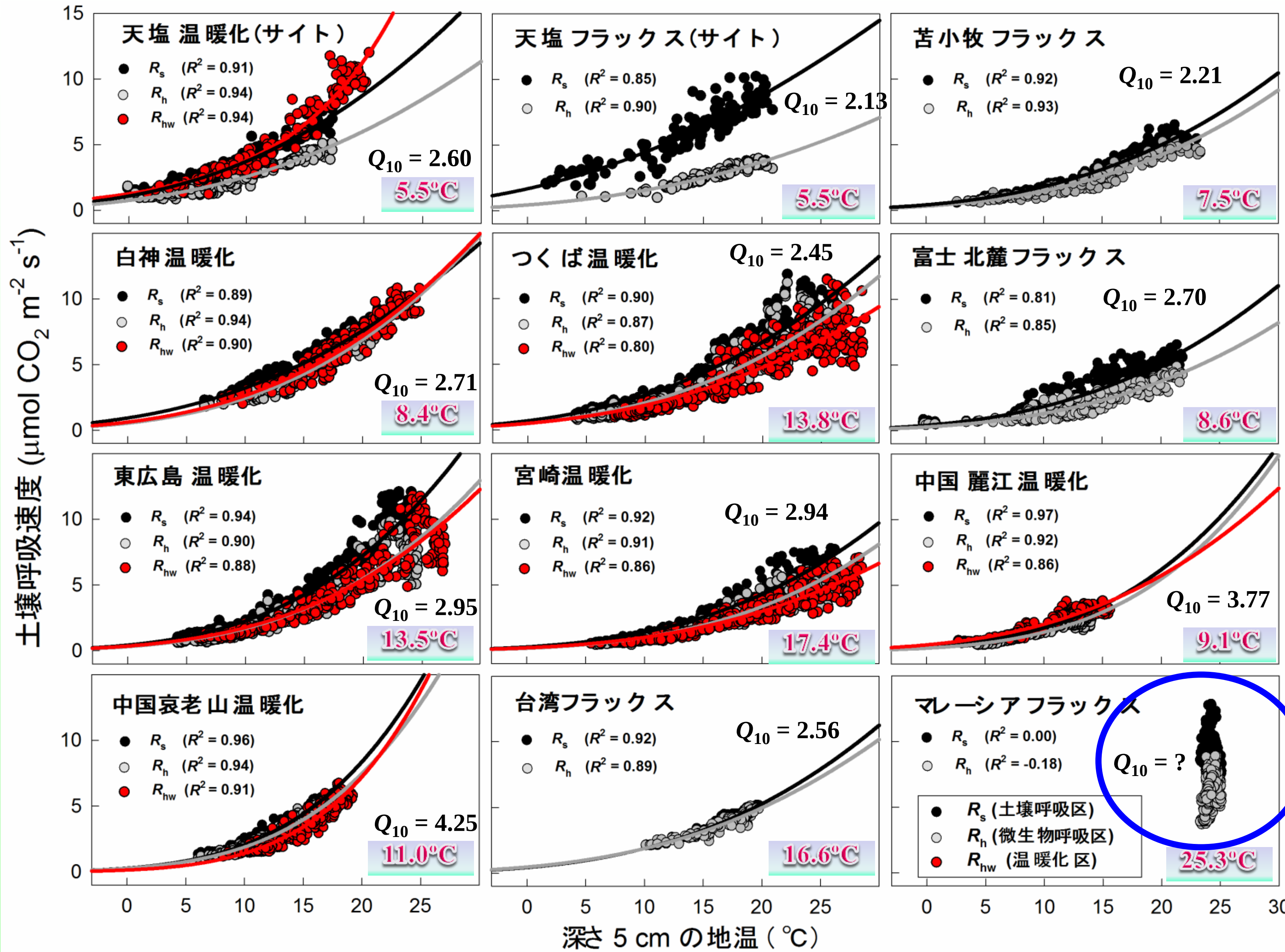
Research paper

Long-term chamber measurements reveal strong impacts of soil temperature on seasonal and inter-annual variation in understory CO_2 fluxes in a Japanese larch (*Larix kaempferi* Sarg.) forest

Munemasa Teramoto*, Naishen Liang*, Jiye Zeng, Nobuko Saigusa, Yoshiyuki Takahashi
Center for Global Environmental Research, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki, 305-8506, Japan

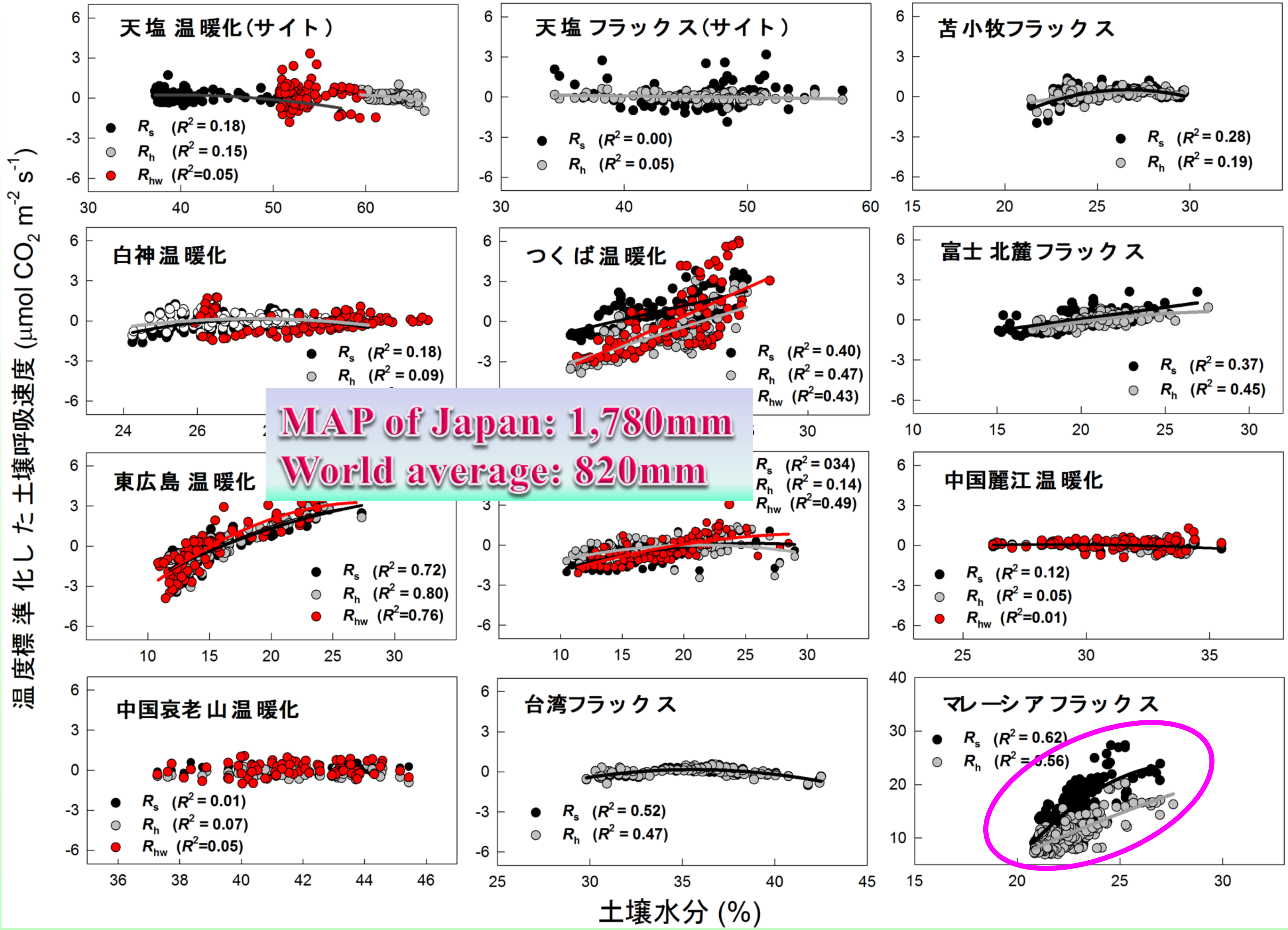
Teramoto et al. 2017, 2019 (AFM)

Soil temperature response of soil CO_2 flux in Asia monsoon forests



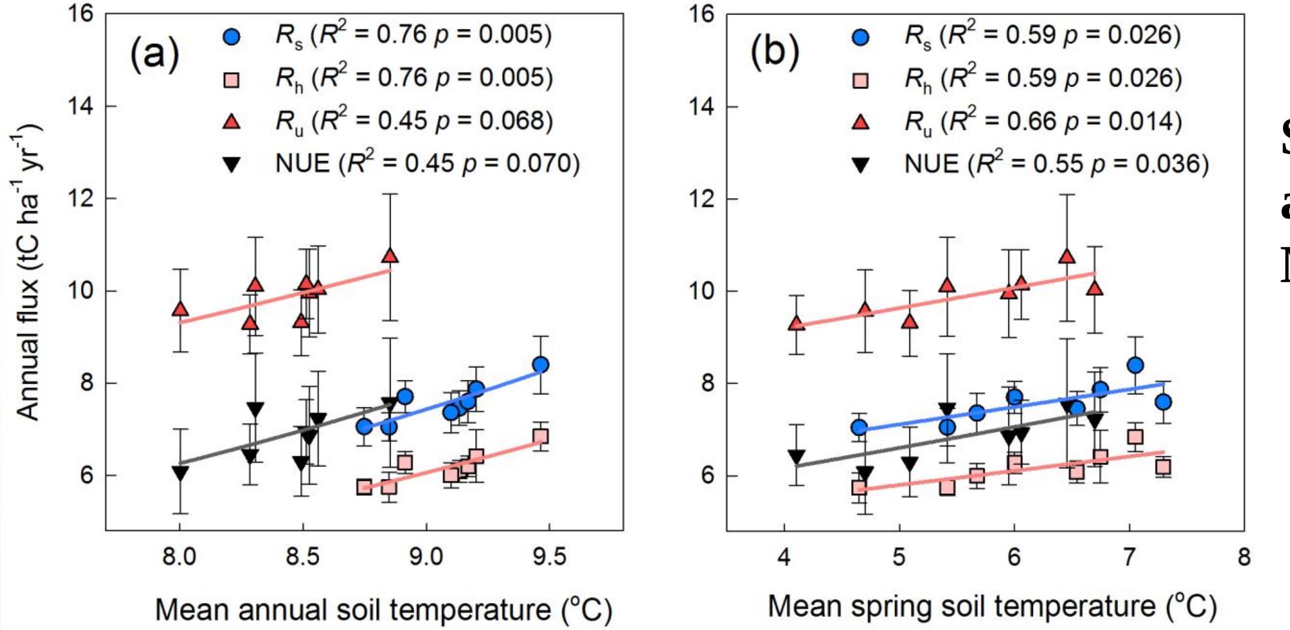
The influence of soil temperature is relatively strong

Soil moisture response of soil CO_2 flux in Asia monsoon forests



The influence of soil moisture is relatively weak

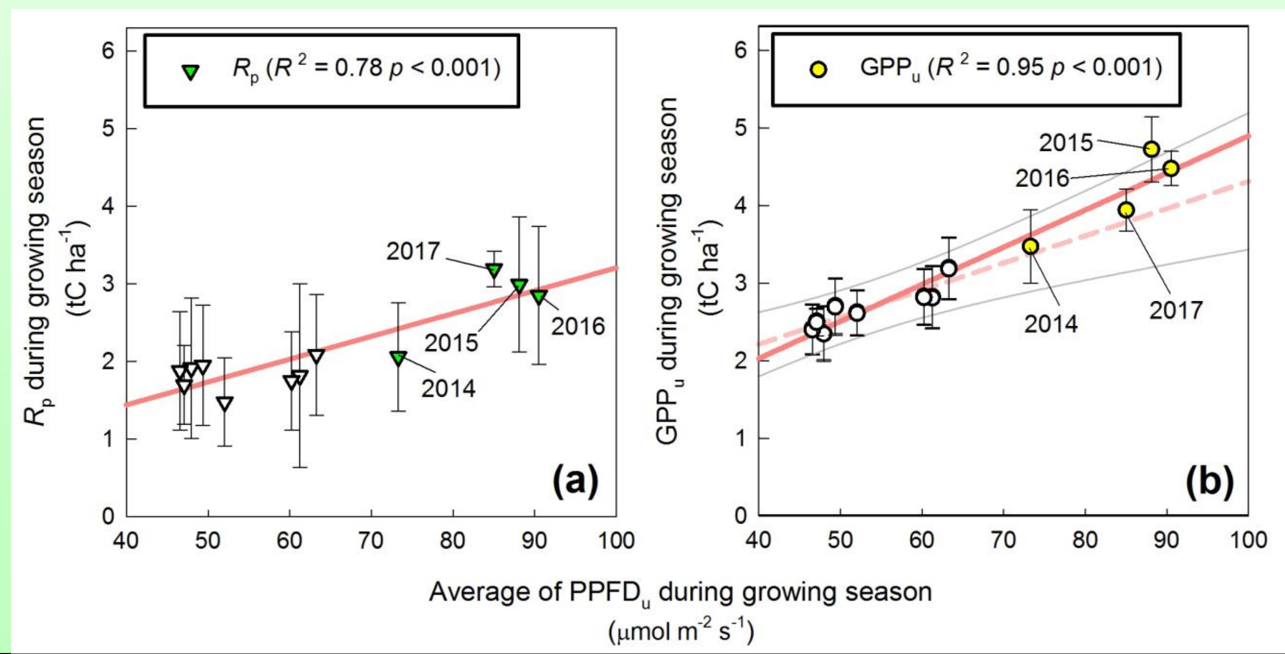
Impacts of climate change on carbon cycle



Soil CO_2 efflux fluctuated about 24% per °C of MAT.

Teramoto et al. 2017, AFM

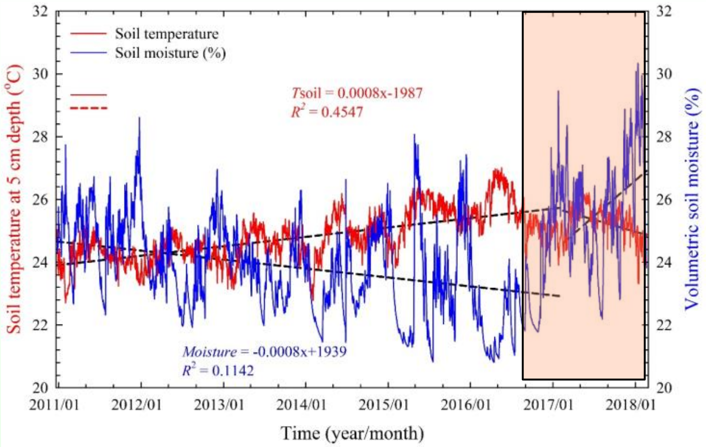
Increased understory photosynthesis balanced the increased respiration as well as the decreased canopy photosynthesis.



Teramoto et al. 2019, AFM

Effect of Land-use Change on Soil CO_2 Efflux

Effect of Land-use Change on Soil CO_2 Efflux



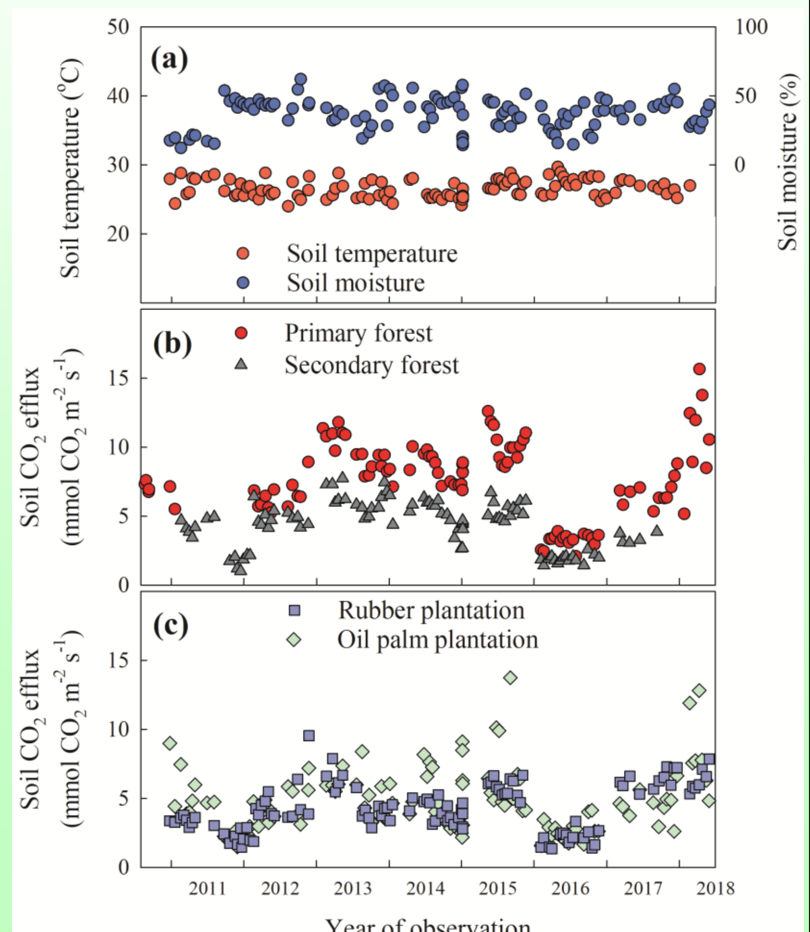
Dramatical climate change occurs in Southeast Asia.

Primary forest: 33.1 tC ha^{-1} y^{-1}（100%）

Secondary forest: 19.9 tC ha^{-1} y^{-1}（60%）

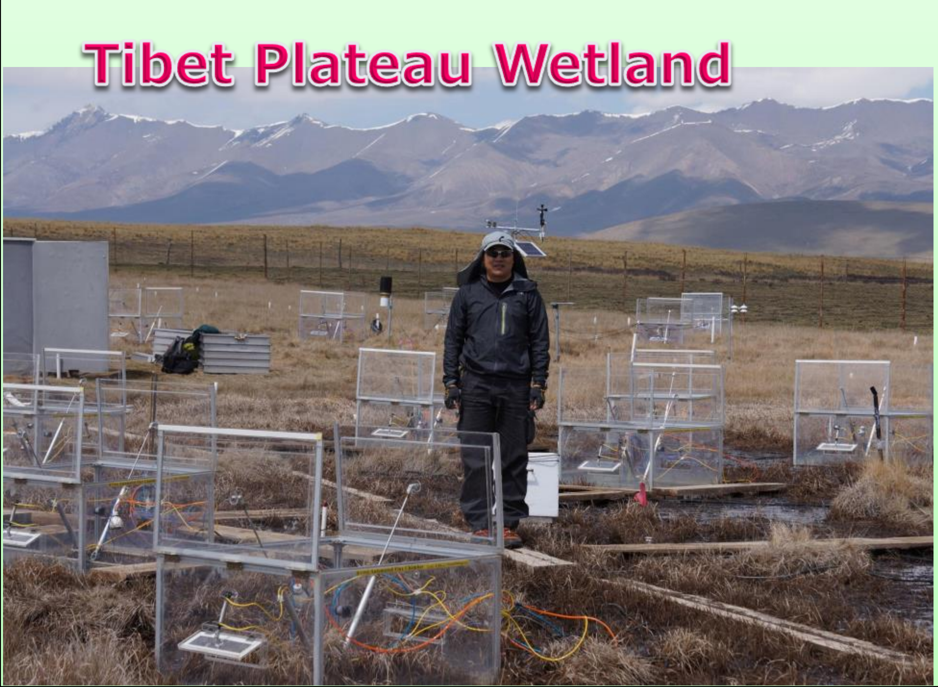
4-12 year old oil palm: 19.9 tC ha^{-1} y^{-1}（60%）

4-12 year old rubber: 17.4 tC ha^{-1} y^{-1}（53%）

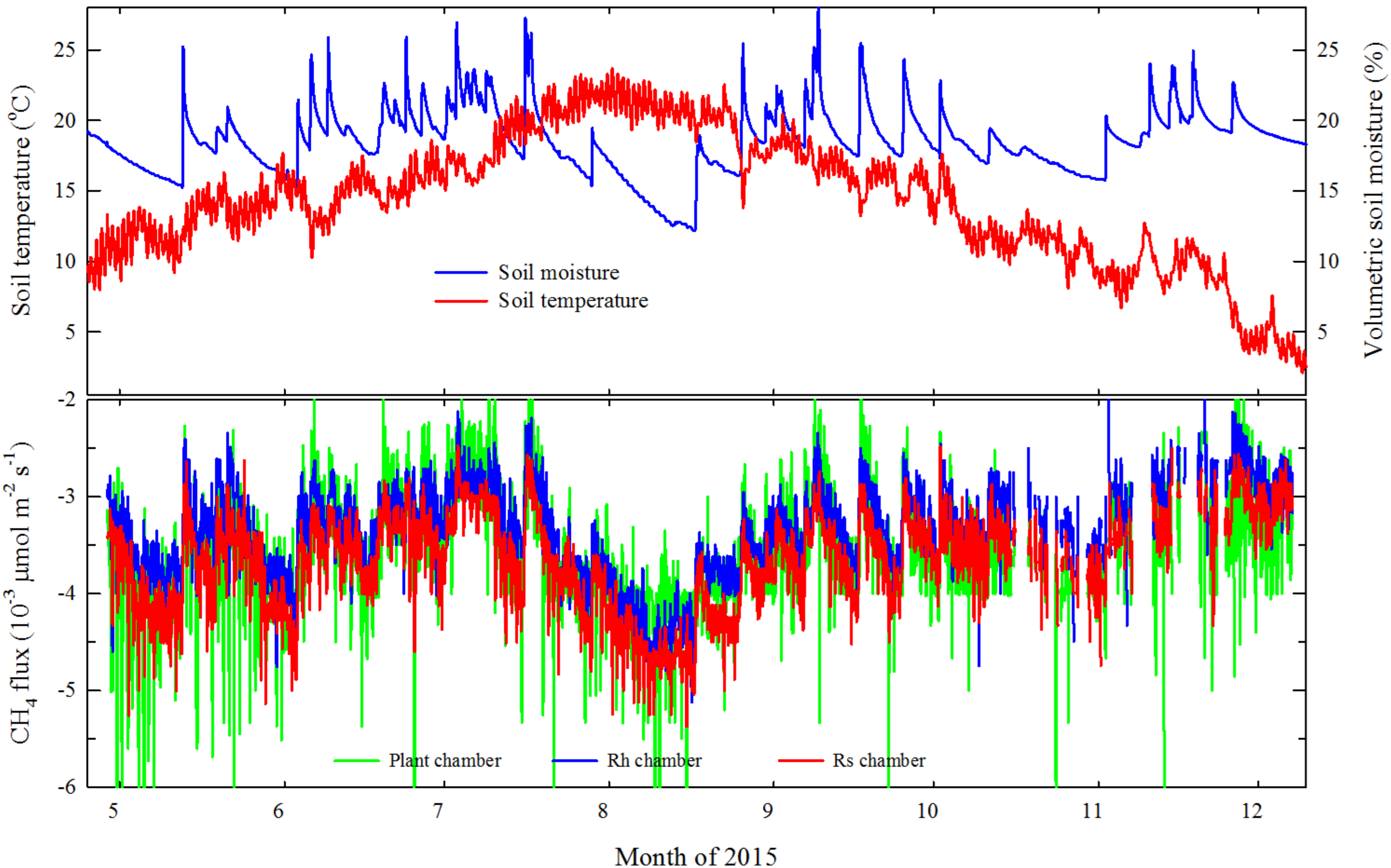


Deforestation or land-use change caused soil degradation in tropics.

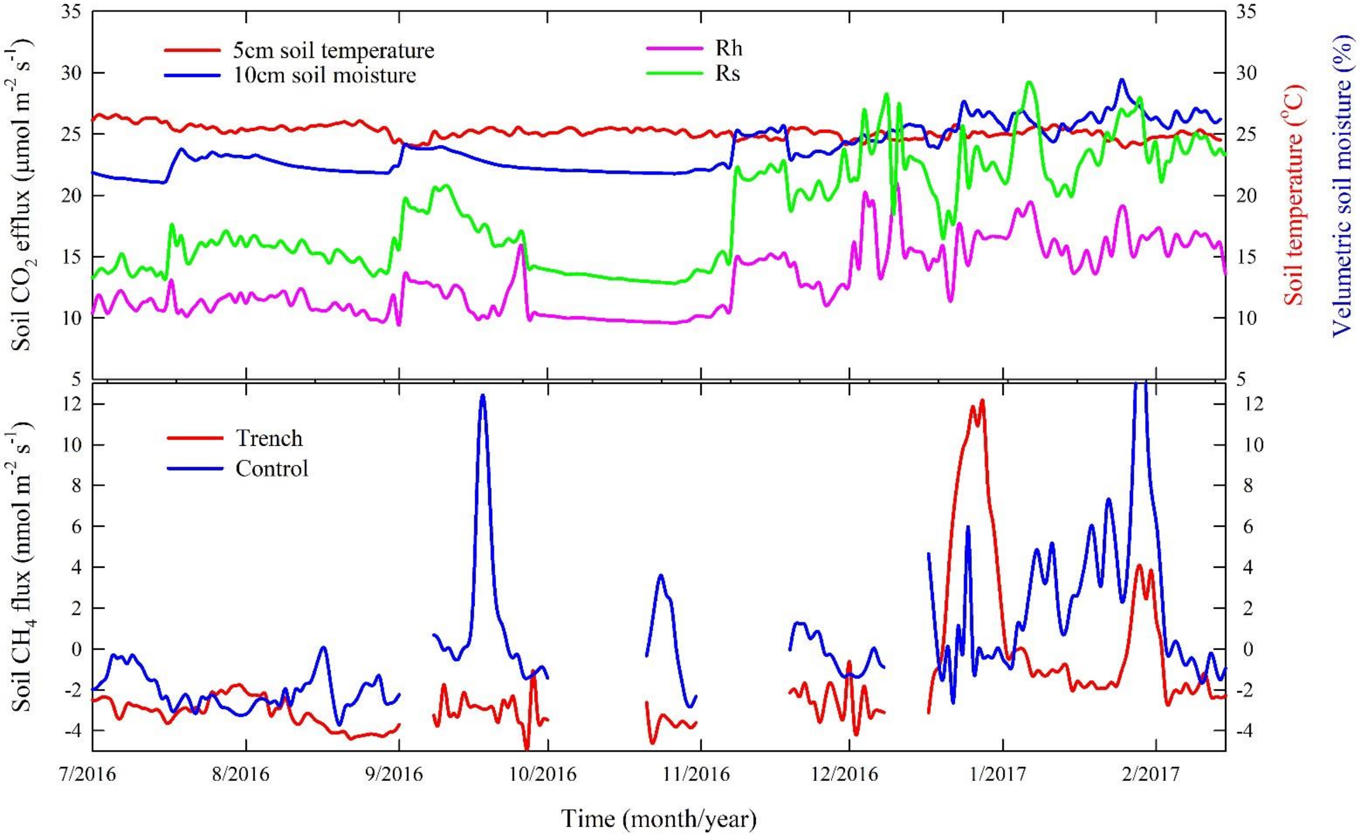
Soil to Ecosystem CH_4 flux

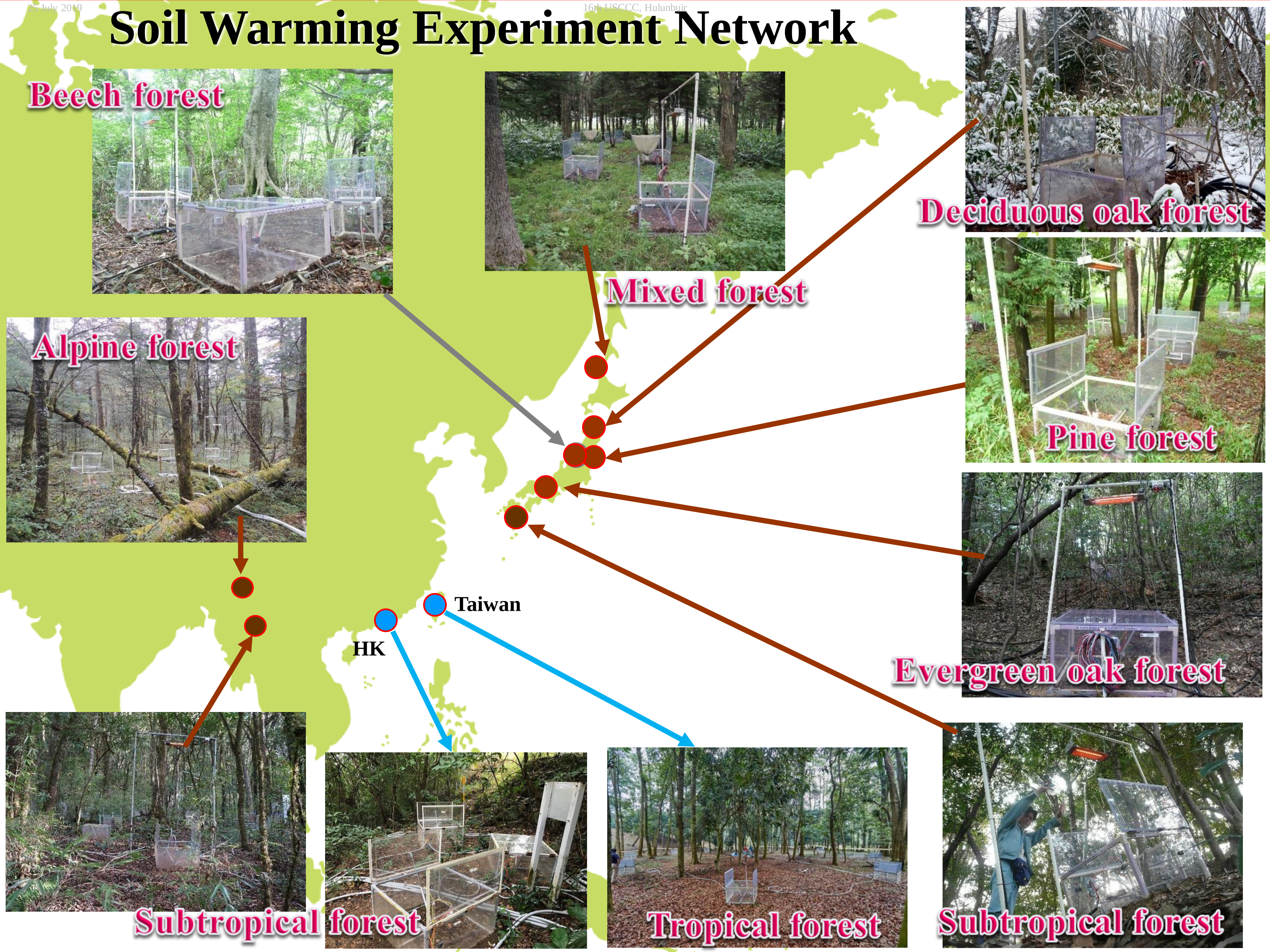


Soil CH_4 Flux of Japaneses Larch Forest (Mt. Fuji)



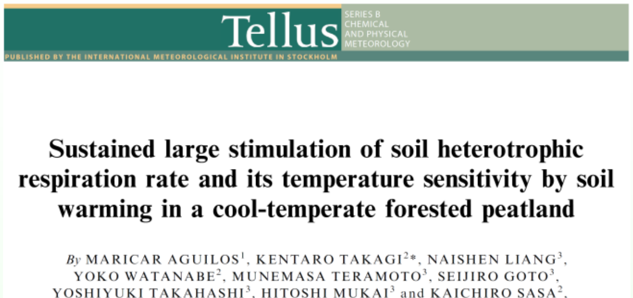
Seasonal soil CO_2/CH_4 flux at Pasoh Tropical Forest




Soil Warming Experiment Network
Beech forest
Mixed forest
Deciduous oak forest
Alpine forest
Pine forest
Evergreen oak forest
Taiwan
HK
Subtropical forest
Tropical forest
Subtropical forest

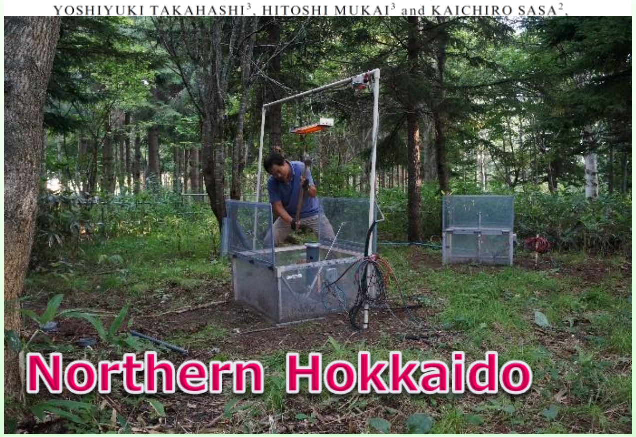
Experiment Designing

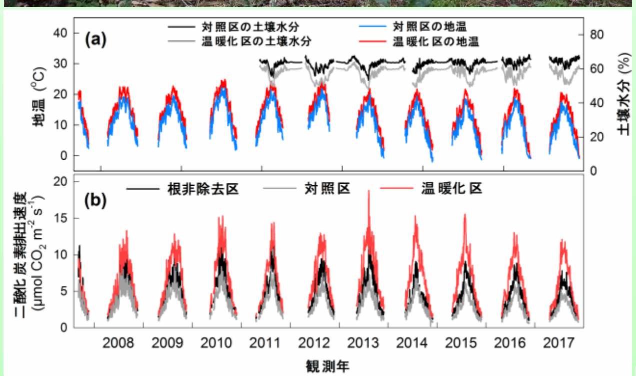
Large Warming Effect on Asia Monsoon Forest Soil Decomposition

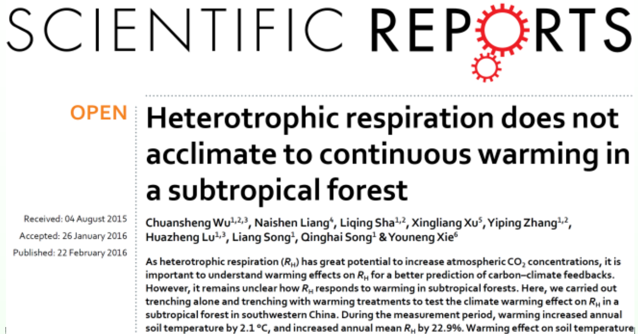

Tellus SERIES B CHEMICAL AND PHYSICAL METEOROLOGY
PUBLISHED BY THE INTERNATIONAL METEOROLOGICAL INSTITUTE IN STOCKHOLM

Sustained large stimulation of soil heterotrophic respiration rate and its temperature sensitivity by soil warming in a cool-temperate forested peatland

By MARICAR AGUILOS[1], KENTARO TAKAGI[2*], NAISHEN LIANG[3], YOKO WATANABE[2], MUNEMASA TERAMOTO[3], SEIJIRO GOTO[3], YOSHIYUKI TAKAHASHI[3], HITOSHI MUKAI[3] and KAICHIRO SASA[2]






SCIENTIFIC REPORTS

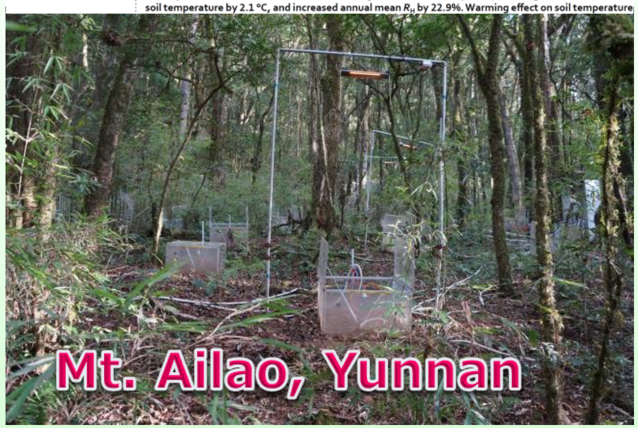
OPEN

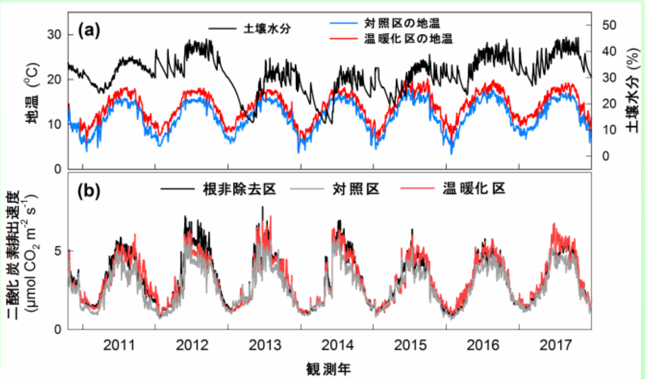
Heterotrophic respiration does not acclimate to continuous warming in a subtropical forest

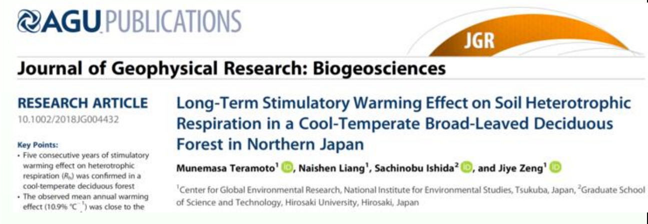
Received: 04 August 2015
Accepted: 26 January 2016
Published: 22 February 2016

Chuansheng Wu[1,2,3], Naishen Liang[4], Liqing Sha[1,2], Xingliang Xu[5], Yiping Zhang[1,2], Huazheng Lu[1,3], Liang Song[1], Qinghai Song[1] & Youneng Xie[6]

As heterotrophic respiration (R_H) has great potential to increase atmospheric CO_2 concentrations, it is important to understand warming effects on R_H for a better prediction of carbon–climate feedbacks. However, it remains unclear how R_H responds to warming in subtropical forests. Here, we carried out trenching alone and trenching with warming treatments to test the climate warming effect on R_H in a subtropical forest in southwestern China. During the measurement period, warming increased annual soil temperature by 2.1 °C, and increased annual mean R_H by 22.9%. Warming effect on soil temperature






AGU PUBLICATIONS JGR

Journal of Geophysical Research: Biogeosciences

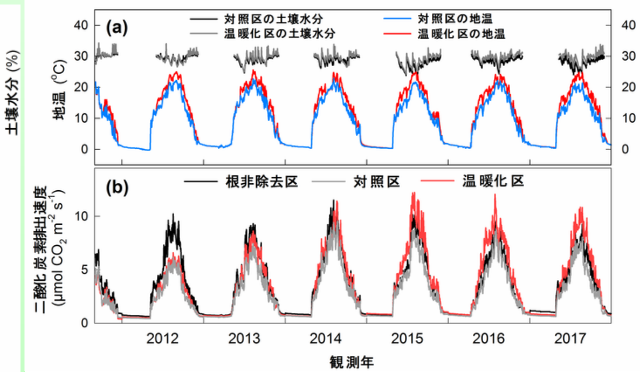
RESEARCH ARTICLE
10.1002/2018JG004432

Key Points:
• Five consecutive years of stimulatory warming effect on heterotrophic respiration (R_H) was confirmed in a cool-temperate deciduous forest
• The observed mean annual warming effect (10.9% °C⁻¹) was close to the

Long-Term Stimulatory Warming Effect on Soil Heterotrophic Respiration in a Cool-Temperate Broad-Leaved Deciduous Forest in Northern Japan

Munemasa Teramoto[1], Naishen Liang[1], Sachinobu Ishida[2], and Jiye Zeng[1]

[1]Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba, Japan, [2]Graduate School of Science and Technology, Hirosaki University, Hirosaki, Japan

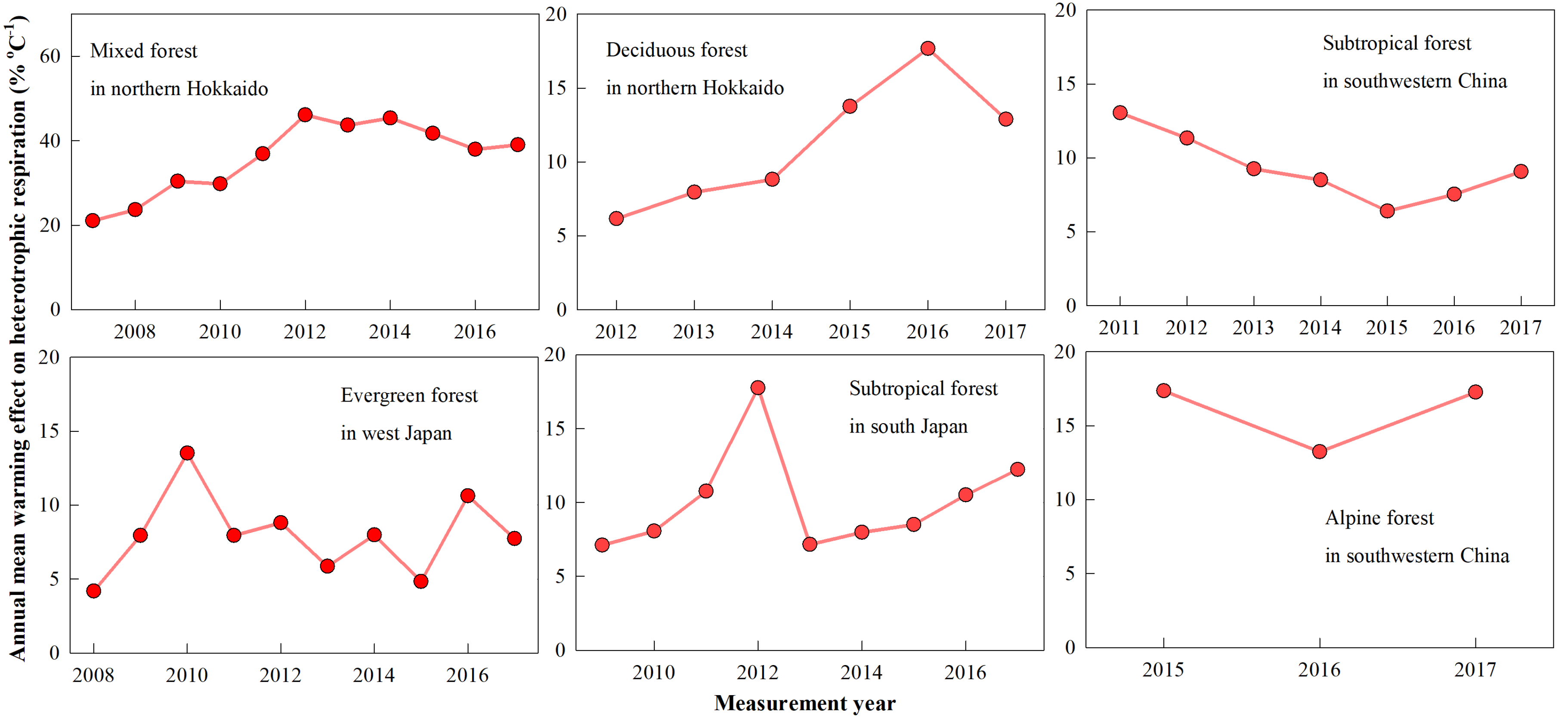


Drought peatland
Hight SOC stock
Low temperature (5.5°C)

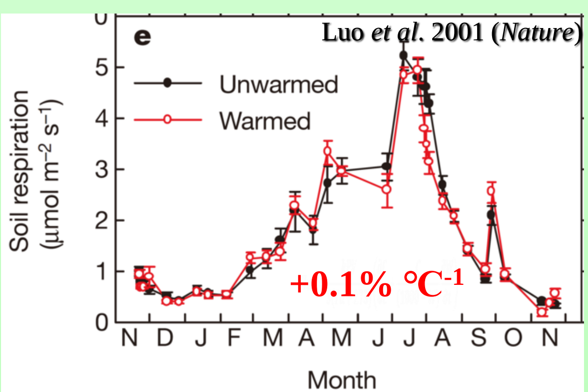
Subtropical mountain
High SOC stock
Easy decomposition

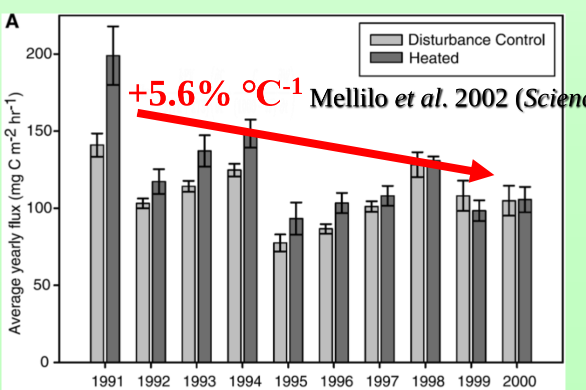
Cold-temperate climate
High SOC stock
Humid soil (>2400mm)

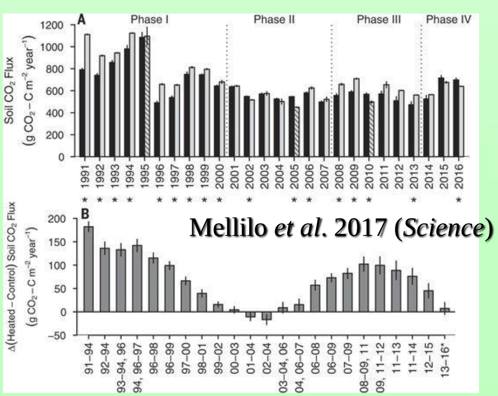
Large Warming Effect on Asia Monsoon Forest Soil Decomposition



Long-term & high warming effect may have strong feedback on global warming

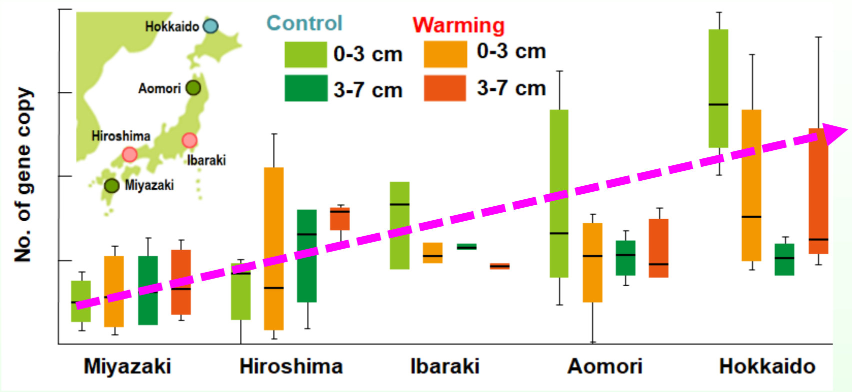






Difference in microbial biomass

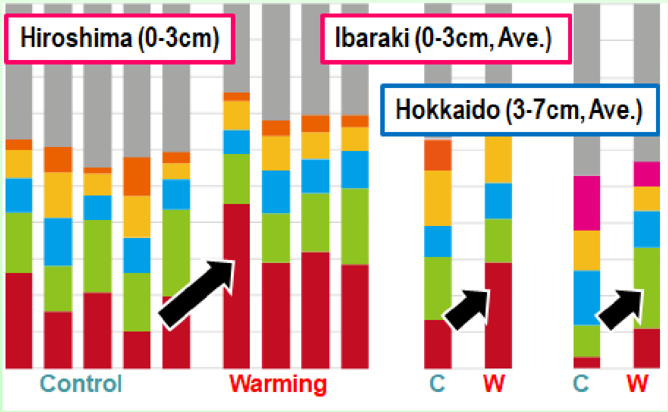
Amount of microbes



There were no significant differences in the amount of microbes between control and warming Ch in any region.

Thus, warming effect on the amount of microbe is limited.

Species composition



Although significant increase of specific microbial groups was observed in secondary forests and planted forest, the increase ratio is relatively small.

Such increase was not observed in primary forests with high diversity keeping from human disturbances.

It was concluded that the low levels of deceleration of Rh observed in Asian forests were originated from stability of microbial community against global warming brought by the high levels of biodiversity !!

Soil ^{14}C Measurement Protocol

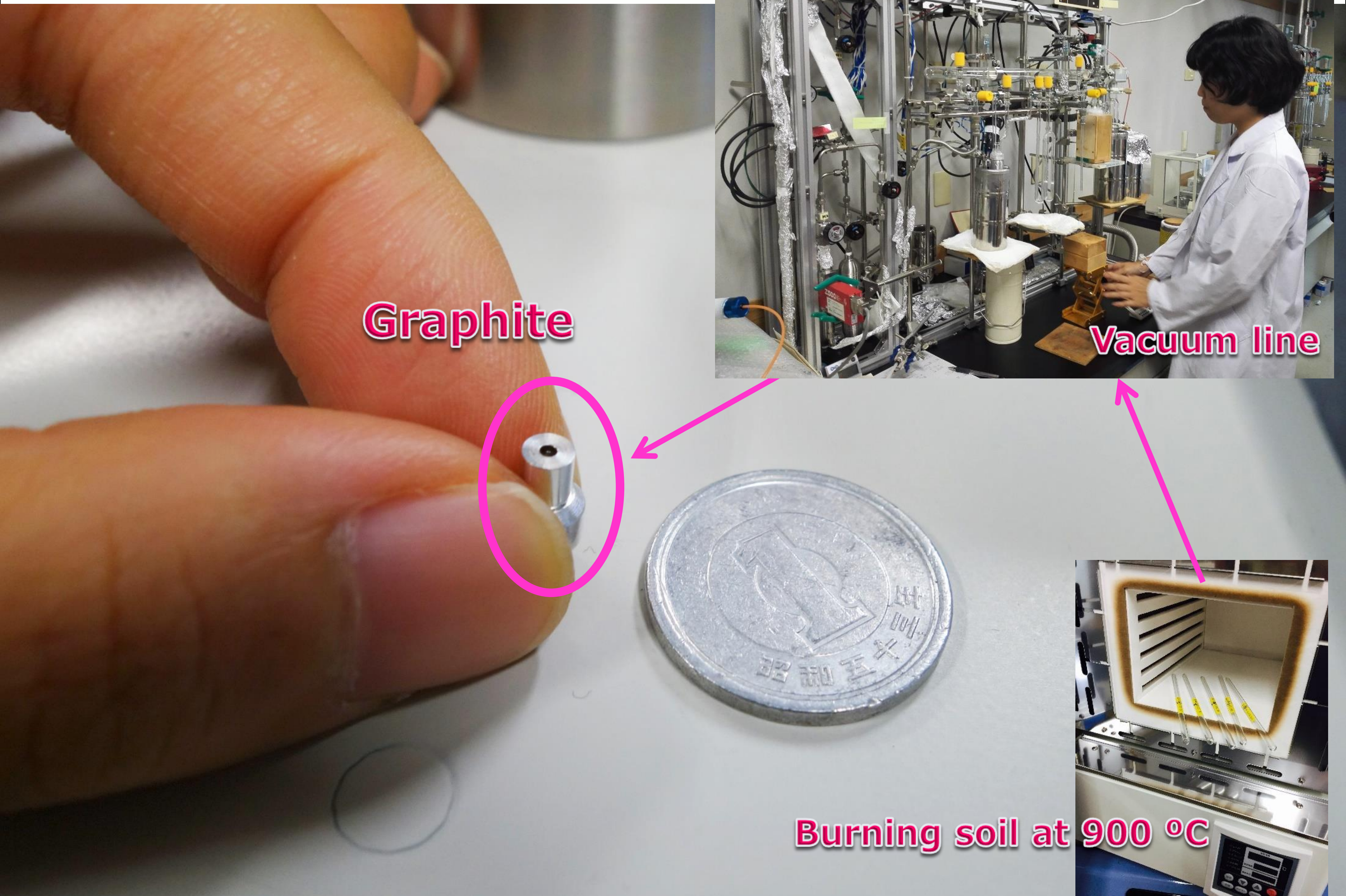
SOC decomposition under warming environment

Soil $\Delta^{14}C$ sampling

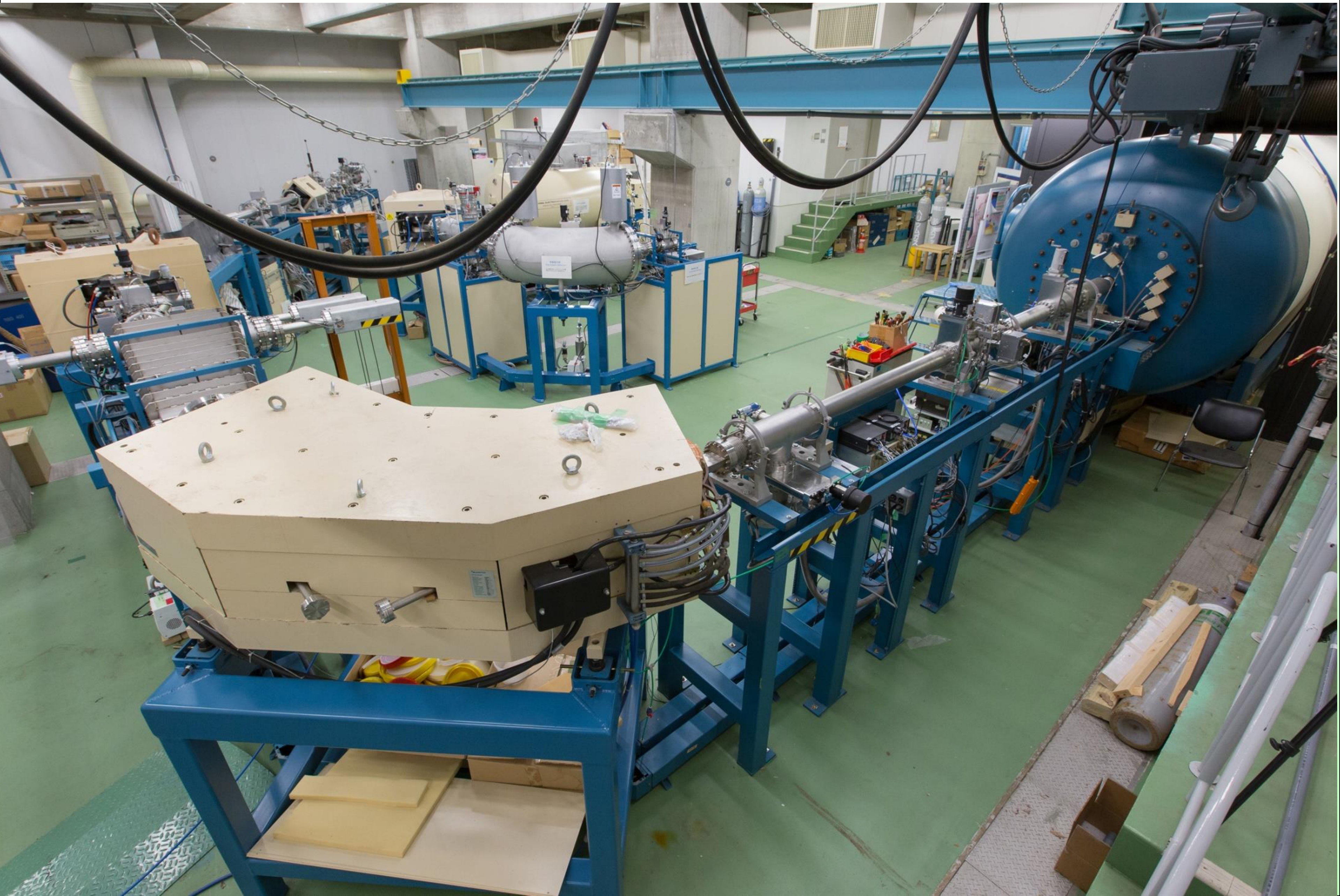
1cm soil profiles

Accelerator Mass Spectrometers (AMS)

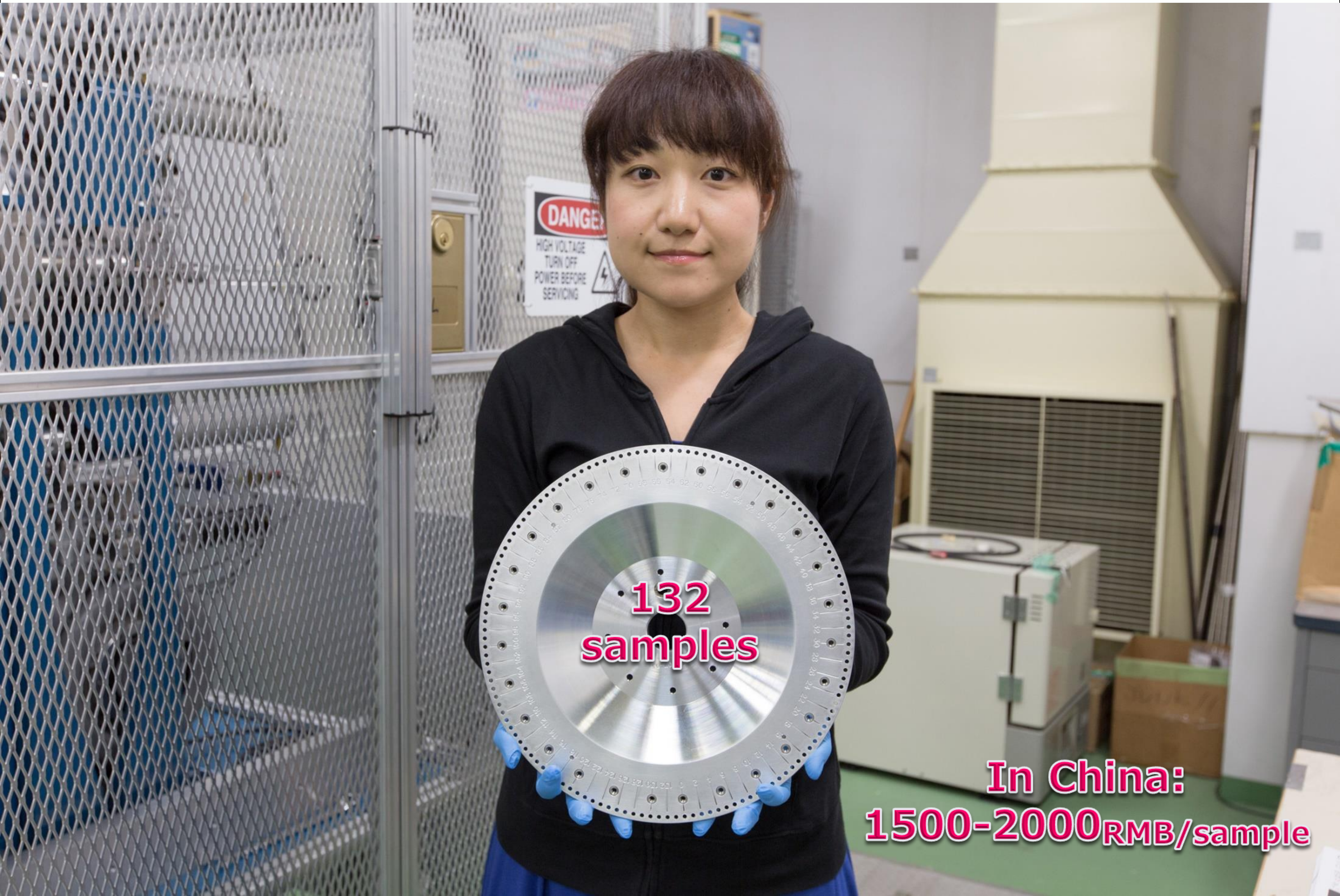
From Soil to Graphite



Two Accelerator Mass Spectrometers (AMS) in NIES

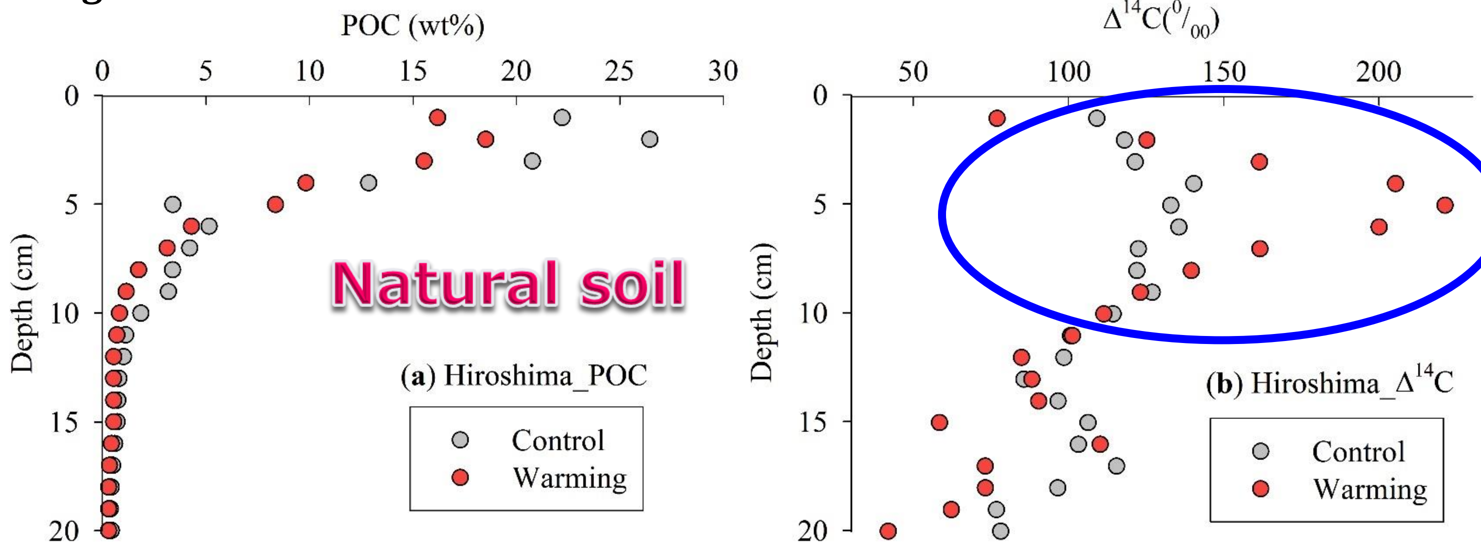


Compact Accelerator Mass Spectrometer (CAMS)



POC & ^{14}C Profiles in Top 20cm Soil

Evergreen Oak Forest in Hiroshima

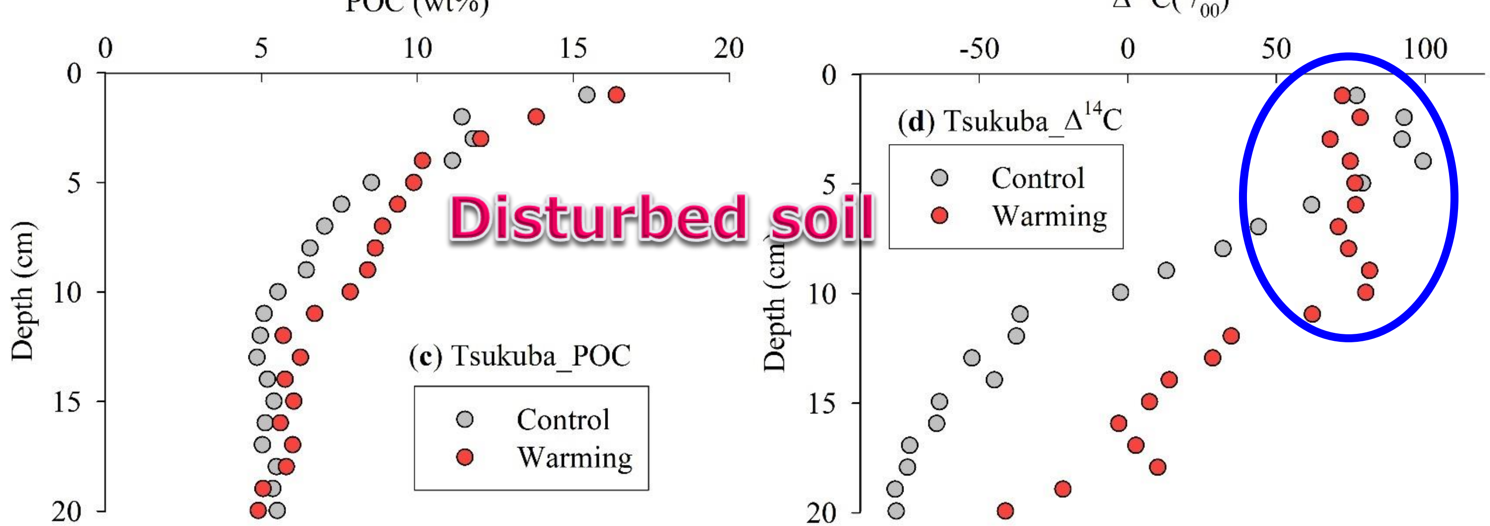


Decomposition

Top 3cm: leaf and fine root litter (new C).

3~8cm: decades old C.

Pine Forest in Tsukuba

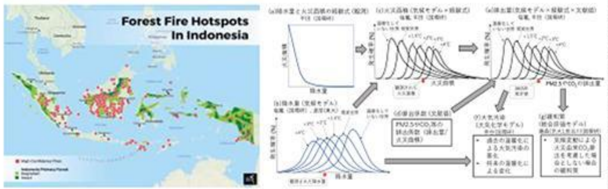


Disturbance in the top soil

NIES Adaptation Program (2018~2020)

PJ1-6: アジア域の陸域生態系劣化に及ぼす温暖化影響とそのメカニズム解明

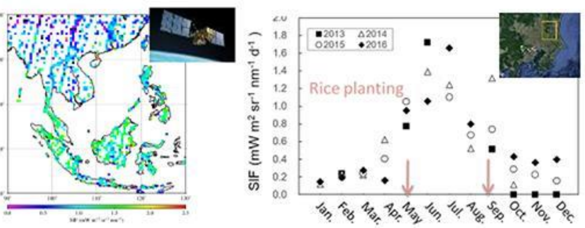
1. 森林火災による森林消失および生態系機能劣化の監視と影響評価



森林観測（衛星、現地）とモデルを組み合わせ：

- このような旱魃、火災、大気汚染は過去の温暖化のせいなのか？ →温暖化の見える化（PJ1-iに貢献）
- パリ協定の1.5℃, 2℃目標が達成できても、どれだけ悪化するのか？ →適応策が必要（PJ2-i,iiiに貢献）
- 1.5℃, 2℃目標が達成できなかった場合には、どうなるのか？ →緩和策のメリット（PJ2-i,iiiに貢献）
- 将来の温暖化によって火災起源のCO_2排出量はどう変化するのか？ →緩和策（PJ2-i,iiiに貢献）

2. 地域生態系サービスの強化に向けた衛星観測データの応用



内容と適応策への貢献:

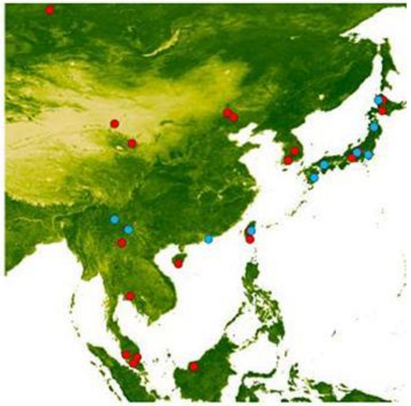
- アジア域における生態系サービスの劣化の人間社会への影響の最小化めざし、現在の陸域生態系の脆弱性およびレジリエンスの空間的な分布を評価する（PJ1-iとPJ2-iに貢献）。
- 陸域生態系の保全に向けた優先度や緊急度を地域ごとに地図化し、近い将来の開発・保全計画に関する政策立案に資する情報を提供する（PJ2-iiiとPJ3に貢献）。

4. 目標気候変動の森林影響・適応策に関する情報収集（全員）

国内、国際的関連研究機関と連携することにより、互いに情報を共有し、適応策に関する情報収集を行い、AP-PLATに情報を提供する。

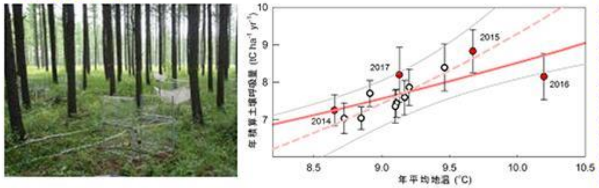
- 森林火災情報：JAXAと東大（衛星データ）、北大（地上観測）
- 泥炭地火災情報：北九州大学、JICA、ベンチャー企業
- 泥炭地利用転換情報：北大・京大（泥炭地に適応する作物の生育法）

観測ネットワーク：



Sub1: マレーシアとインドネシアを中心とした熱帯アジア
Sub2: 東アジアと東南アジアを中心としたアジア全域
Sub3-1: 日本を中心とした東アジアと東南アジア（赤点）
Sub3-2: 日本を中心とした東アジア（青点）

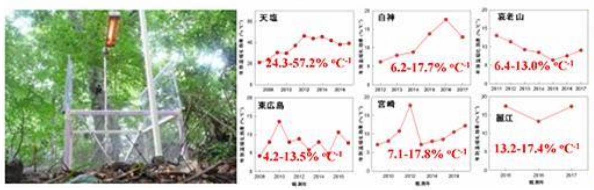
3-1.アジアの森林土壌を中心とした陸域生態系における温暖化影響の定量的検出



内容と適応策への貢献:

- 日本とアジアの約30ヶ所の森林サイトにおける土壌呼吸を中心とした炭素収支観測・解析する事で、生態系機能の変化に対する現行の気候変動や撹乱、土地利用変化の影響評価を行う（PJ1-iに貢献）。
- 統一的なプロトコルで得た観測結果をデータベースとして、将来予測モデル（PJ2-iiiに貢献）や適応策（PJ3に貢献）に貢献する。

3-2.温暖化操作実験によるアジアの森林土壌有機炭素動態に及ぼす温暖化影響のメカニズム解明



内容と適応策への貢献:

- アジアの代表的な10ヶ所の森林において温暖化操作実験を行い、気候変動に対する森林土壌環境への影響や応答メカニズムを解明する（PJ1-ivに貢献）。
- 生態系モデルへの実際の気温応答データとしてパラメータを提供する（PJ2-iiiに貢献）。
- 陸域生態系の保全に関わる適応策の策定に資する、科学的根拠を提供する（PJ3に貢献）。

Establishing Pasoh Facilities as an Observational Base for Studies on Tropical Forest Ecosystems (2012~)

International coordination

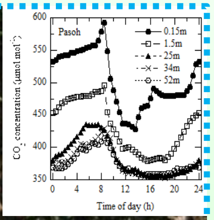
Holding the steering committee meeting for strengthening NIES-FRIM-UPM MoU

International symposium & field campaign
(knowledge exchange & capacity building)

Biodiversity

Preliminary study on regeneration & decomposition related biodiversity.

Mission:
To bring together the NIES and Malaysian leading scientists for understanding climate-related carbon cycle and biodiversity of tropical forests by strengthening Pasoh facilities as an overseas observational base.

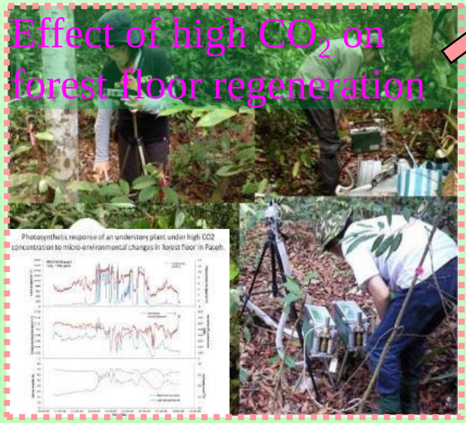


Processing study on tropical forest carbon cycle

Meteorology tower

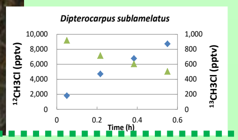
Canopy walkway

Effect of high CO_2 on forest floor regeneration



BVOC

Emission of methy halides from tropical forest



NIES cabin

Pasoh facility setup & maintenance

Conclusions

1. High-diversities in ecosystems
2. Global significance
3. Variations of climates
4. Extreme climate events
5. Network research