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A nationwide soil carbon calculation system for Japanese agricultural land

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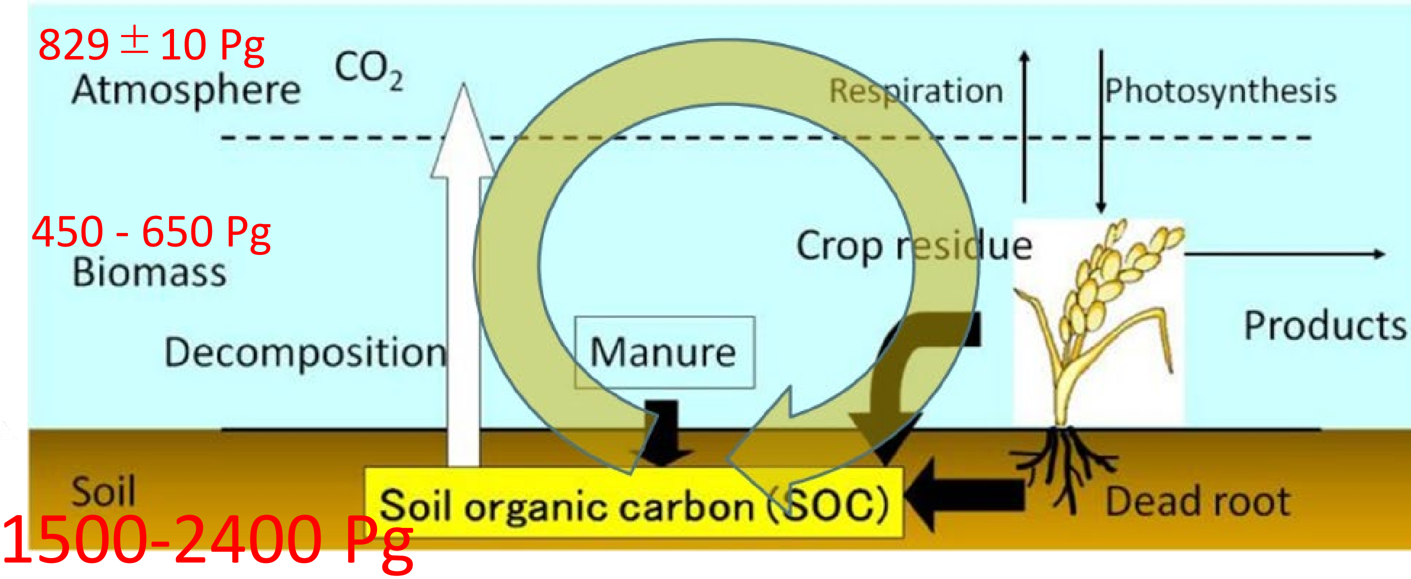
Contents

Japan uses the IPCC Tier 3 modelling method to calculate CO_2 emissions or removals derived from changes in soil carbon in agricultural land.

- Introduction: Soil carbon sequestration and climate change mitigation.
- Validation and modification of soil C model.
- Development of a nationwide calculation system.
- Use of the system for National Inventory Report (NIR) and Nationally Determined Contribution (NDC).
- Web-based decision support tool by using model.
- Importance of primary data: long-term experiments.

Soil carbon sequestration & climate change mitigation



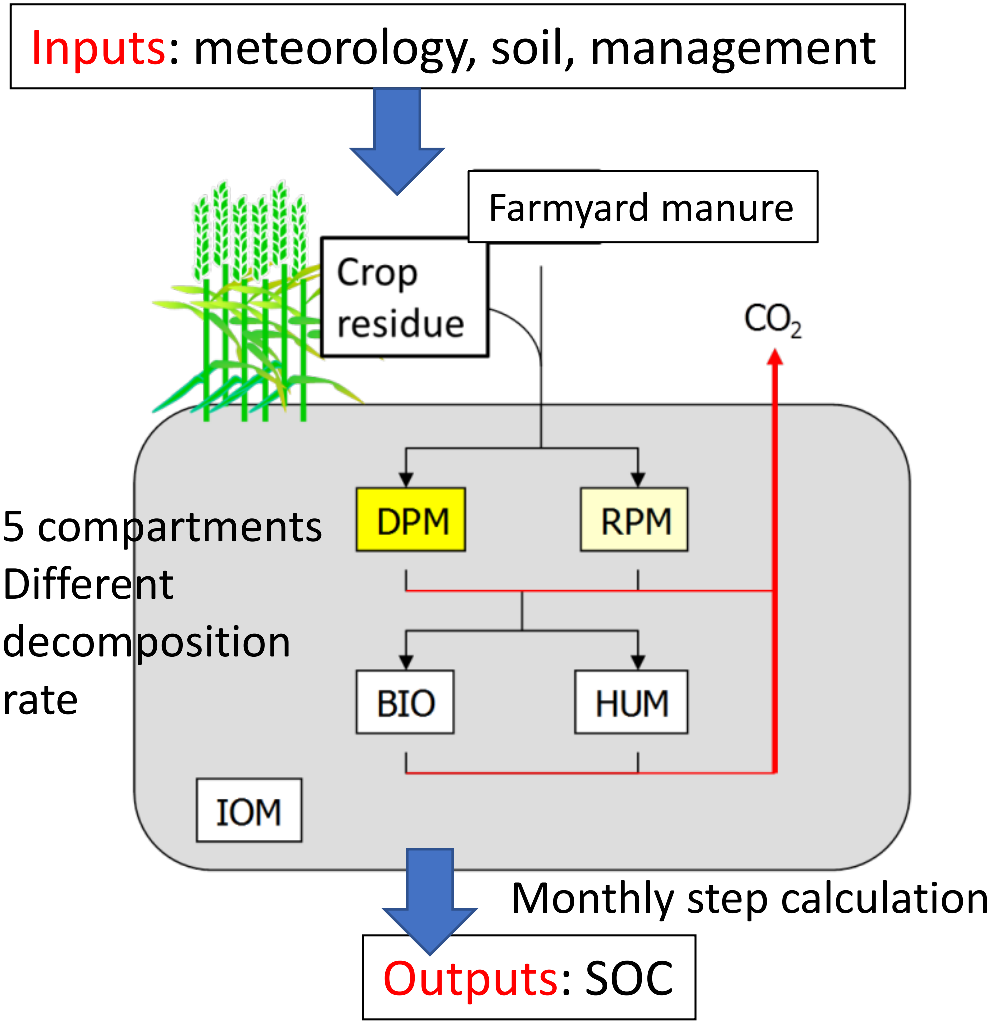
- "Carbon" accumulated as dark-colored "soil organic matter": Important index of productivity.
- Size of soil C pool is huge.

"The 4 per 1000 initiative" for soil C sequestration.

Storing C in soils has huge potential to mitigate increase in atmospheric CO_2 and contribute to sustainable food production.

Soil C model: useful tool for future prediction and spatial evaluation

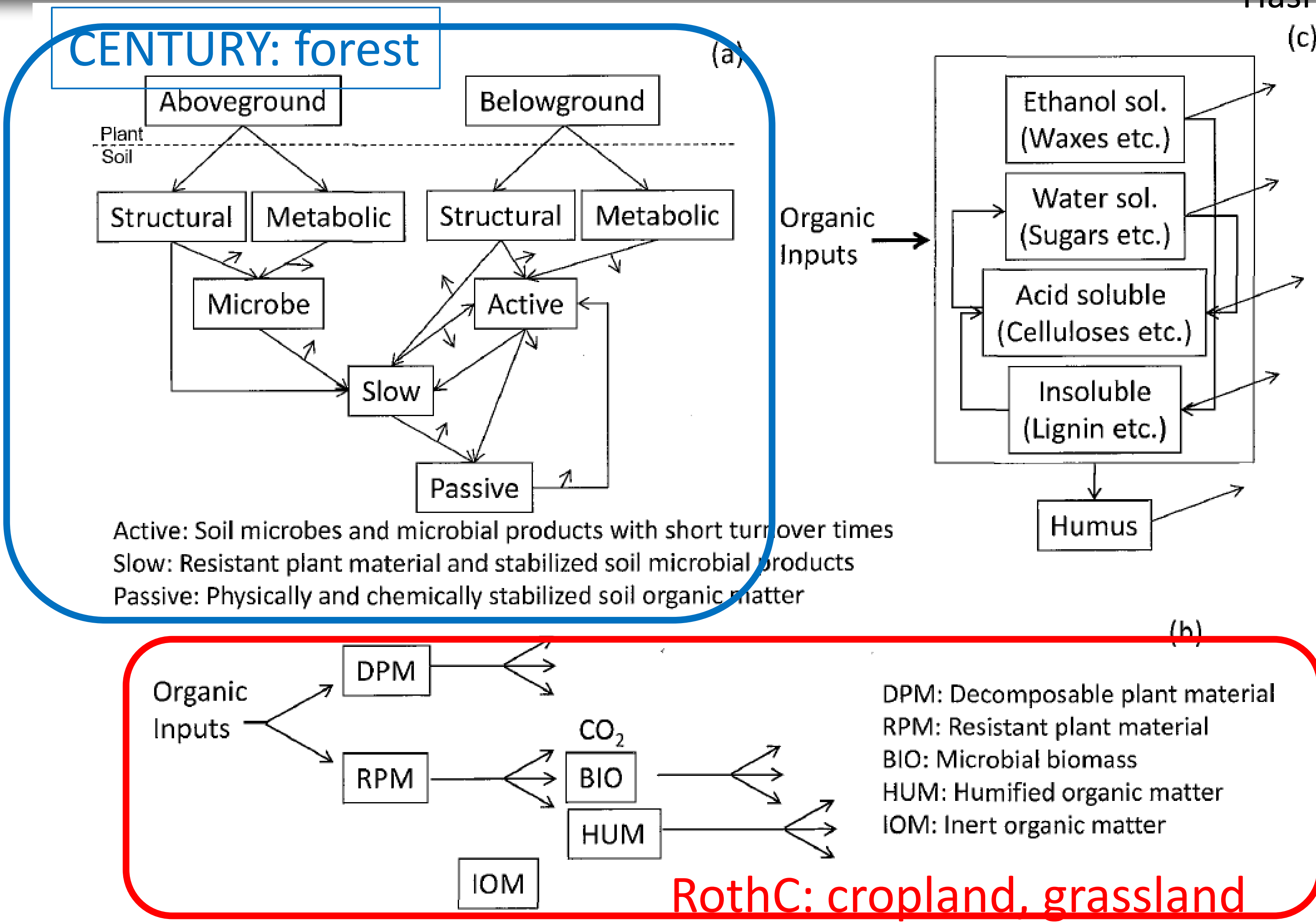
Rothamsted Carbon (RothC) model



- One of widely used soil C models developed in UK.
- Simpler structure has advantage for model modification.

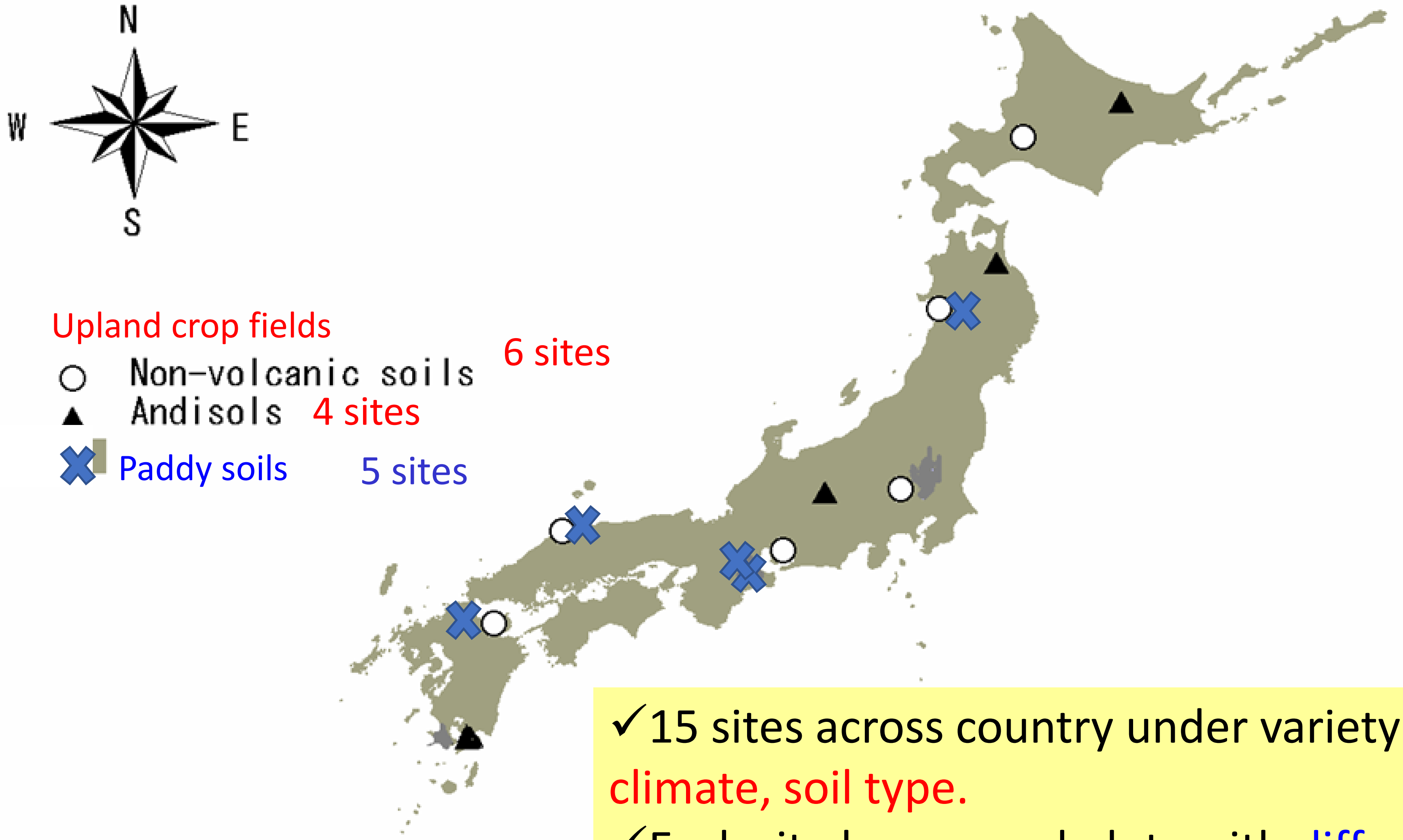
CENTURY model is used for Forest

Hashimoto (2025)



- Similar structure. RothC is simpler.

Long-term experiments for model validation



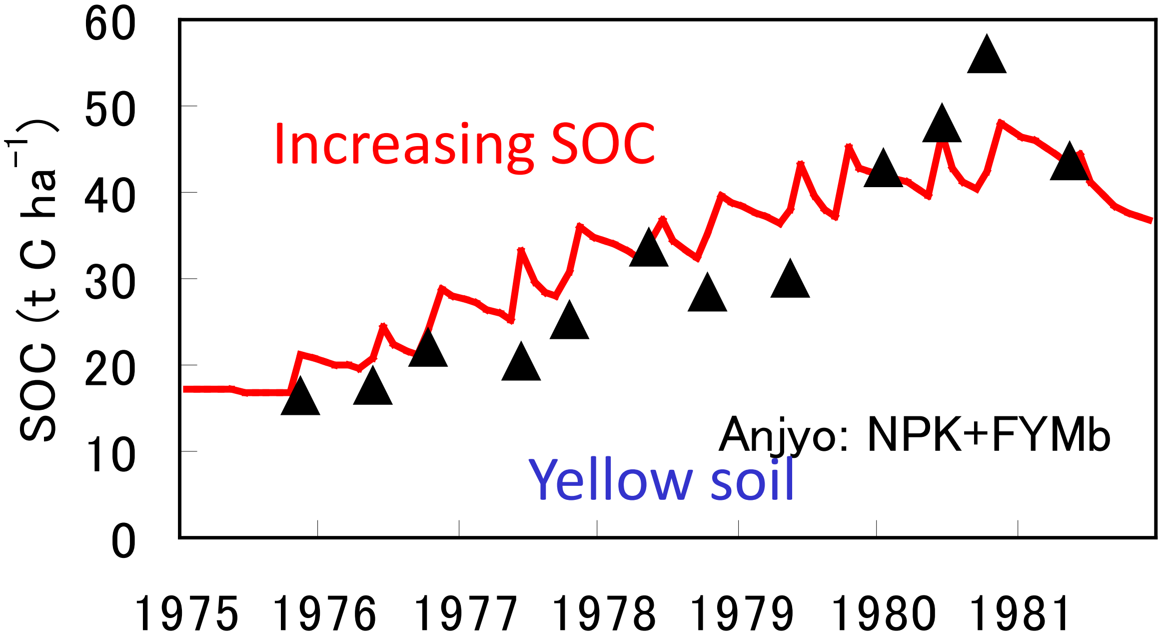
✓15 sites across country under variety of climate, soil type.

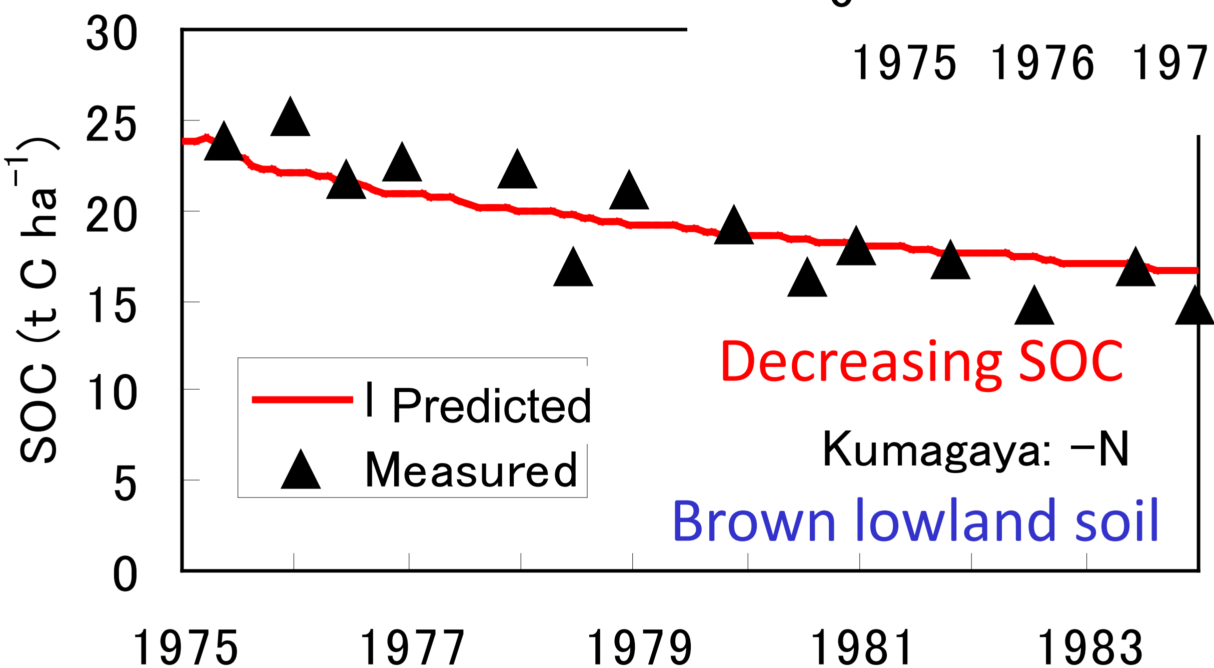
✓Each site has several plots with different management (NPK, manure, straw, etc.).

Performance of RothC in non-volcanic upland soils

Good performance.

Without any modification or calibration.

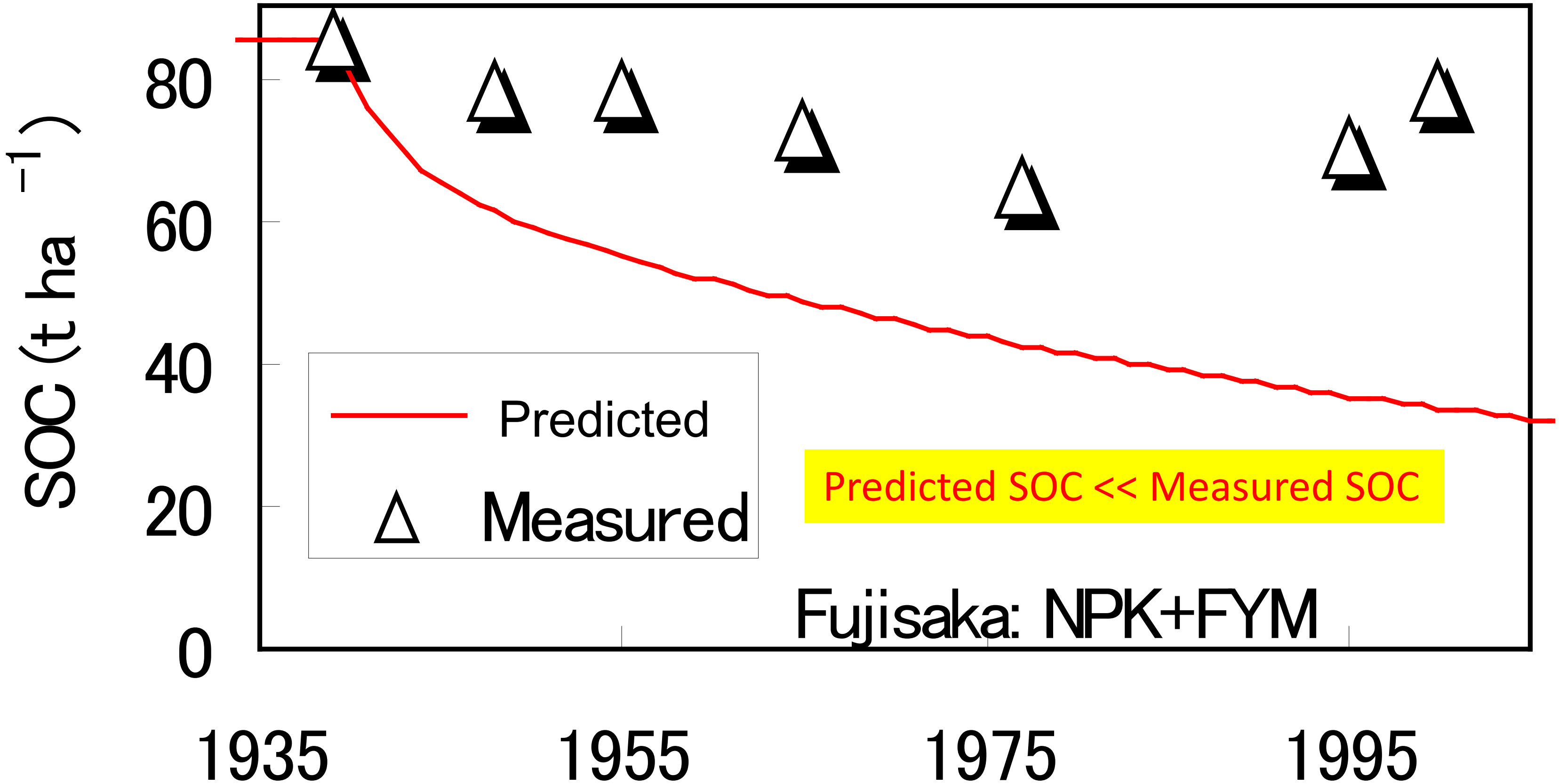




- 6 sites under various climate condition.
- Various soil types.
- Various management.

(Shirato & Taniyama, 2003)

But in Andosols……



The model underestimated the SOC.

(Shirato et al., 2004)

Andosols have high C concentration

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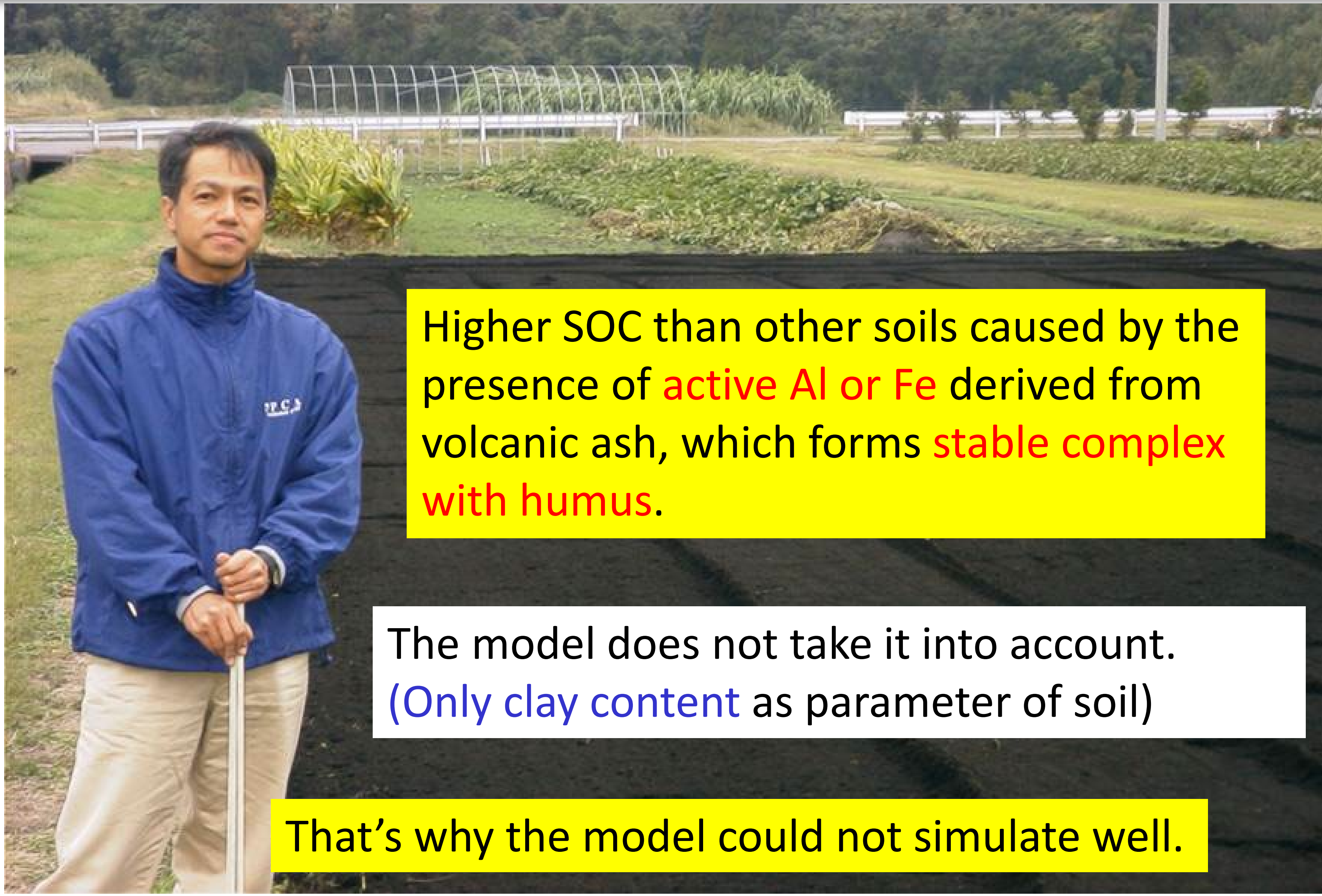


Higher SOC than other soils caused by the presence of active Al or Fe derived from volcanic ash, which forms stable complex with humus.

The model does not take it into account. (Only clay content as parameter of soil)

That’s why the model could not simulate well.

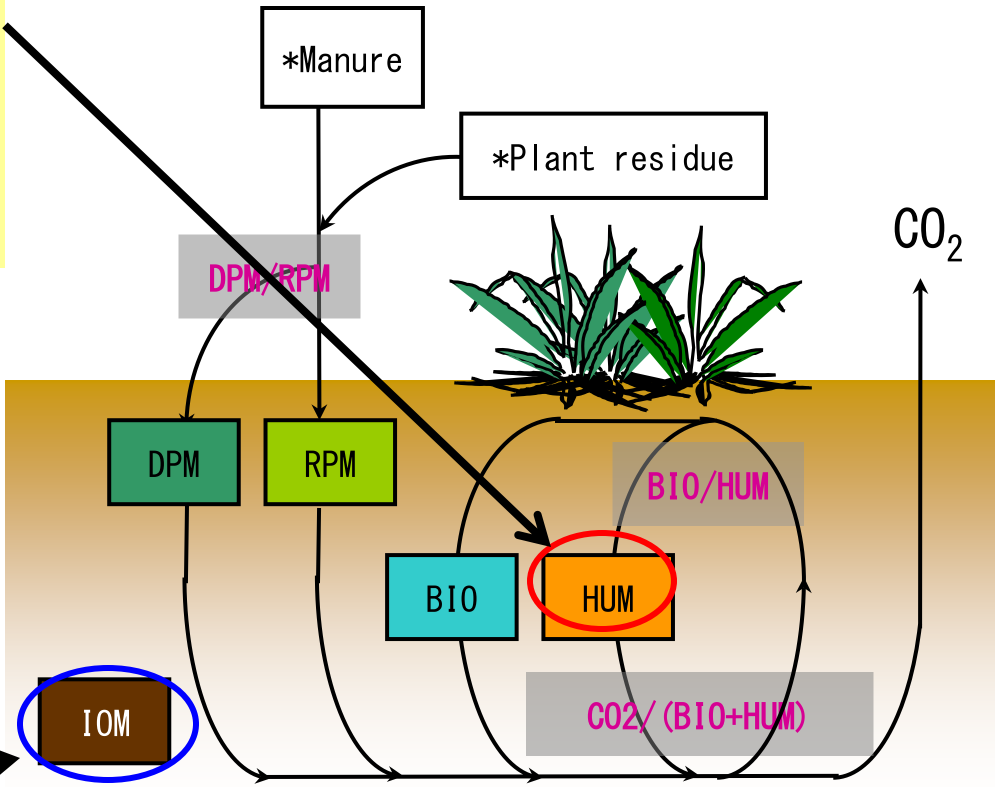
How to modify the RothC for Andosols

Active Al or Fe derived from volcanic ash forms stable complex with humus ➔ Slow decomposition

1. Changing HUM (humus) decomposition rate constant . by dividing with a factor(F), which changes with the amount of active Al or Fe.

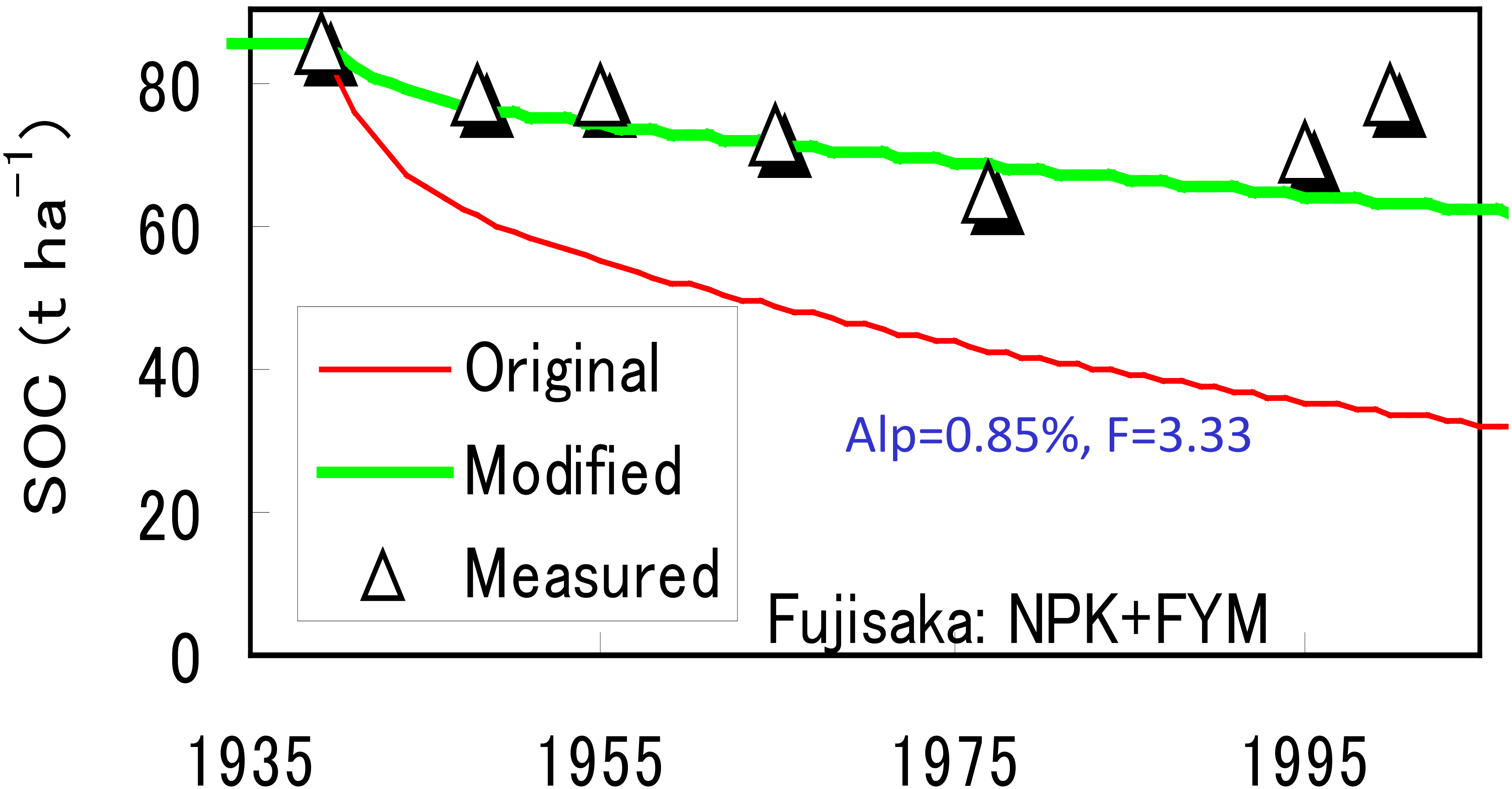
F=2.50 Alp + 1.20 (Alp: Pyrophosphate extractable Al)

In soils with much Al-humus complex, SOC decompose slowly.



2. IOM (Inert Organic Matter)=0

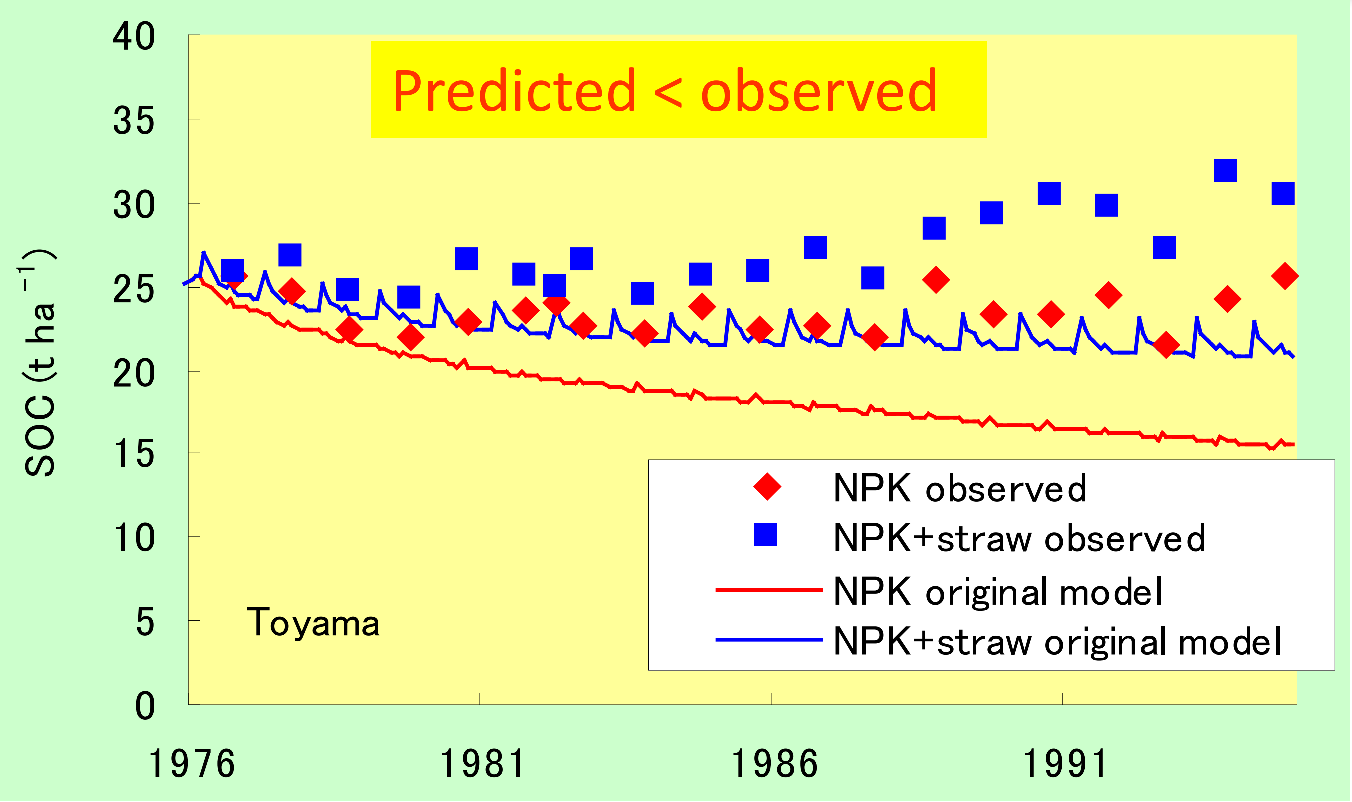
Modified model for Andosols



The modified model had much improved fit with measurement data.

(Shirato et al., 2004)

What happen in paddy soils ?



The model underestimated SOC, as expected
(slower decomposition because of anaerobic condition)

(Shirato & Yokozawa, 2005)

How to modify the RothC for paddy soils?

The model underestimated SOC, as expected
(slower decomposition because of anaerobic condition)

- We can slow down the decomposition rate of C in rice growing period.

- How about in non-rice growing period?

  Paddy soils have different microorganism composition (e.g. Smaller proportion of fungi, which play major role in decomposing lignin or cellulose, than bacteria)

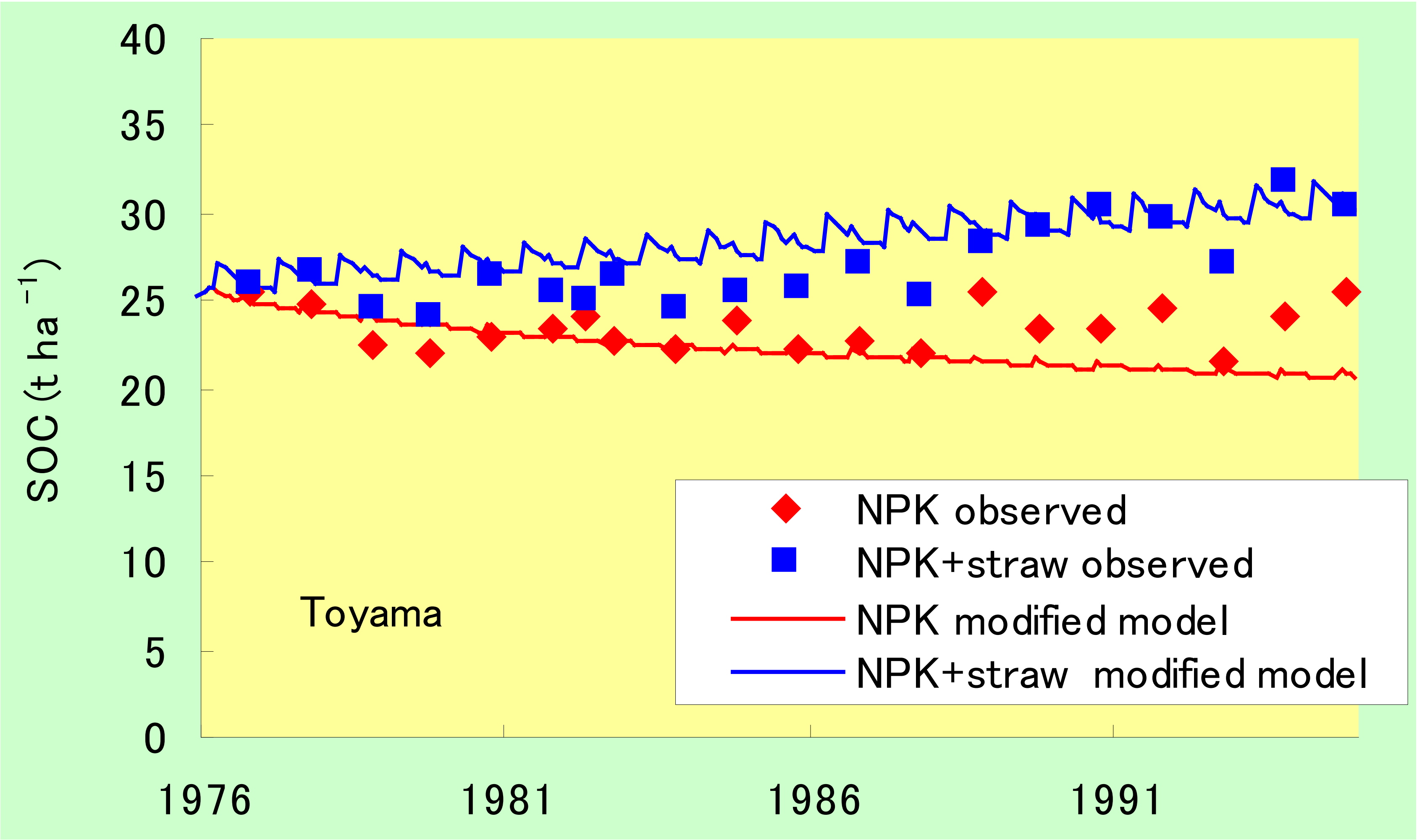
  ➔ decomposition may slower than upland soils, too.

Decided to modify the model by…

1. Changing the decomposition rates of the RothC during the submergence period (summer) and the period without submergence (winter), separately.
2. Find out the optimum combinations of the decomposition rate.

Modified model for paddy soils

0.2 and 0.6 times slower decomposition rate, in rice growing season (submerged) and another period, respectively.



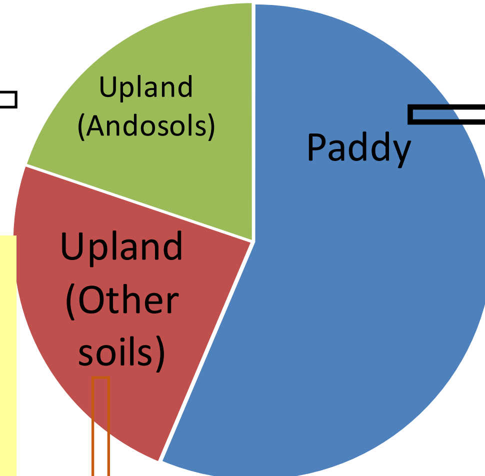
Good agreement with measurement.

(Shirato & Yokozawa, 2005)

Validation and modification of the RothC: Japanese version

Andosols

Arable soils: ~500 million ha



Paddy soils

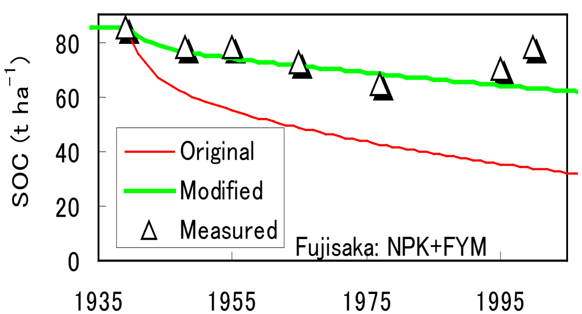
Stable humus with active Al
➔Slow decomposition of "HUM" pool

Anaerobic condition
➔Slow decomposition

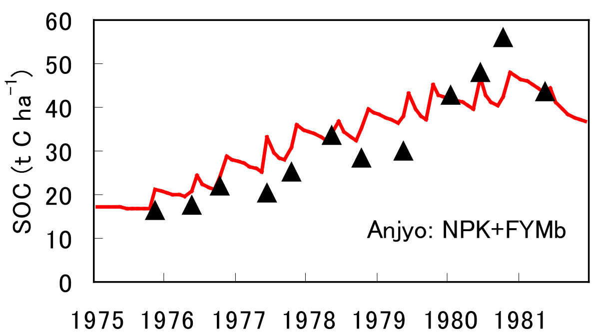
Modified model

Original RothC: successful

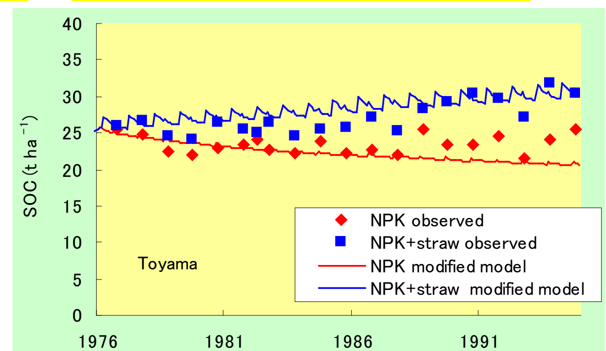
Modified model



(Shirato et al., 2004)



(Shirato & Taniyama, 2003)

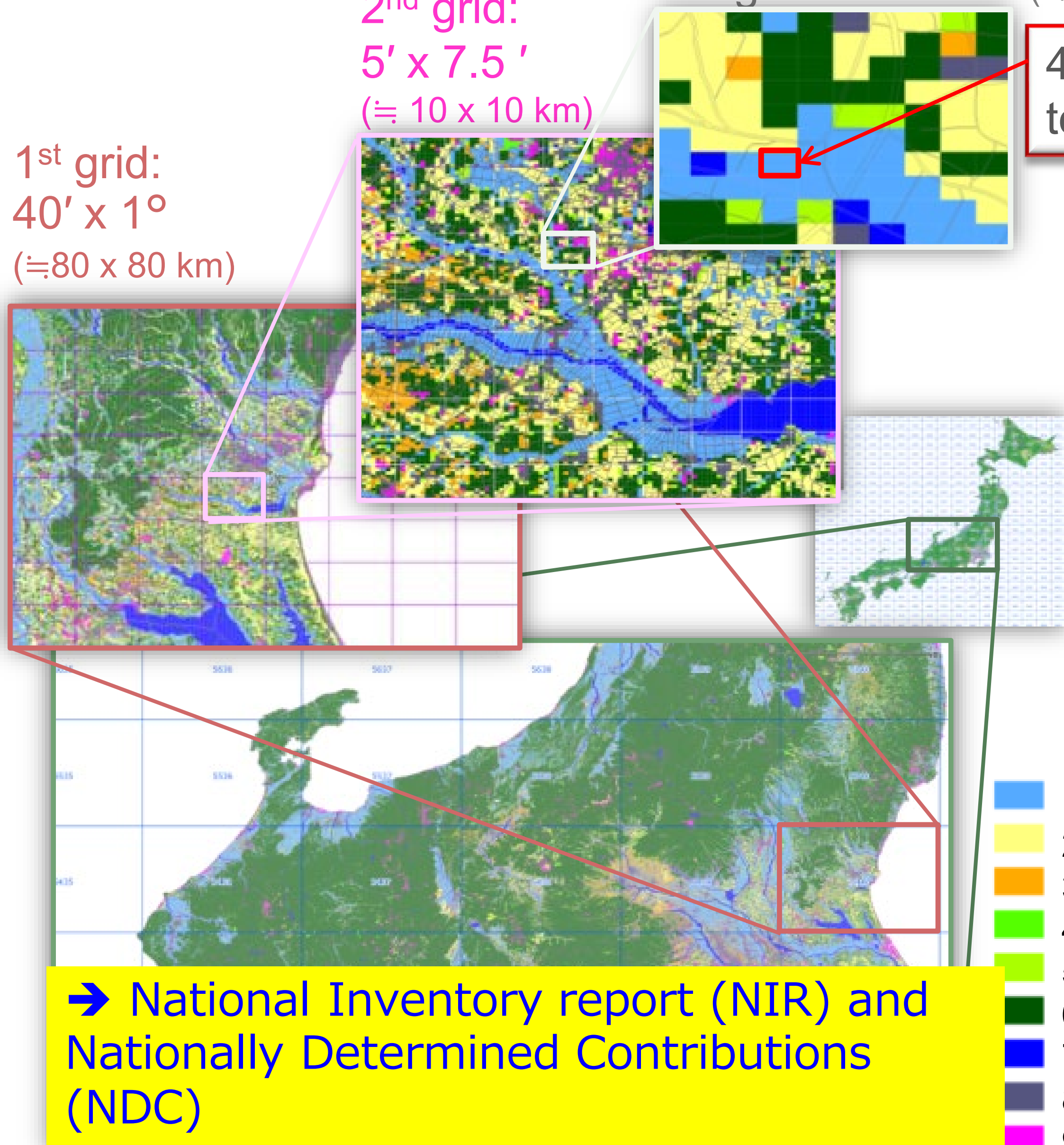


(Shirato & Yokozawa, 2005)

➔Nationwide soil C calculation system by using 3 versions

Nationwide calculation system of soil C

Spatial resolution: 100m × 100m grid



✓Soil map
✓Land use map (1976, 1987, 1991, 1997, 2006, 2020)

✓Meteorology (1km)
✓Agricultural activity (47 prefecture)

- 1 paddy
- 2 cropland
- 3 orchard
- 4 managed grassland
- 5 unmanaged grassland
- 6 forest lands
- 7 wetlands
- 8 settlements
- 9 other lands

➔ National Inventory report (NIR) and Nationally Determined Contributions (NDC)

Contribution to Japan's NIR and NDC

- NIR: RothC model calculation is used for CO_2 emission/removal derived from changes in the amount of soil C in cropland & grassland from NIR 2015.

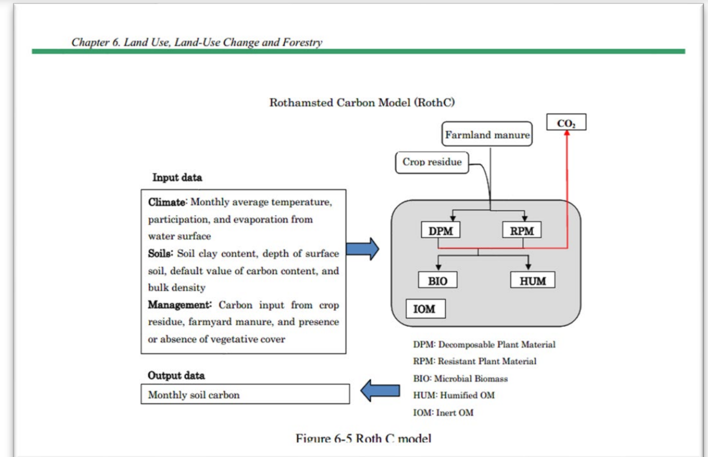
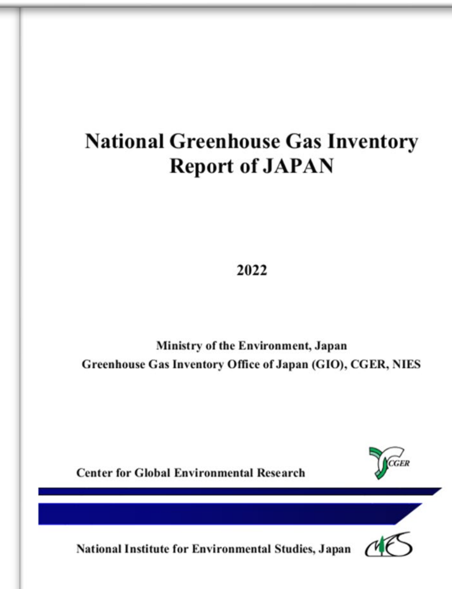


Figure 6-5 Roth C model

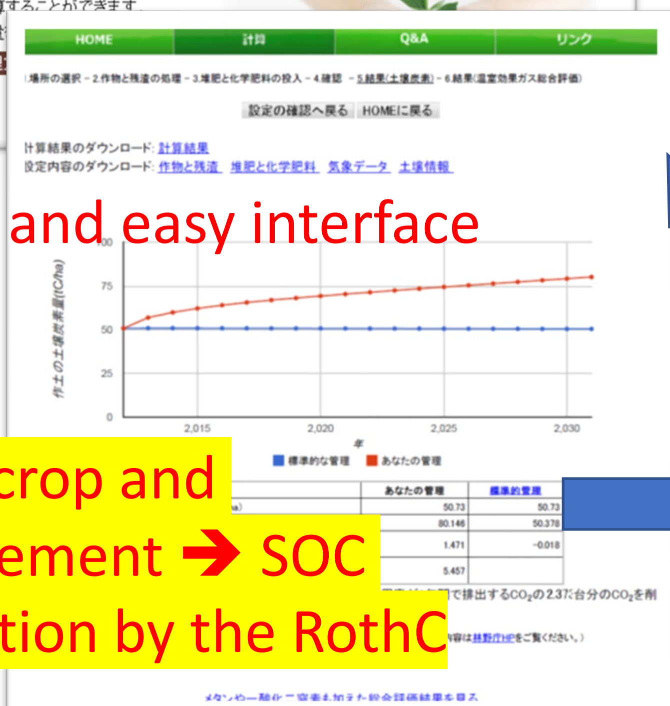
- NDC: Cropland & grazing land management: 7.9 Mt-CO_2* removal in 2030 by increasing organic matter input to soils.



*Intended Nationally Determined Contributions (INDC): Greenhouse Gas Emission Reduction Target in FY2030 (Ministry of Foreign Affairs of Japan)

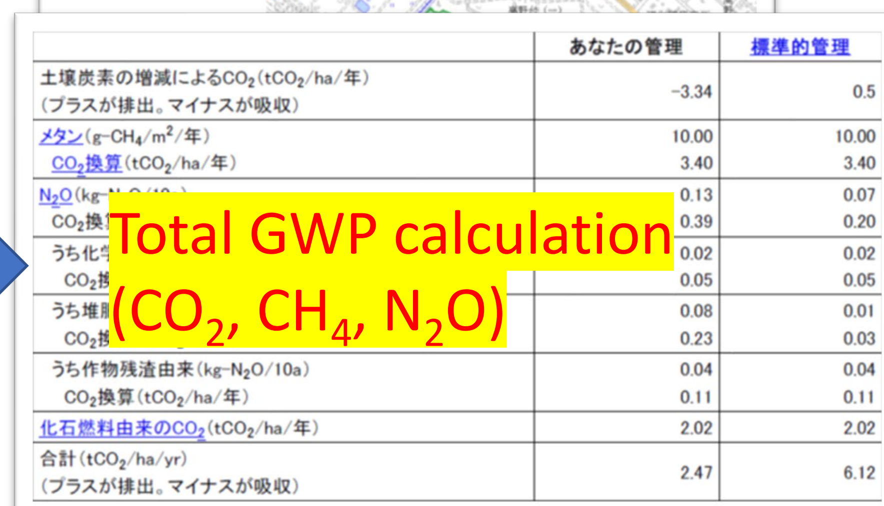
Web-based decision-support tool visualizing soil C and GHGs emission

Click on map to get meteorology and soil data of the field



Simple and easy interface

Select crop and management ➔ SOC calculation by the RothC

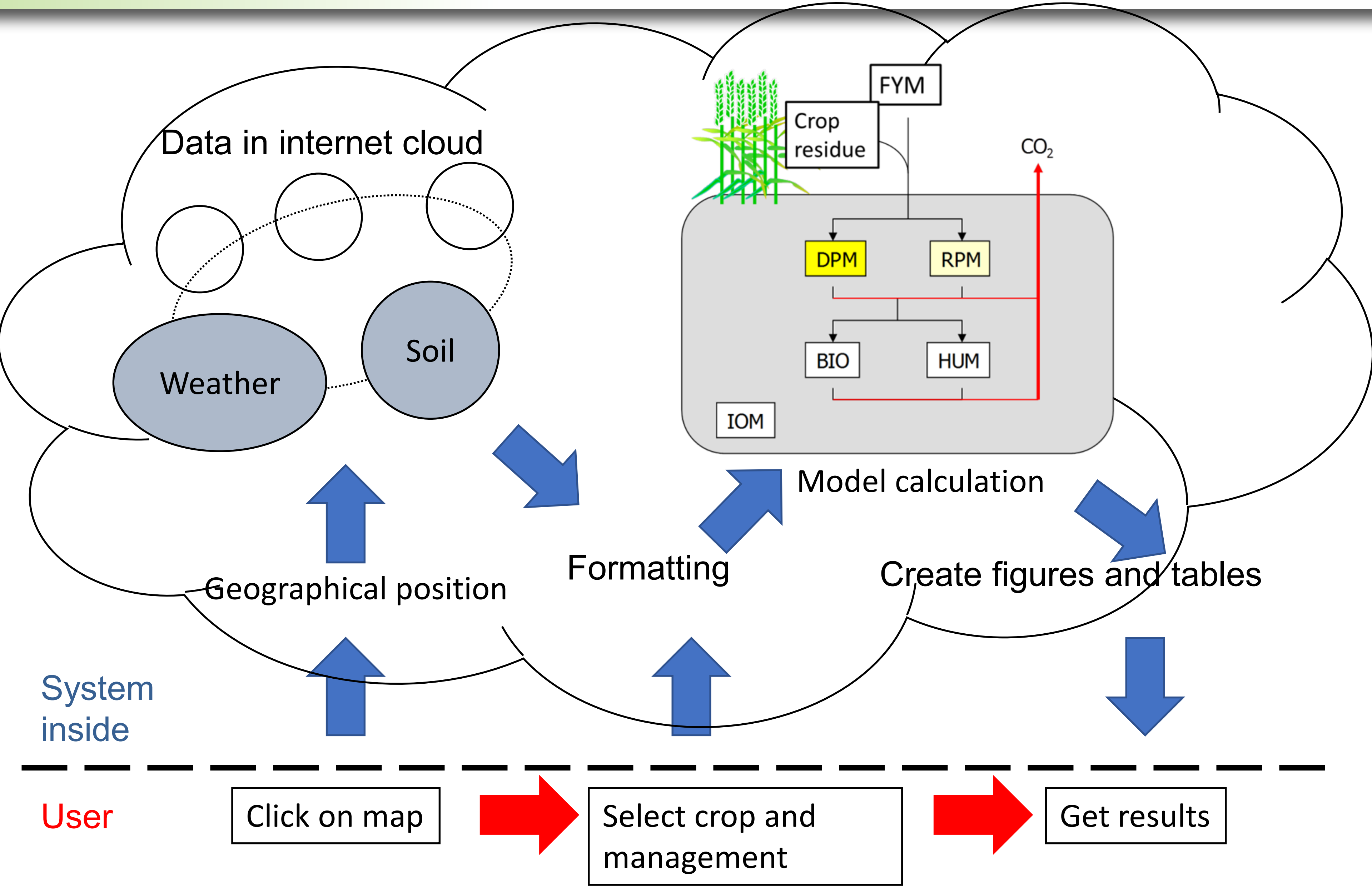


	あなたの管理	標準的管理
土壌炭素の増減によるCO_2(tCO_2/ha/年)(プラスが排出。マイナスが吸収)	-3.34	0.5
メタン(g-CH_4/m^2/年)	10.00	10.00
CO_2換算(tCO_2/ha/年)	3.40	3.40
N_2O(kg-	0.13	0.07
CO_2換	0.39	0.20
うち化学	0.02	0.02
CO_2換	0.05	0.05
うち堆肥	0.08	0.01
CO_2換	0.23	0.03
うち作物残渣由来(kg-N_2O/10a)	0.04	0.04
CO_2換算(tCO_2/ha/年)	0.11	0.11
化石燃料由来のCO_2(tCO_2/ha/年)	2.02	2.02
合計(tCO_2/ha/yr)(プラスが排出。マイナスが吸収)	2.47	6.12

Total GWP calculation (CO_2, CH_4, N_2O)

https://soilco2.rad.naro.go.jp/

How it works


Data in internet cloud
Weather
Soil
FYM
Crop residue
CO_2
DPM
RPM
BIO
HUM
IOM
Model calculation
Geographical position
Formatting
Create figures and tables
System inside
User
Click on map
Select crop and management
Get results

Asian Network of long-term experiments

Primary data (long-term experiments) is important.
Models cannot be developed without measurement data.

ALTENA
Asian Long-Term Experimental Network for Agriculture

Since 2017

- Most of studies published on long-term field experiments are from Europe and north America. Not many from Asia.
- Networking long-term experiments in Asian countries can be valuable.
- Enormous variation in climate, soil type, and cultural practices.

Summary

- Japan uses IPCC Tier 3 modelling method to report CO_2 emission/removals from changes in agricultural soil C.
- The RothC model was validated and modified.
- A nationwide soil C calculation system was developed.
- This calculation system is used for NIR and NDC.
- A web-based decision support tool was developed.
- Primary data (e.g. long-term field experiments) are basis for all above.
- Soil C sequestration contribute both climate change mitigation and food security. These models and tools can help to widely disseminate mitigation options.