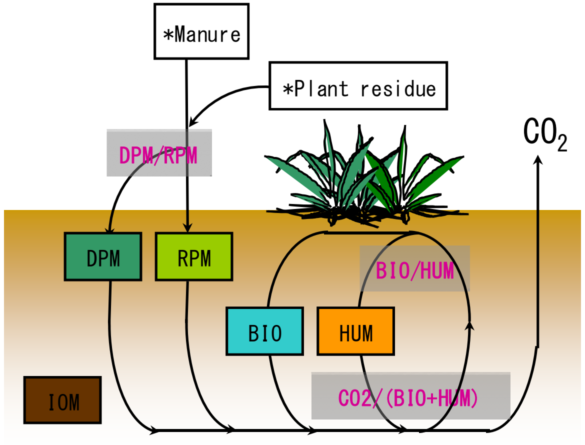
Simulating soil organic carbon stock change in Japanese agricultural land with the RothC model



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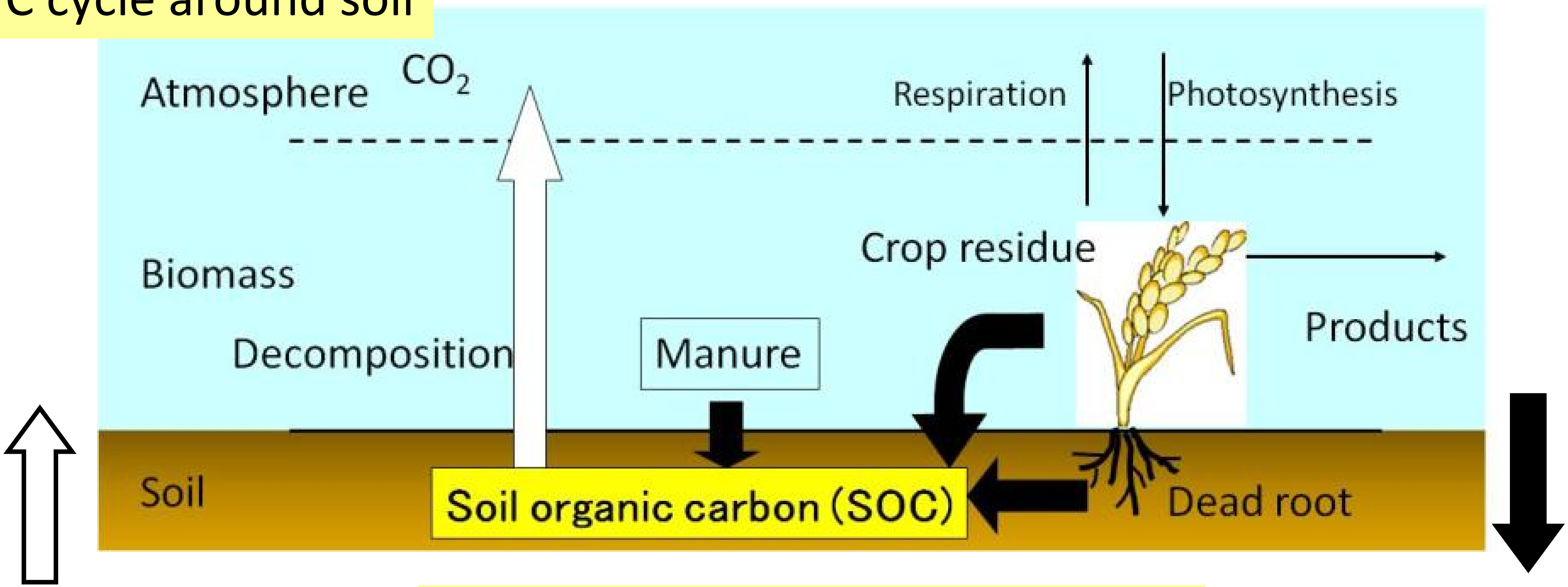
NIAES

Contents

- Why SOC models?
- Rothamsted carbon (RothC) model
- Validation and modification of the RothC (Plot scale)
- Country-scale simulation of SOC

Why SOC models ?

C cycle around soil



Output

Input

Factors Controlling Soil C Balance

- Temperature, Moisture
- Soil texture, pH
- Tillage

- Quality
- Quantity

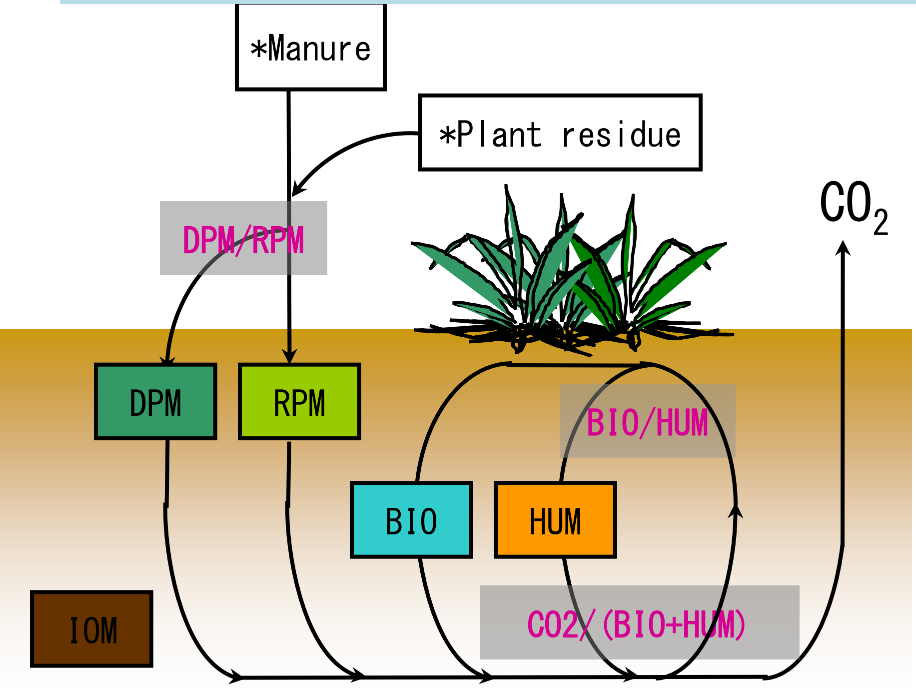
of C input (Residue, manure)

SOC turnover <u>models which cover these factors</u> are useful tools.

Rothamsted Carbon model

One of leading SOC models

Divide soil C and plant C into 5 conceptual compartments
having different turnover rate = decomposability
↓
Calculate C movement among compartments
↓
Simulate soil C dynamics



5 compartments

Decomposition rate

Fast ↕ Slow

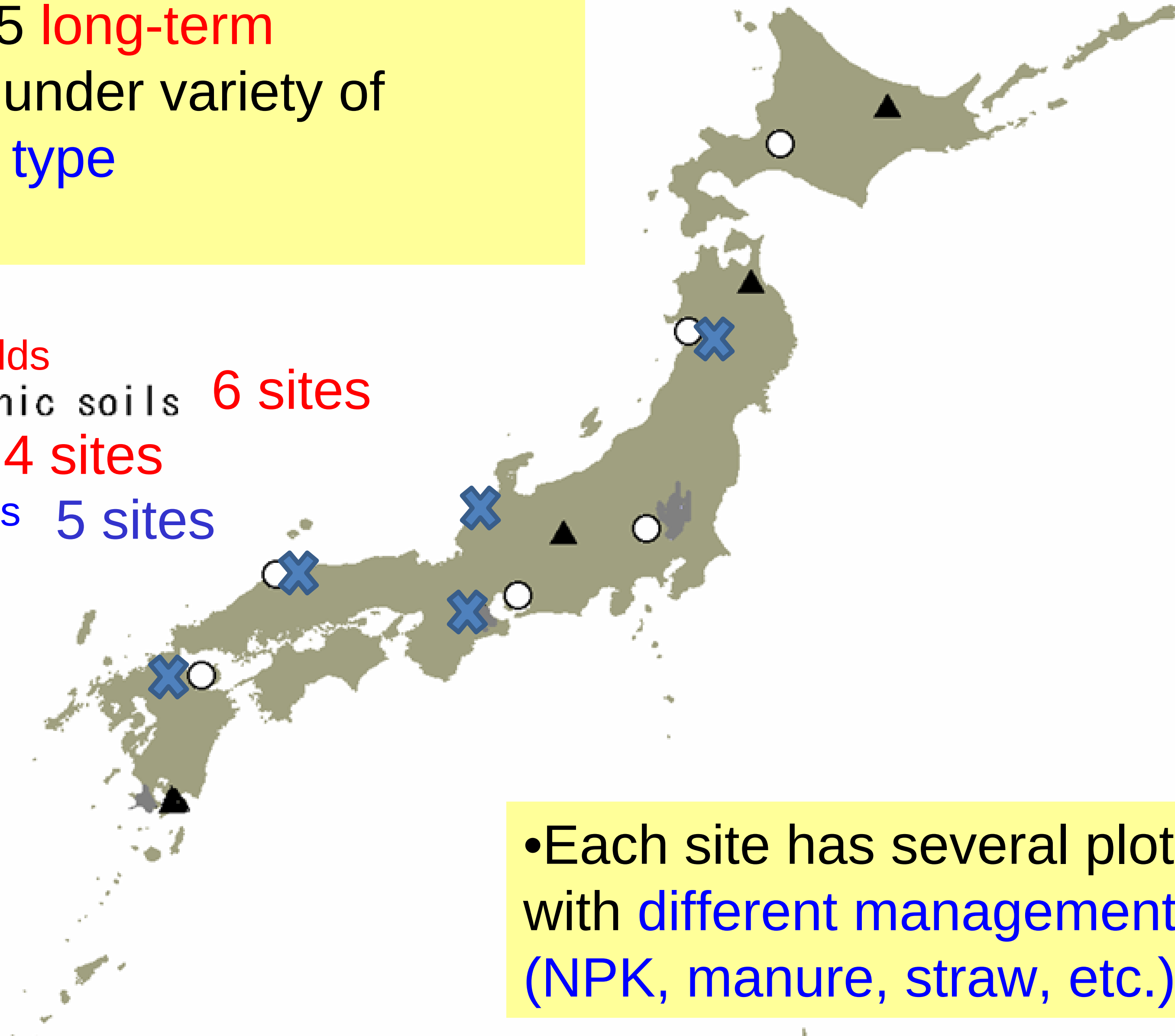
- DPM: Decomposable Plant Material
- BIO: Microbial Biomass
- RPM: Resistant Plant Material
- HUM: Humus
- IOM: Inert Organic Matter

Total C

Widely used, but not yet tested in Japan (or in Asia)

Validation of the RothC in Japan

•Data from 15 long-term experiments under variety of weather, soil type



Upland crop fields

○ Non-volcanic soils 6 sites

▲ Andisols 4 sites

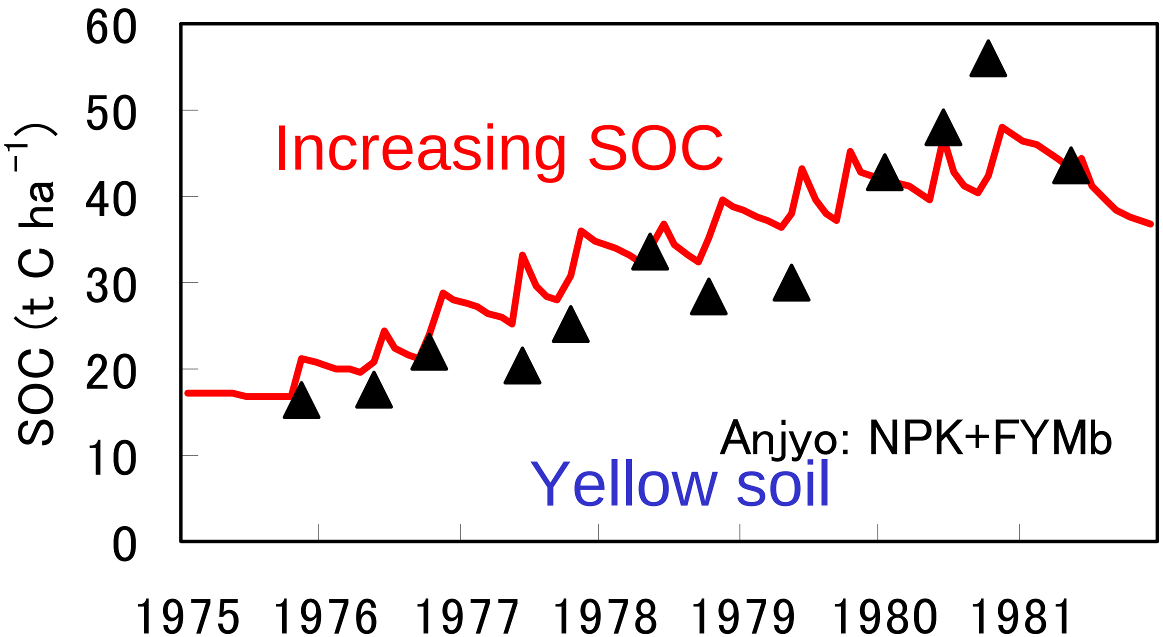
✖ Paddy soils 5 sites

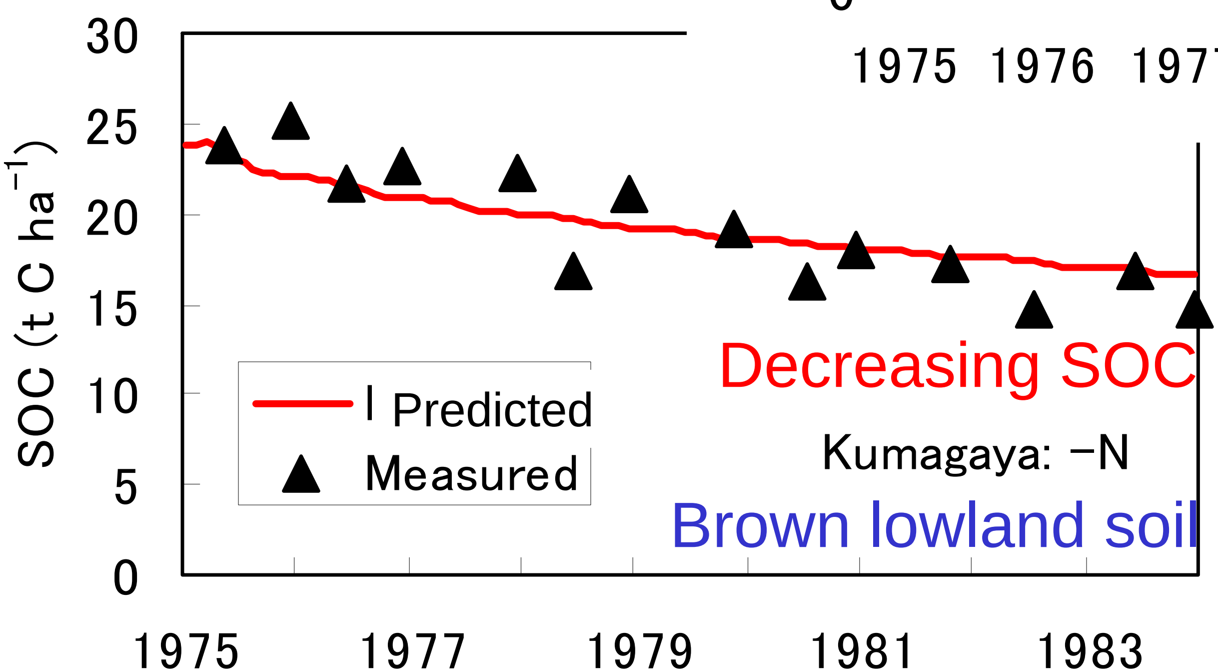
•Each site has several plots with different management (NPK, manure, straw, etc.)

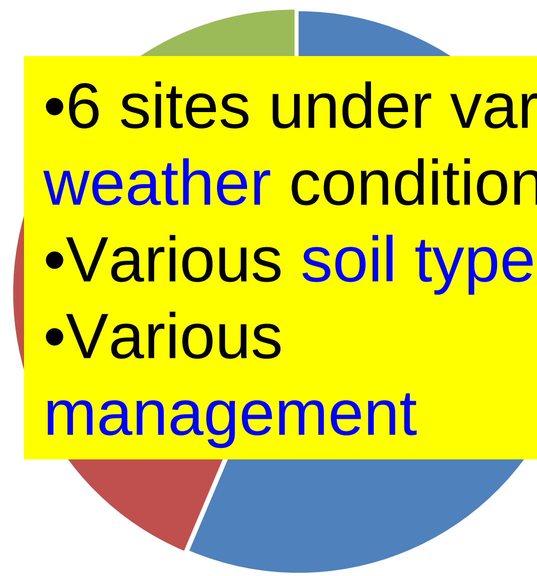
Performance of RothC in non-volcanic upland soils

Good performance

Without any modification or calibration



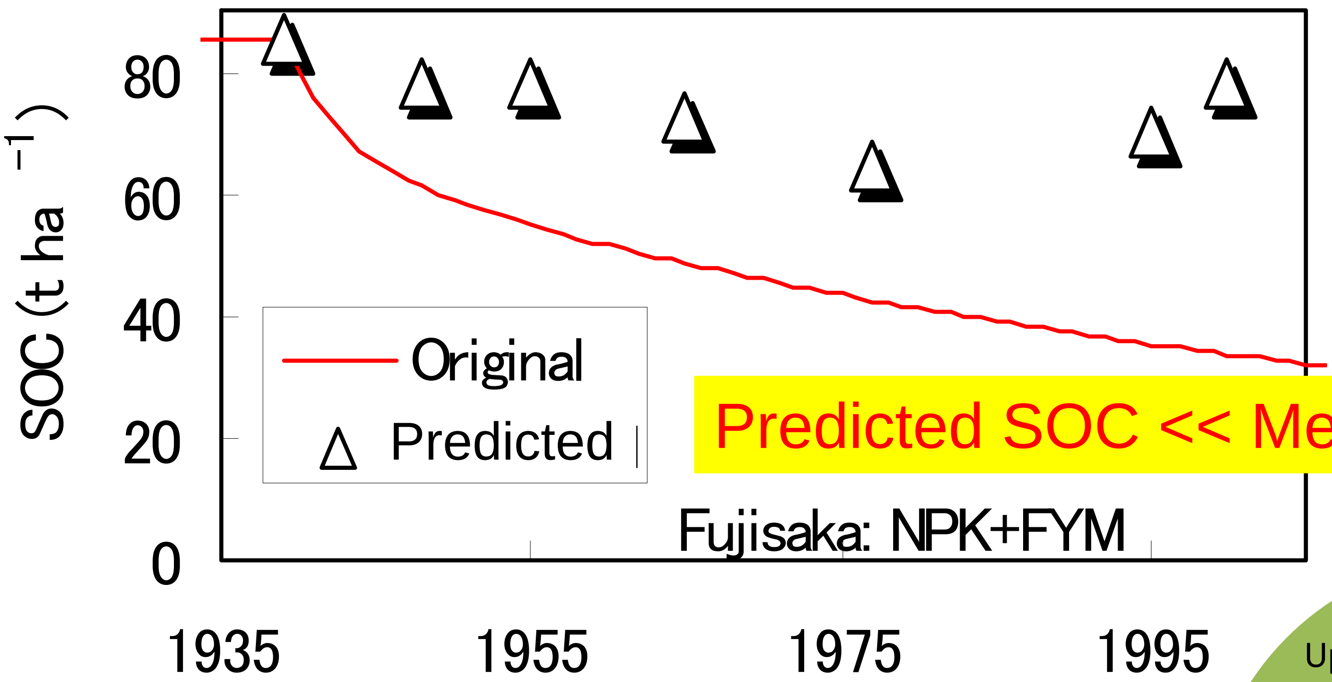




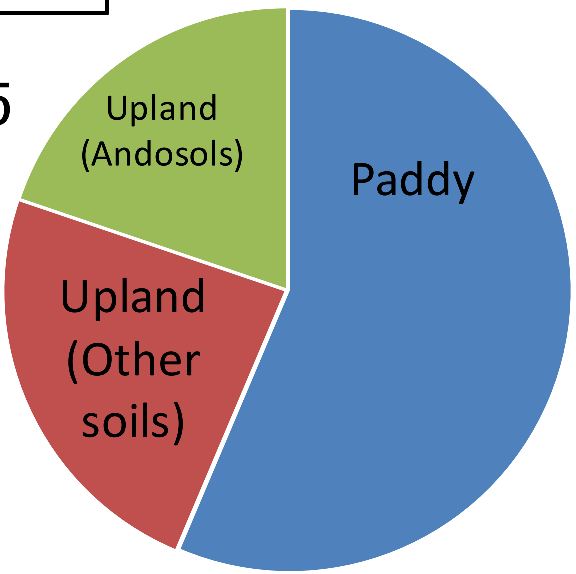
- 6 sites under various weather condition.
- Various soil types.
- Various management

(Shirato & Taniyama, 2003)

But in Andosols……



Predicted SOC << Measured SOC



(Shirato et al., 2004)

The model underestimated the SOC

Andosols have high C concentration

•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 this into account.
(Only clay content as parameter of soil)

Need modification

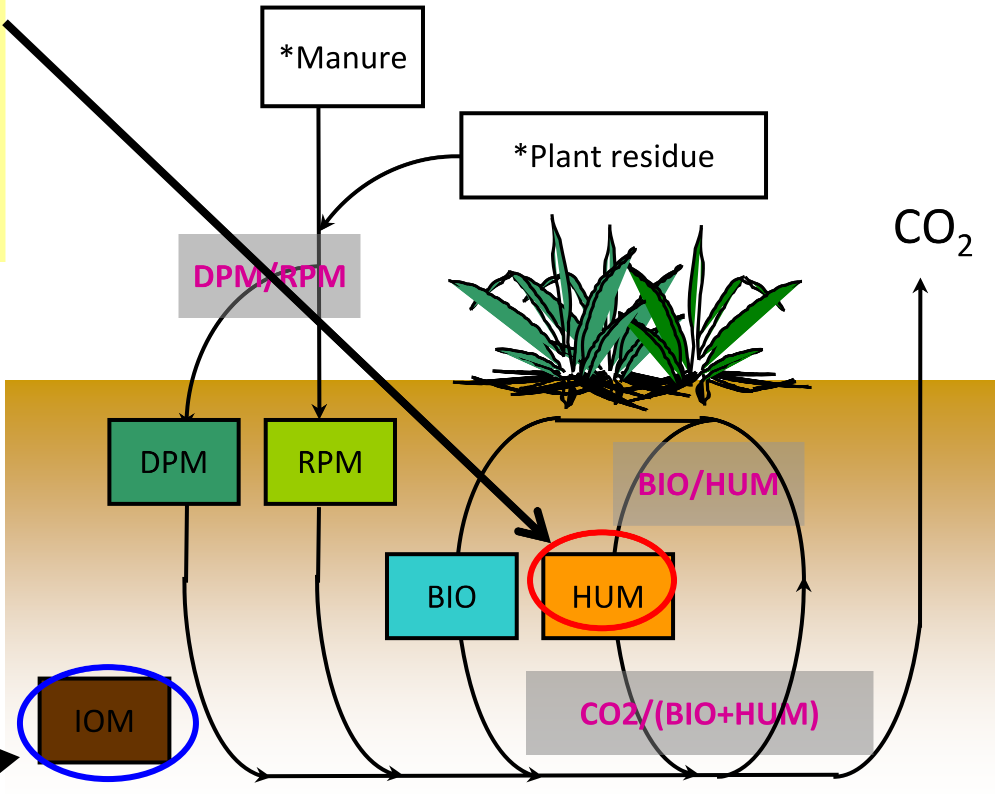
How to modify the RothC for Andosols

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

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

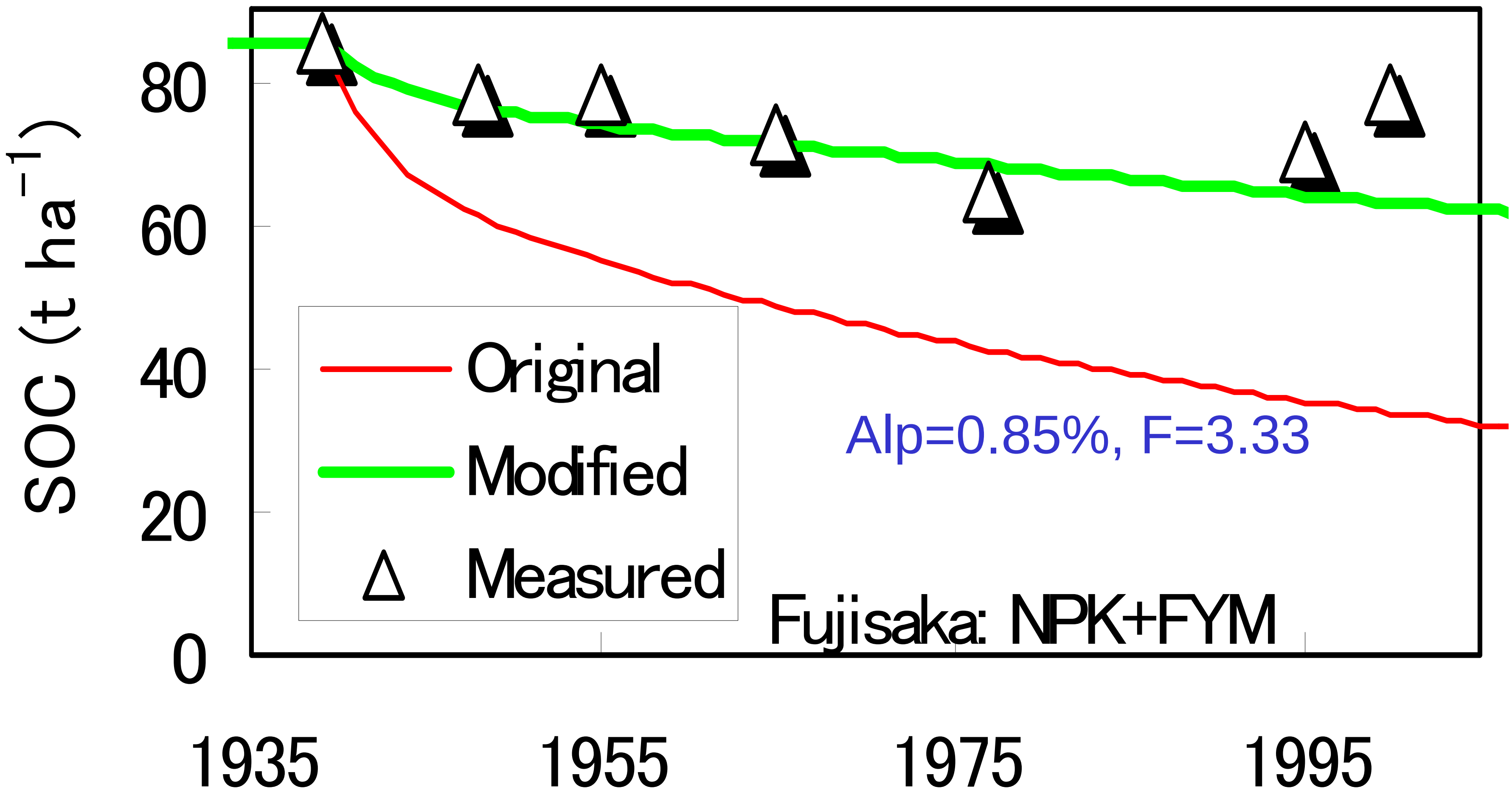
F=2.50 Alp + 1.20 (Alp: Pyrophosphate extractable

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



2. IOM=0

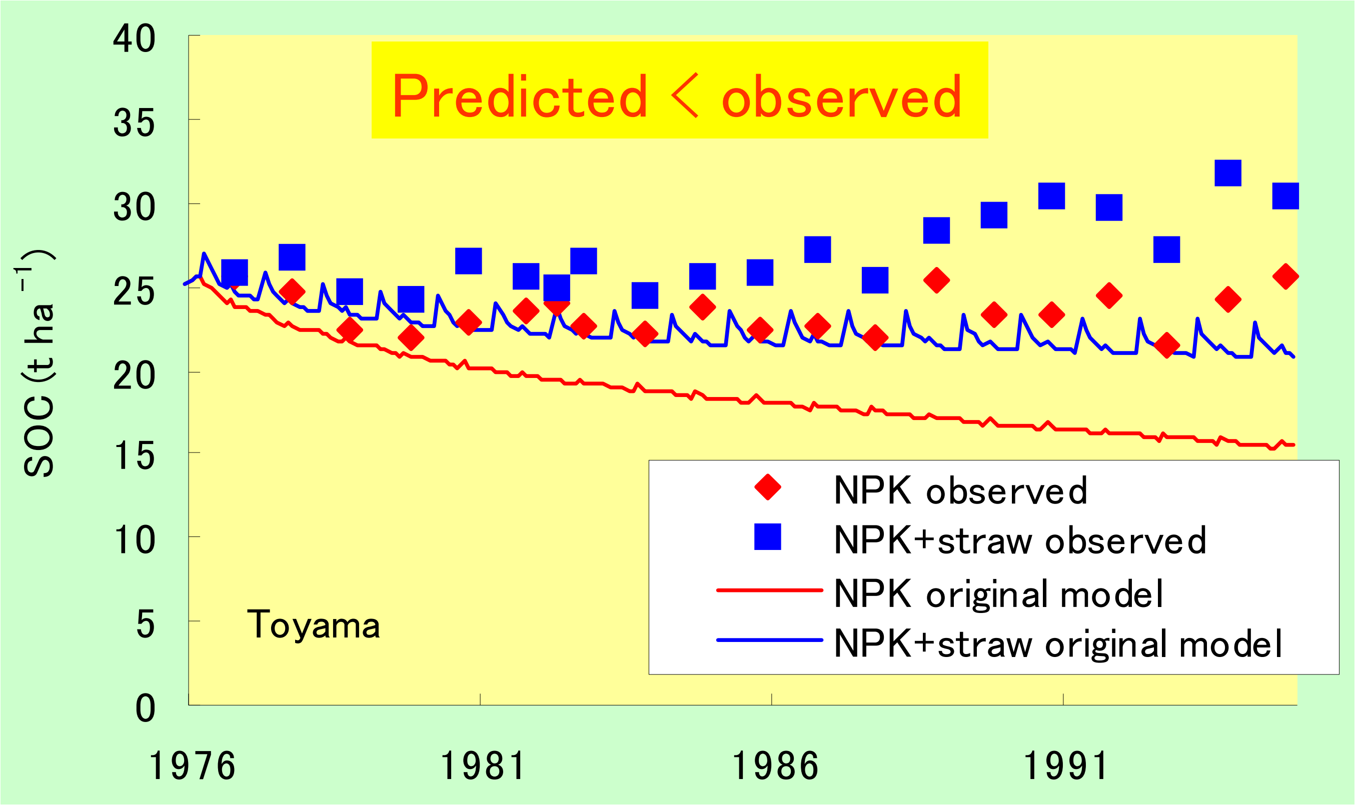
Modified model for Andosols



Better performance than the original RothC

(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?

- Predicted SOC＜observed (as expected)

- Rice growing period: anaerobic condition ➔ slow decomposition

- How about 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)

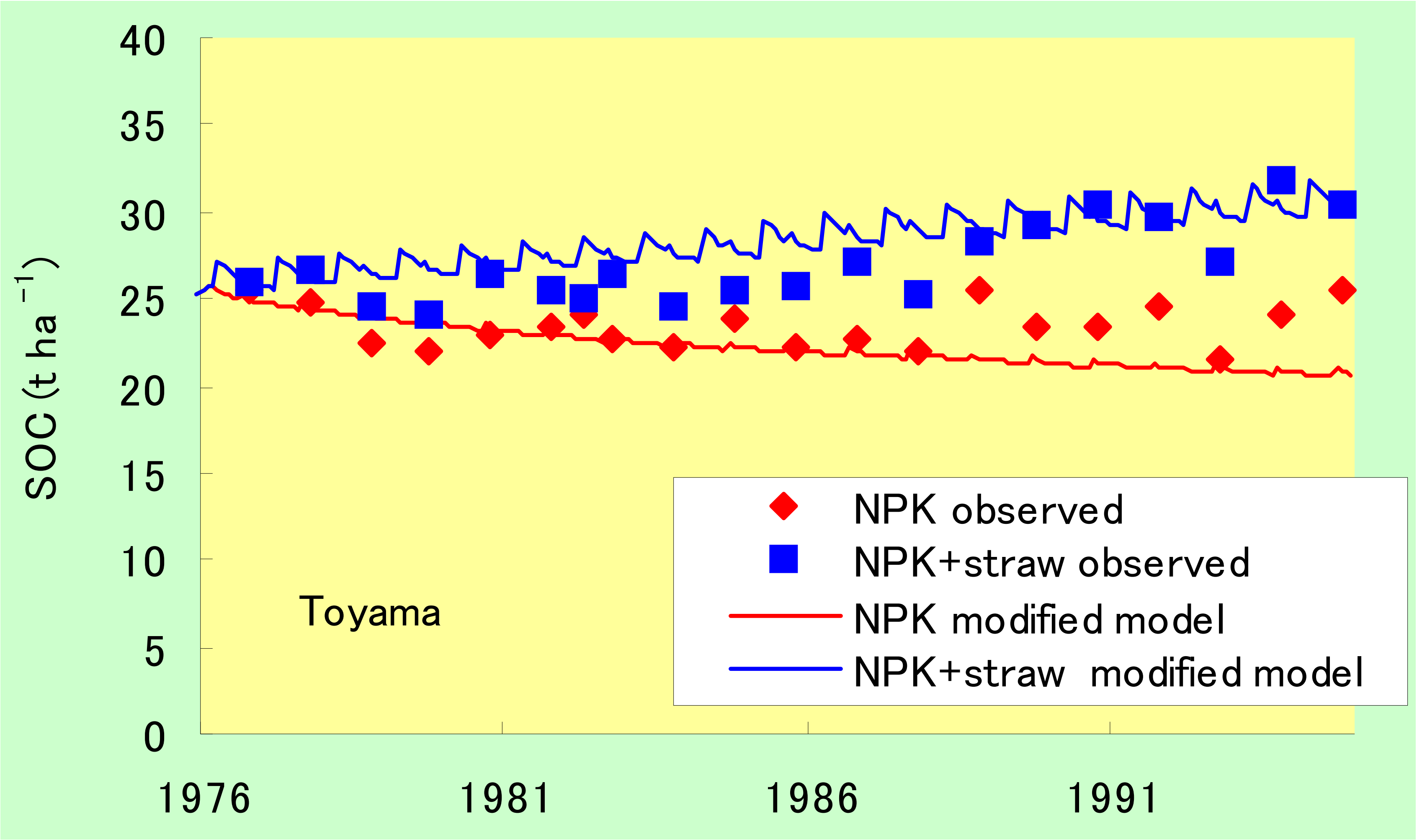
  ➔ decomposition may be slower than upland soils, too.

Decided to modify the model by…

1.Changing the decomposition rates of the RothC during the submergence period and the period without submergence , 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 drained period, respectively

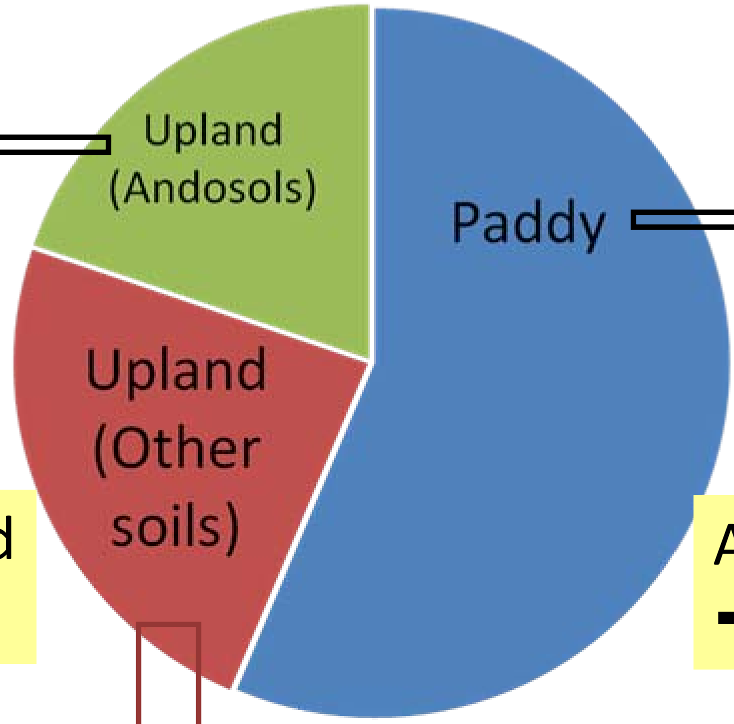


Good agreement

(Shirato & Yokozawa, 2005)

Summary: Validation and modification of RothC in Japan

Half of upland soils: Andosols



Half of arable soils: paddy

Volcanic ash derived
➔Stable humus

Anaerobic condition
➔Slow decomposition

Proportion of area of soil types in Japanese arable land

Modified model

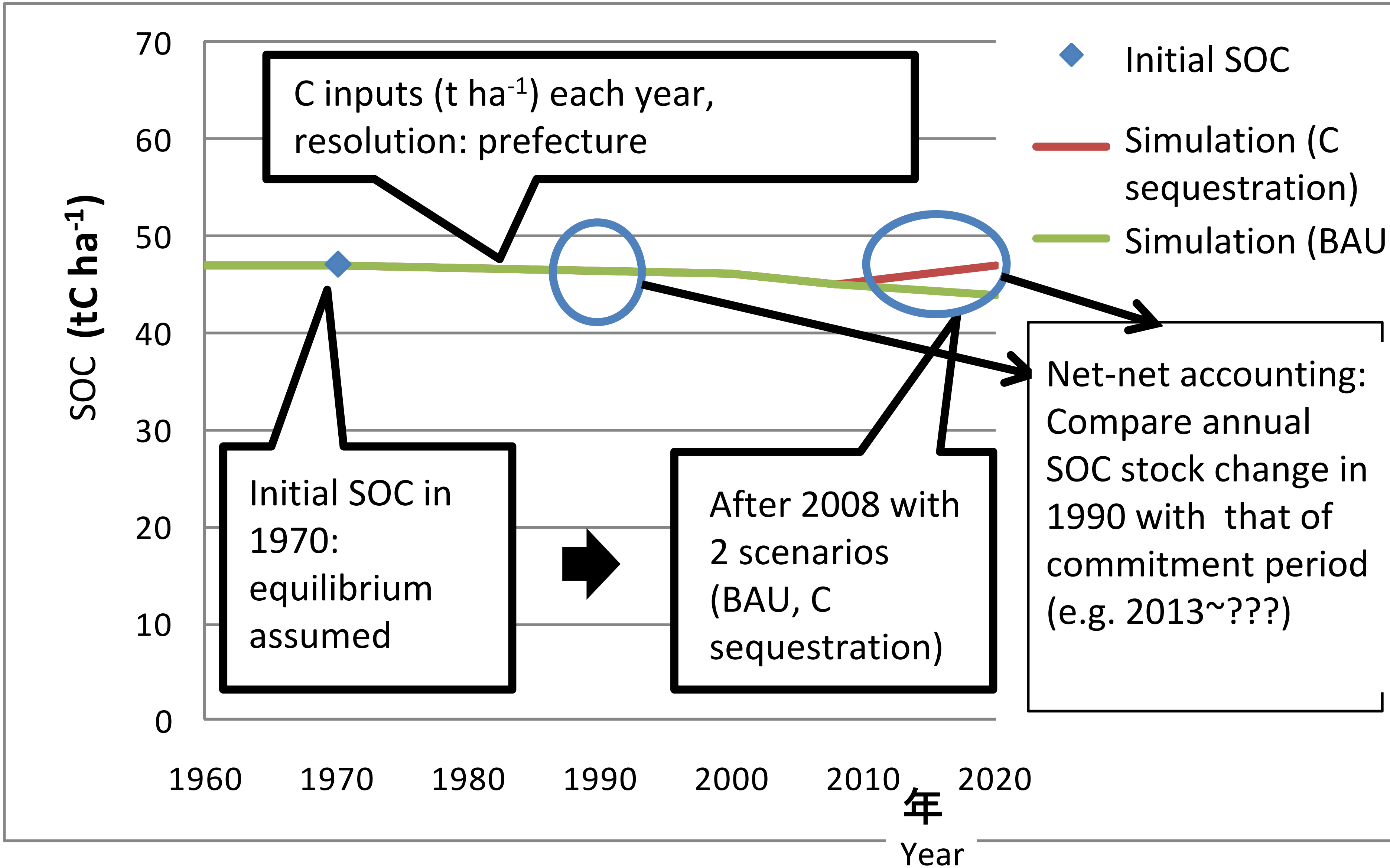
Original RothC is OK

Modified model

Next step: Country scale simulation

Country scale simulation of SOC 1970-2020

Spatial resolution: 100 m grid



Selection of 3 versions of the RothC

Grids in which
area of **paddy fields > upland crop fields**

YES → Paddy soils version

（Shirato & Yokozawa, 2005）

No ↓

Soil map of “Fundamental Soil Survey for Soil Fertility Conservation” (1979)

Grids in which
Dominant soil series was Andosols group

Andosols, Wet Andosols, Gleyed Andosols

YES → Andosols version

（Shirato et al., 2004）

No ↓

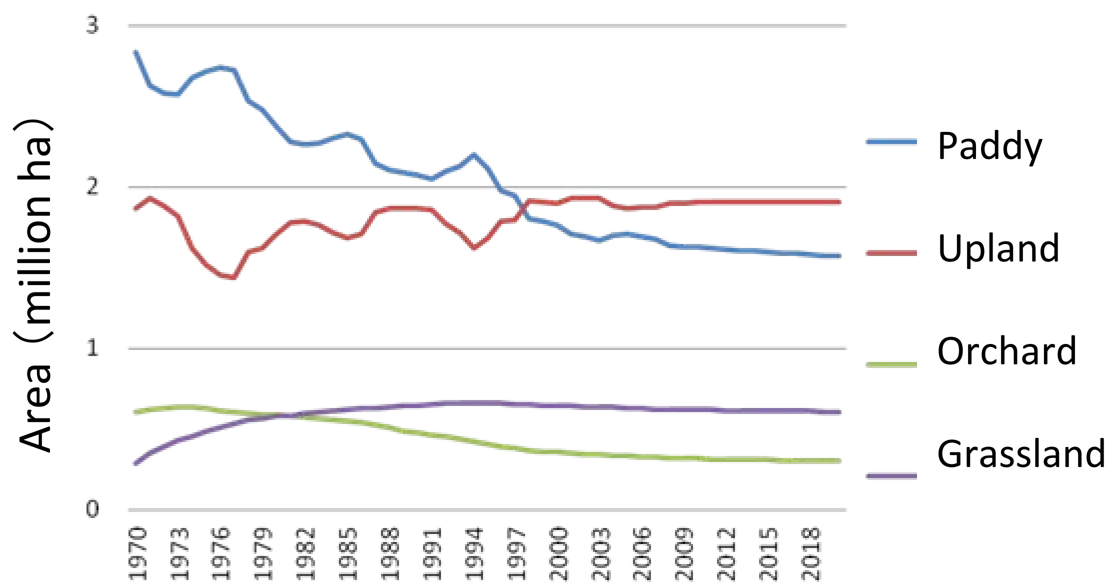
Original RothC-26.3

（Coleman & Jenkinson, 1996）

Land use change

•Area of four agricultural land use (paddy, upland, orchard, grassland) has been changing

•Different version of the RothC, different management (C inputs) should be applied for different land use.

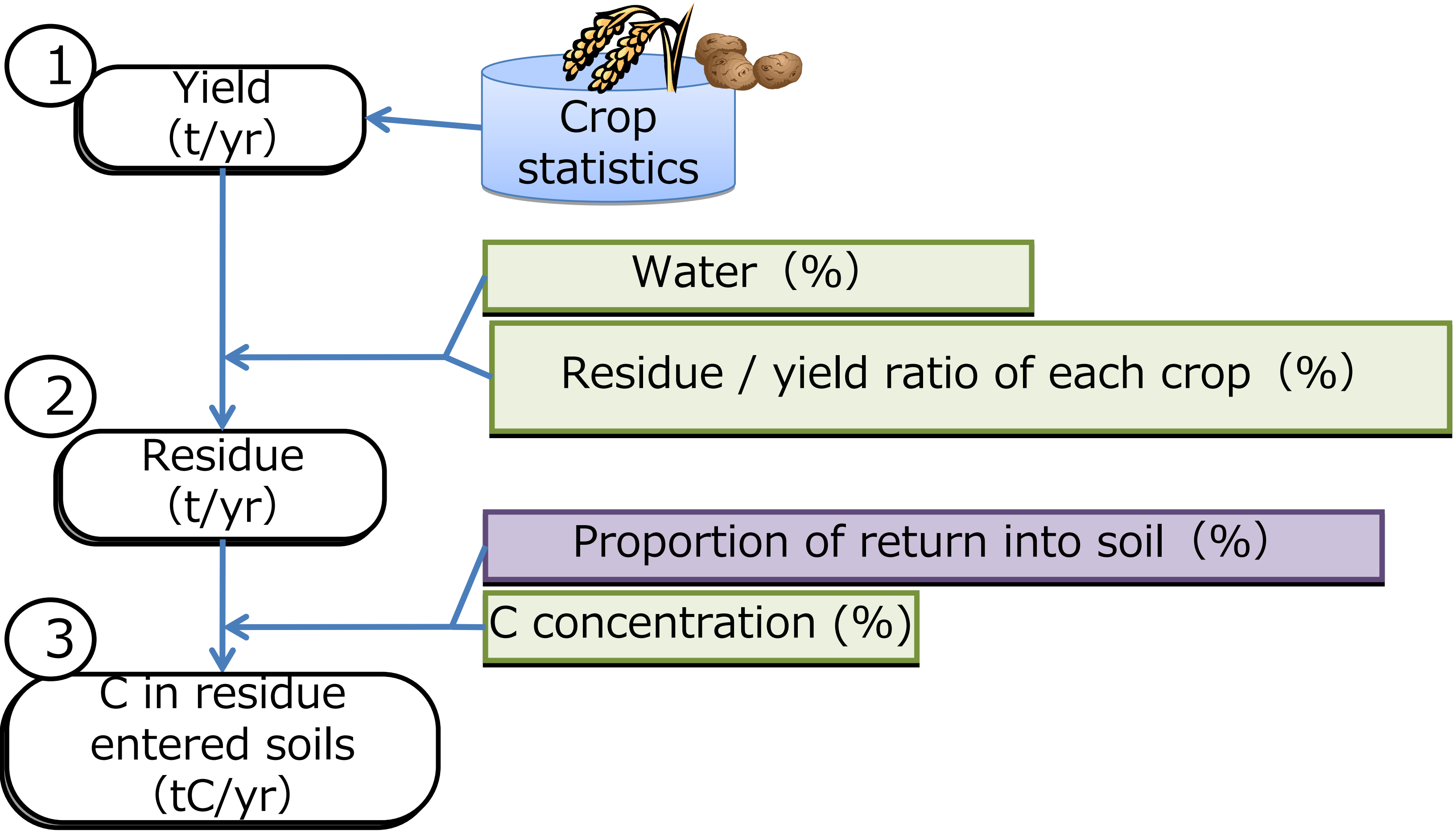


•Land use change history data for each grid should be constructed.

	1970	1971	1972	·	·	·	·	2018	2019	2020
Simulation unit	P	P	U	U	U	U	U	P	P	P
	O	O	O							
				G	G	G	G	G	G	G

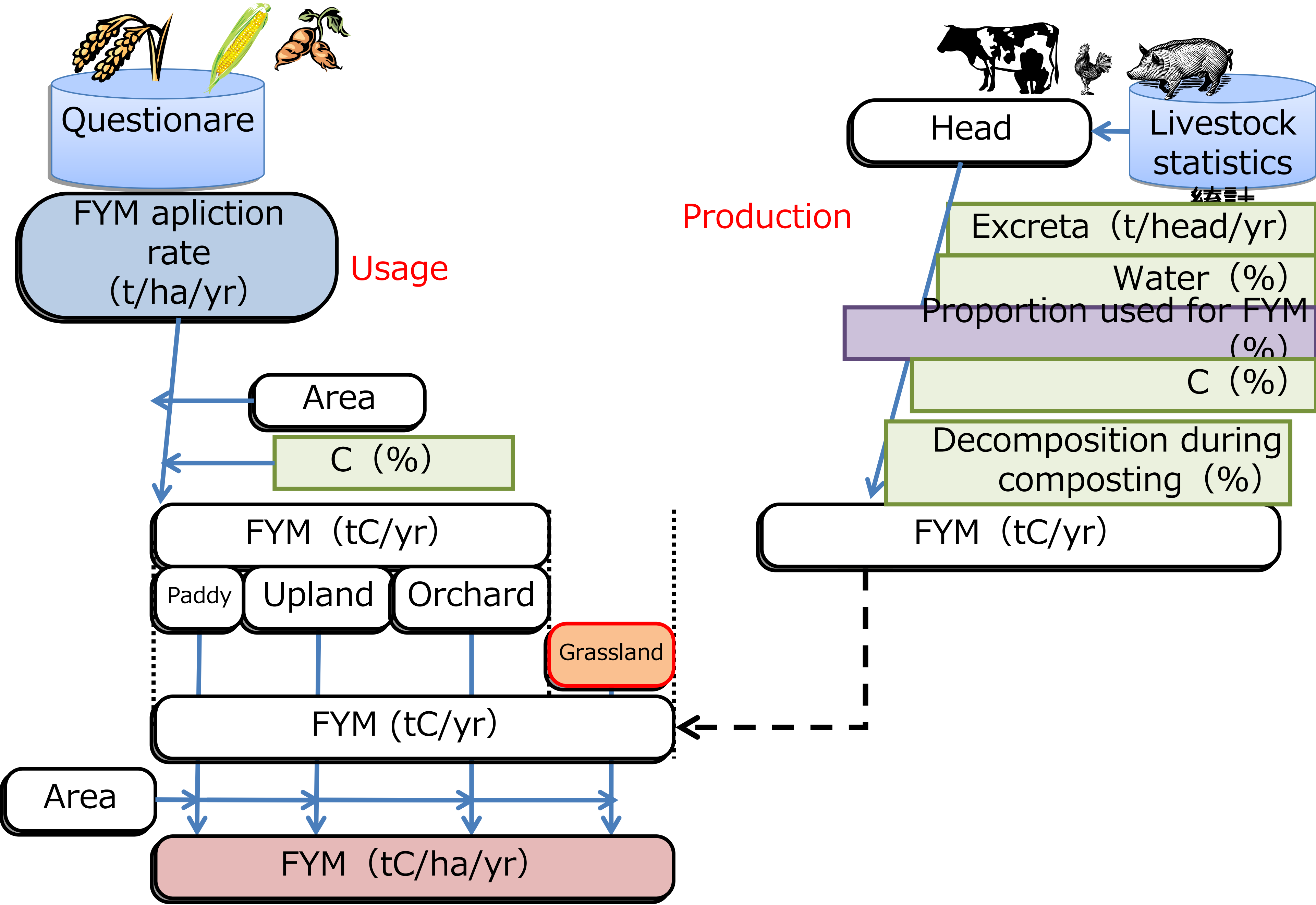
P: paddy
U: upland
O: orchard
G: grassland

Estimating C inputs 1)crop residue

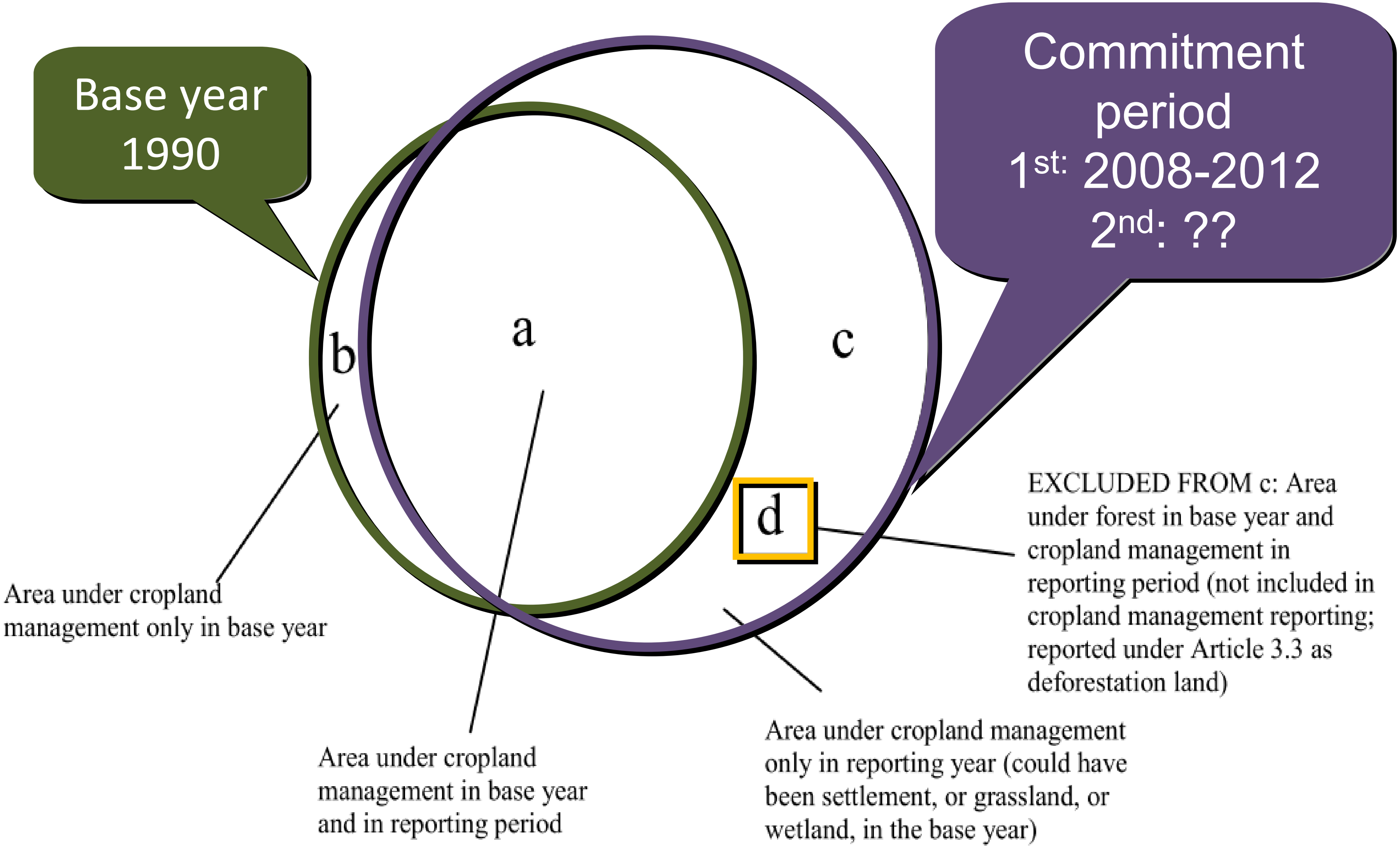


・4 land use (paddy field, upland crop, orchard, grassland)
・47 prefecture
・51 years: 1970～2020

Estimating C inputs 2)FYM



Accounting in Kyoto Protocol:
Different land area: base year ⇔ commitment period



GPG-LULUCF 2003

Summary

- The RothC was validated against long-term experiments in Japan.
- Good performance in non-volcanic upland soils, Modified for paddy soils and Andosols.

- Country-scale SOC simulation system was constructed.
- SOC in Japanese agricultural lands tended to decrease over time.
- Annual SOC stock change was affected by temperature and the amount of C input to soils.
- Net-net accounting method following Kyoto protocol resulted in net removal of CO_2 .