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RESEARCH STRATEGIES FOR MITIGATION AND ADAPTATION OF CLIMATE CHANGE IN AGRICULTURE SECTOR OF JAPAN

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ABSTRACT

The target given to Japan for the first commitment period of the Kyoto Protocol is to reduce average emissions of greenhouse gases (GHG) by six percent from the base year. For the successful achievement of the target, Japanese government has revised the Kyoto Protocol Target Achievement Plan in March 2008, in which options for mitigating GHG emissions from agriculture are included. On the other hand, the impacts of climate change on agriculture can already be seen in some cropping systems of Japan. Therefore, research outputs both for mitigation and adaptation of climate change in agricultural sector are requested in Japan without delay. Currently, series of research projects are carried out by cooperating research institutes and universities to meet the immediate necessities. One of the research projects supported by the Ministry of Agriculture, Forestry and Fisheries, entitled "Evaluation, adaptation and mitigation of global warming in agriculture, forestry and fisheries: research and development", comprehensively studies the effects of global warming on Japanese agriculture, forestry and fisheries, and aim to develop technologies for mitigation and adaptation.

Carbon cycles in Japanese agricultural lands, as well as forest lands, are quantitatively estimated by combining monitoring data and modeling. Soils can be either a sink or a source of atmospheric CO_2 depending on the balance between C input to soils and C decomposition in soils. There are many factors controlling soil C balance. We can control some factors but cannot control others. For example, increasing C input to soils by application of manure can increase soil C. Reducing C decomposition by introducing no-tillage system can also increase soil C. We have conducted long-term experiments with continuous organic matter application under typical soil type and cropping system of each prefecture (over 150 sites in total), which demonstrated that soil carbon stock increased through organic matter application such as compost. Using such long-term data, we are developing the soil carbon model to predict SOC dynamics in future through climate and/or management change.

Agriculture is identified to be a major source for methane (CH_4) and nitrous oxide (N_2O), which contribute about 70% and 60%, respectively, in Japanese GHG inventory. Field experiments for evaluating mitigation options for these gases are conducted in agricultural lands and animal industry have been conducted at various sites in Japan. These experiments have demonstrated promising options that can mitigate the emissions significantly (10% to >50%), compared with each corresponding control treatment. Those options include composting rice straw, improving mid-season drainage practices for CH_4 from rice cultivation, fertilizer management for N_2O from upland fields, and diet management for animals. Some of the options, such as improved mid-season drainage in rice cultivation, are now in the extension stage. In addition to the field experiments, process based or statistical models are developed to estimate the emission rates of CH_4 and N_2O, together with their mitigation potentials, in Japanese agriculture.

The projected increase of atmospheric CO_2 concentration ([CO_2]) and global warming will have significant impacts on future agricultural productivity. While elevated atmospheric [CO_2] will promote growth and yield of rice, warmer climates may reduce the yield. The net change of the crop productivity will depend on the extents of these counteracting effects of future climates, and the magnitude and even the direction of the change will be subject to an uncertainty due to the lack of our capability to predict the respective and interactive effects under field conditions. Attempts are underway to fill the gap between chamber and open-field observations, using facilities such as free-air CO_2 enrichment (FACE) systems. The primary effect of elevated CO_2 is enhanced photosynthetic rates, but season-long CO_2 enrichment (200 ppmv above the ambient) in the field showed a substantial decrease in the photosynthetic enhancement as the growth stage progresses. This resulted in a

relatively modest yield enhancement around 14% for rice, but also suggests that there is a possible room for improvement in the CO_2 fertilization effect. Extreme temperature events during the critical period for reproductive development and/or anthesis have long been known to increase floret sterility and thereby reduce grain yield substantially. Under elevated [CO_2], stomatal conductance is reduced so that leaf, canopy and panicle temperatures are increased; this can exacerbate the heat induced spikelet sterility. Large genotypic variations in heat avoidance/tolerance traits will provide us with opportunities to develop countermeasures against heat stresses in the future.

To grasp the actual influence of global warming on agricultural production in Japan, a questionnaire was sent to prefectural institutes for agricultural research. All prefectures replied that global warming had affected on at least one fruit tree species. Fruit qualities have clearly changed, for example coloring faintly, enlarging, reduction of acid, softening and spoiling rapidly. Freezing injury and late frost damage has increased in north Japan which is colder area. It is predicted that the favorable regions to cultivate apples and satsuma mandarins will gradually move northward. Over 70% of prefectures recognized effects of warming on rice, vegetable, and flower cultivation. Horticultural crops are likely to be more sensitive to global warming than other agricultural crops. Our survey elucidated many effects of recent warming, such as changes in the length of crop-growing periods, reductions in feed intake and feeding efficiency of livestock, and reductions in yields of wheat, barley, vegetables, flowers, milk, and eggs.

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Research Strategies for Mitigation and Adaptation of Climate Change in Agriculture Sector of Japan

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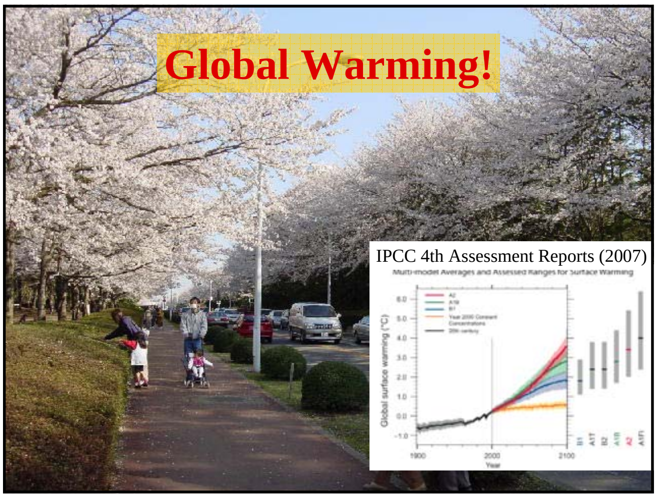


Mitigation and Adaptation of Climate Change in Agriculture Sector of Japan

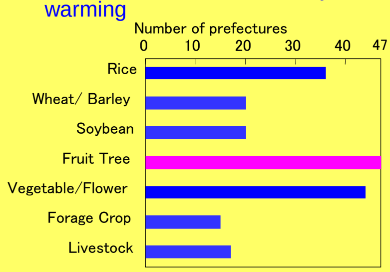
Background for Research Strategies

- Japanese government has revised "the Kyoto Protocol Target Achievement Plan" in March 2008, in which options for mitigating GHG emissions from agriculture are included.
- The impacts of climate change on agriculture, both yields and quality, can already be seen in most of the cropping systems of Japan.
- Therefore, research outputs both for mitigation and adaptation of climate change in agricultural sector are requested in Japan without delay.

Evidences for the Impacts of Climate Change on Japanese Agriculture

- To gather information concerning changes of agricultural production due to recent climate change in Japan, we conducted a survey within public institutes for agricultural research in 47 prefectures.

The number of prefectures recognizing at least one evidence caused by recent global warming



Reported Impacts of Climate Change on Japanese Agriculture

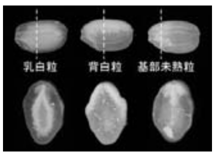
Rice
Significant reductions in yield and quality of rice in southern Japan.

Other cereal crops
Some prefectures reported the effects on yield and quality of wheat and barley.

Fruit tree
Fruit qualities have clearly changed, for example coloring faintly, enlarging, reduction of acid, softening and spoiling rapidly.

Vegetables and flowers
Reductions in the growing periods of leafy and root vegetables as well as fruits vegetables.

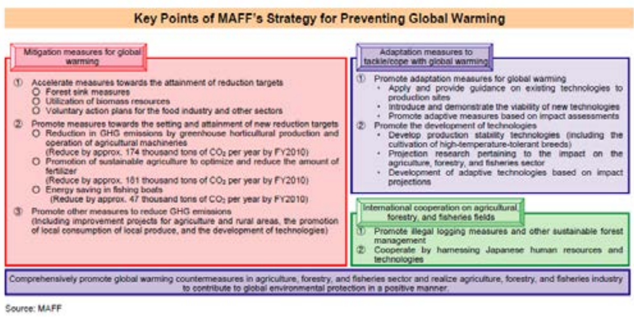
Livestock and forage crops
Reductions in yields of temperate grass and maize were reported in various parts of Japan.



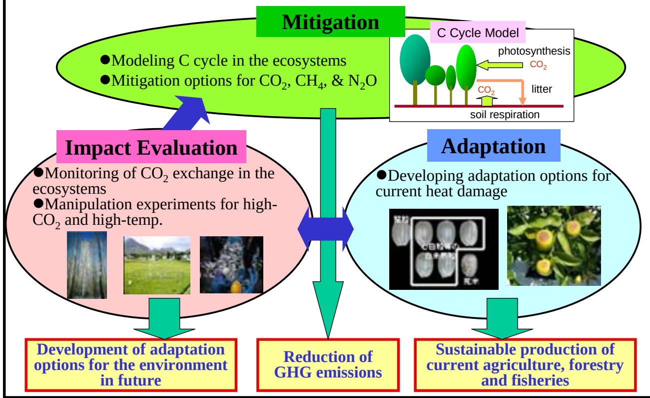
Clouding of rice


Tanning of apple

Ministry of Agriculture, Forestry and Fisheries (MAFF) established MAFF's Strategy for Preventing Global Warming in June 2007

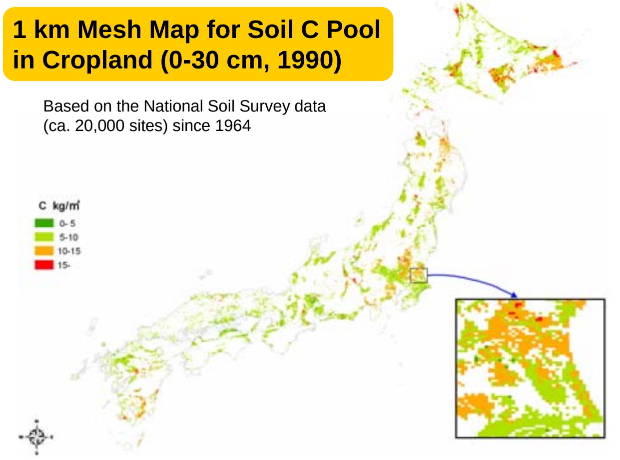


A Research Project (FY2006-2010) supported by the MAFF
"Evaluation, Adaptation and Mitigation of Global Warming in Agriculture, Forestry and Fisheries: Research and Development"



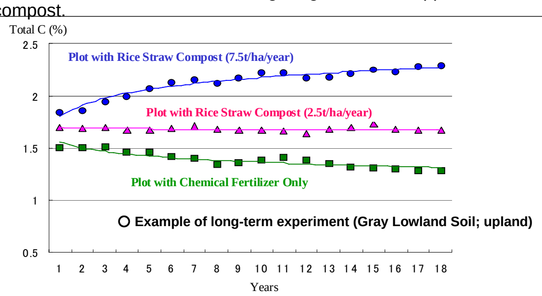
1 km Mesh Map for Soil C Pool in Cropland (0-30 cm, 1990)

Based on the National Soil Survey data (ca. 20,000 sites) since 1964



Long-term experiments in Japan

○ Since 1975, the MAFF has conducted long-term experiments with continuous organic matter application under typical soil type and cropping system of each prefecture (over 150 sites in total), which demonstrated that soil carbon stock increased through organic matter application such as compost.



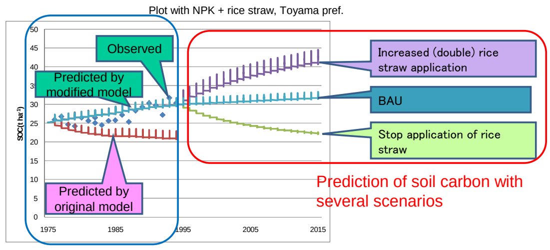
Data:"Basic Survey of Soil Environment (Benchmark Survey)" Yamaguchi Pref. Agricultural Research Institute. Figure for a year is the three-year average including the previous and the next year to that year.

Modeling soil carbon dynamics

○ A research project is carried out by MAFF to develop Japanese version of 'Soil carbon turnover model' to predict the soil carbon stock change associated with the changes in management practices.

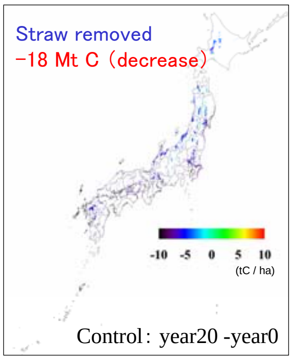
○ We have validated the Rothamsted Carbon Model against Japanese long-term experimental datasets and modified the model for paddy soils and for Andosols.

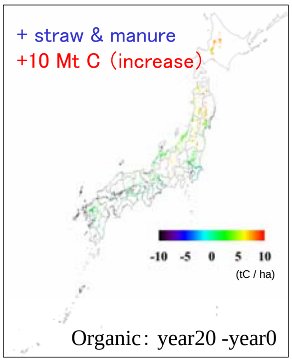
Example of validation and modification of the model for Japanese paddy soils



Validation and modification using long-term datasets
(Decomposition of OM in paddy soil is slower than upland because of anaerobic conditions)

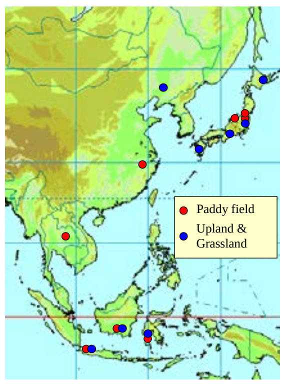
Estimated Soil C Change in Paddy Fields





Cf: absorption by forest lands = 94 Mt C yr⁻¹(2004)

Field Experiments for CH_4&N_2O Mitigation

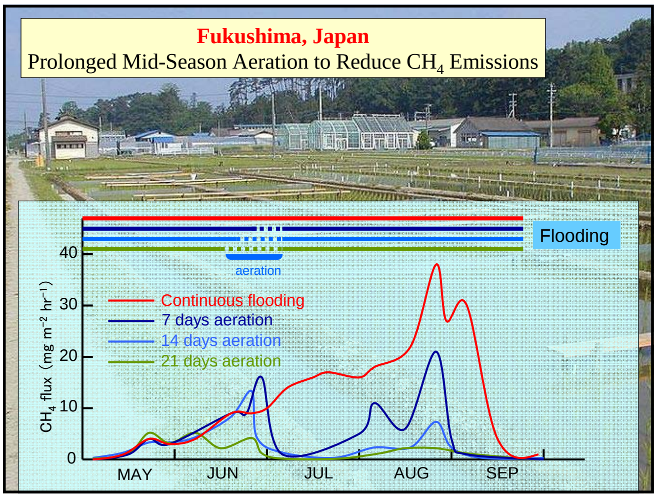


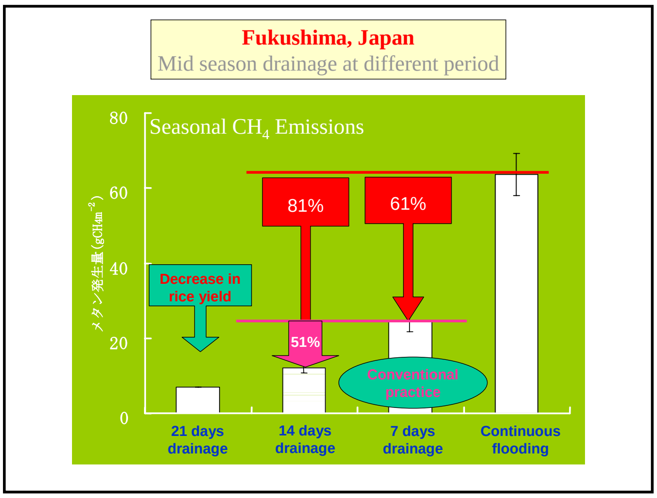
Paddy fields
OM management: CH_4
Yamagata (Japan), Yixin (China), Khon Kaen (Thailand)

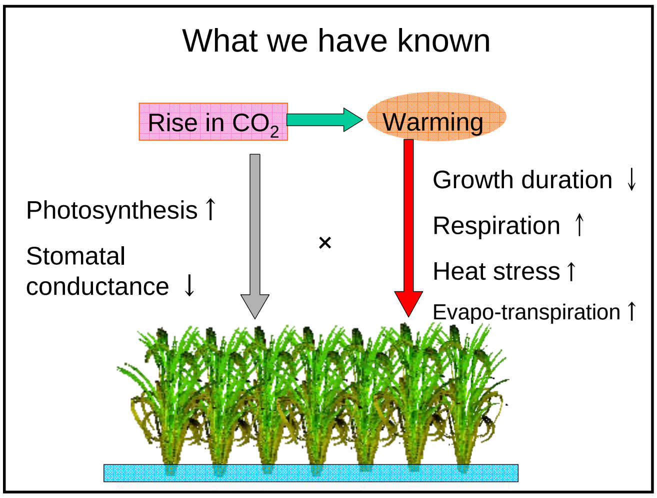
Paddy fields
water management: CH_4
Fukushima, Niigata (Japan)
Indonesia

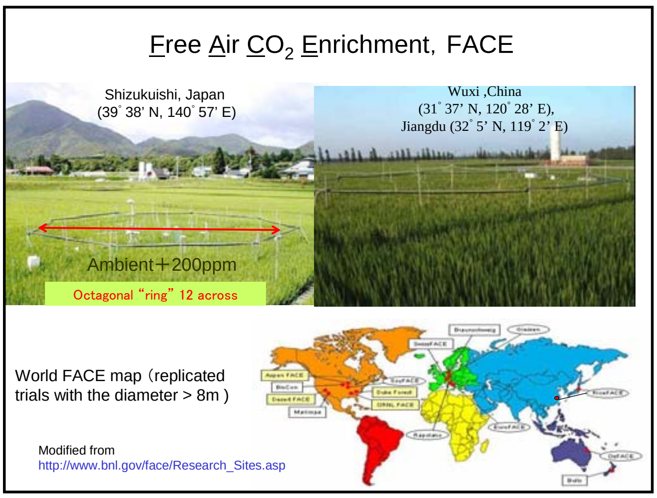
Uplands & Grasslands
Fertilizer management: N_2O
Konsen, Tsukuba, Kumamoto (Japan)
Shenyang (China), Indonesia

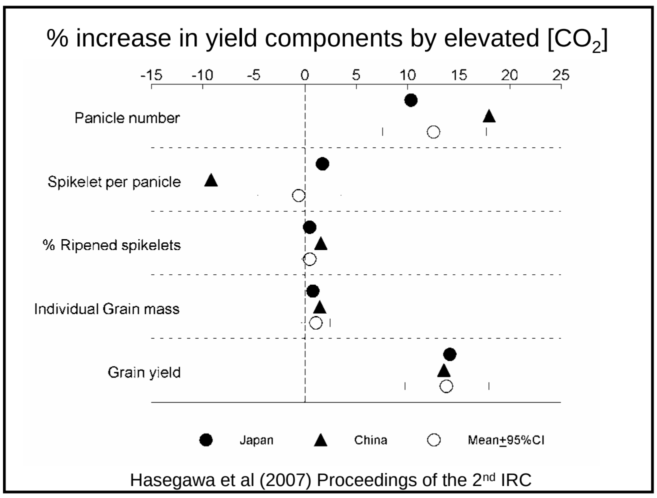

Monitoring GHG Emissions by Closed Chamber Techniques


Fukushima, Japan
Prolonged Mid-Season Aeration to Reduce CH4 Emissions
Flooding
aeration
Continuous flooding
7 days aeration
14 days aeration
21 days aeration
CH4 flux (mg m-2 hr-1)
0
10
20
30
40
MAY
JUN
JUL
AUG
SEP

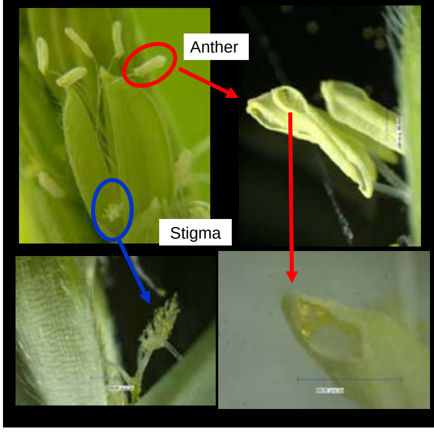

Fukushima, Japan
Mid season drainage at different period
Seasonal CH4 Emissions
メタン発生量 (gCHm-2)
80
60
40
20
0
Decrease in rice yield
81%
61%
51%
Conventional practice
21 days drainage
14 days drainage
7 days drainage
Continuous flooding


What we have known
Rise in CO2
Warming
Photosynthesis ↑
Stomatal conductance ↓
×
Growth duration ↓
Respiration ↑
Heat stress ↑
Evapo-transpiration ↑


Free Air CO2 Enrichment, FACE
Shizukuishi, Japan
(39° 38' N, 140° 57' E)
Wuxi ,China
(31° 37' N, 120° 28' E),
Jiangdu (32° 5' N, 119° 2' E)
Ambient+200ppm
Octagonal "ring" 12 across
World FACE map (replicated trials with the diameter > 8m)
Modified from
http://www.bnl.gov/face/Research_Sites.asp


% increase in yield components by elevated [CO2]
-15
-10
-5
0
5
10
15
20
25
Panicle number
Spikelet per panicle
% Ripened spikelets
Individual Grain mass
Grain yield
Japan
China
Mean±95%CI
Hasegawa et al (2007) Proceedings of the 2nd IRC

Heat stress on fertility



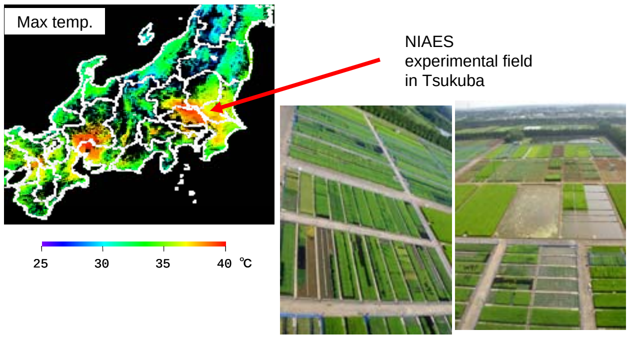
Temperatures above 34-35ºC around flowering disturb anther dehiscence & pollen shedding （Matsui et al. 2001).

↓

Sterility

increases by 16％ with a 1ºC increase above 34-35ºC （form Kim et al. 1996）.

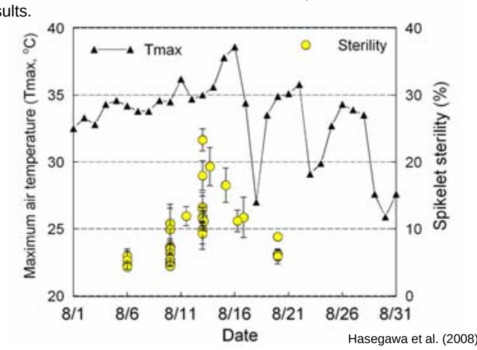
Heat events occurred in central parts of Japan in 2007
（Maximum temperature distribution mid-August)



Collected panicle samples from 34 bays to measure spikelet sterility.

Maximum air temperature at NIAES, Tsukuba (▲) &
spikelet sterility of the rice plants (●) plotted heading dates

Spikelet sterility was higher right after the heat event in mid-August, but the extent was somewhat smaller than expected from the chamber results.

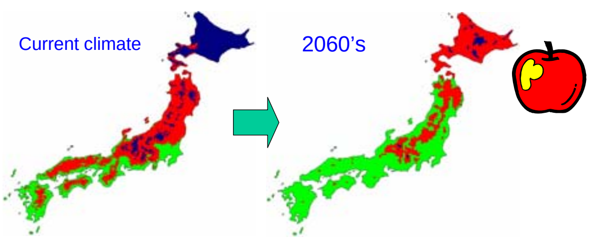


Hasegawa et al. (2008) JJCS

Summary for temperature effects

- Extreme heat events can be serious threats to the future rice production even in the temperate regions, but field-level evidence is still limited to predict accurately the
- In fact, heat events in 2007 in Japan increased spikelet sterility but to a less extent than expected from the chamber study.
- The keys to reduce uncertainties in prediction and to develop adaptation strategies include;
  - difference between air temperature and panicle/ meristem temperatures
  - CO_2 x T (x management/genotypes) interactions .

- The favorable regions to cultivate apples and satsuma mandarins will gradually move northward in Japan.



Temperature zone appropriate for the cultivation (7-13℃)
Temperature zone above 13℃
Temperature zone below 7℃

(Sugiura and Yokozawa, 2004) 23

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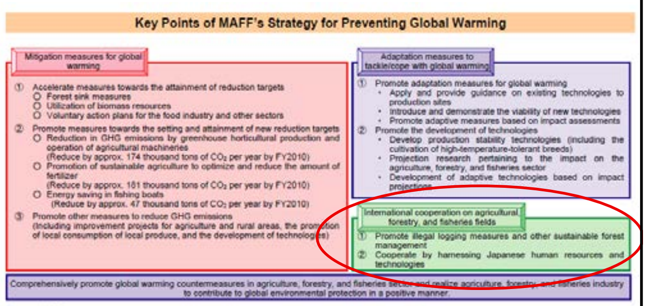

Source: MAFF