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ADAPTATION OPPORTUNITIES TO GLOBAL CLIMATE CHANGE IN AGRICULTURE IN ASIA-PACIFIC

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ABSTRACT

Agricultures in not a few Asian countries are facing difficult situation for sustaining future food security and livelihood under increasing population and scarce resources. Global climate change associated with continued greenhouse gas emissions is predicted to give enormous influences on agriculture within this century through changes in potential crop growth period, positive and negative effects of increased temperature on crop and livestock production, increased frequency and severity of droughts and floods, and increased pests, diseases and soil degradations (IPCC, 2007). Global climate change is likely to further exacerbate food security and livelihood in Asia, unless effective adaptation to it.

There are many measures for agricultures to adapt to global climate change: altered genotypes and cropping seasons, adaptive resource management, altered crop species and cropping systems, creation of innovative genotypes and technologies, infrastructural development, social correspondence, and their integration. Adoption of altered genotypes and cropping seasons is the most basic measure for reducing risks of crop damages or failures due to increased abiotic and biotic stresses under global warming climates. This adaptation requires genotypes to safely complete their life cycles under given climatic conditions, to have high resistances to abiotic and biotic stresses and, hence, to perform high yields. Especially, crop resistance to environmental stresses at reproductive development stage is important for successful adaptation, because a short-term stress in this stage often give crucial effect on the yield. A simulation study on rice suggested that adoption of genotypes with lower sensitivity to flowering-time heat stress only by 1-2 ^{o}C than the current cultivars and adaptive cropping seasons drastically improved negative effects of global warming on the yield (Horie et al., 1996).

Resource management is another measure for agricultural adaptation to global climate change. This includes water and nutrient management technologies for their efficient use, such as mulching, field incorporations of clay-rich soils and organic materials, micro and drip trickle irrigations, and application of controlled-release fertilizers of which release pattern highly match given temperature conditions. Also, integrated pest management is expected to play important roles in reducing increased biotic stresses to crops and animals under global warming.

When negative effects of global climate change exceed the adaptation capacities of the above mentioned measures, adoption of altered crop species and cropping systems may be required. This includes replacement of C_3 crops with C_4 species, change from double rice cropping systems to upland-lowland rotation systems to save water and reduce insect and disease damages, and so on. Creation of innovative genotypes with much higher resistances to biotic and abiotic stresses is undoubtedly important measure for agricultural adaptation to global climate change. This requires plant breeding by marker-assisted methods and gene transformation technologies as well as by traditional breeding methods. Another measure for agricultural adaptation is the development of infrastructures such as water reservoirs, irrigation and drainage channels for water control, tidal-wave protection dikes and terrace channels for soil erosion protection. Further, social correspondence is indispensable component for the adaptation. This includes consensus and policies for better use of water and other resources, education and capacity building of farmers, increased accessibility to information and technologies, and policies for food stocks and trade for food security.

There are many opportunities for agricultural adaptation to global climate change through the above mentioned measures and their integration. Technology development for most of these measures is being tackled in diverse areas of agricultural sciences by national and international organizations. The important is the acceleration of the technology development, for many symptoms of global climate change is being observed worldwide (IPCC, 2007). The technology specifically needed for agricultural adaptation is information technologies for monitor and prediction of climate effects on

agro-ecosystems; agricultural hazard maps; early warning to biotic and abiotic stresses; and for decision support for adaptive management

KEYWORDS
Global climate change, agriculture, adaptation, environmental stress, Asia

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IPCC, 2007. Climate: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge, UK, 976pp.

Horie, T. T. Matsui, H. Nakagawa and K. Omasa, 1996. Omasa et al. (eds): Climate Change and Plants in East Asia. Springer Verlag, Tokyo , 39-59.

Adaptation Opportunities to Global Climate Change in Agriculture in Asia-Pacific

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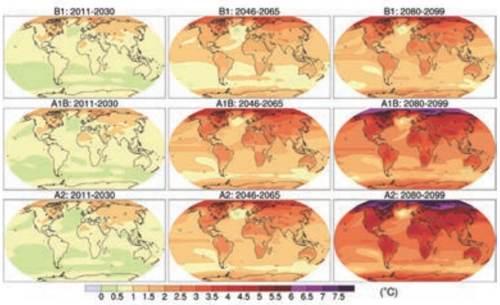
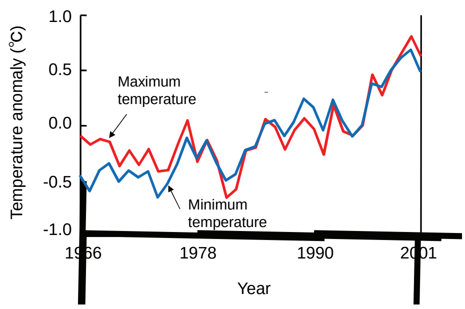
Projection of global climate change



IPCC AR4, 2007

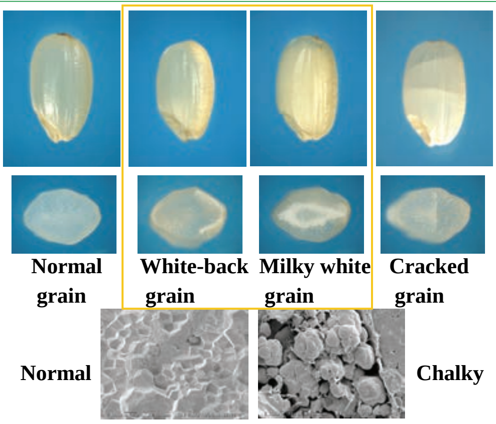
Warming trends observed in Japan: Yearly changes in temperature



Yearly changes in Japan-average anomalies in summer (June to August) season-averaged daily minimum and maximum temperatures over 40 years (1964-2003) period. (Urbanization effects were excluded)

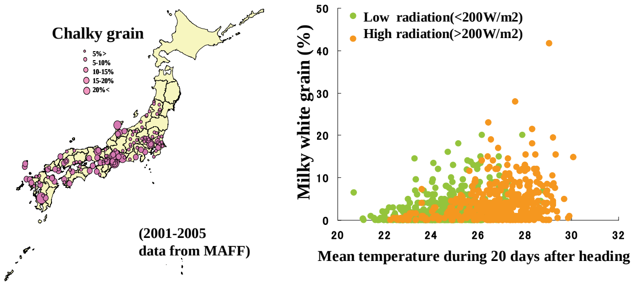
(Kawatsu et al. 2007)

Global warming effect on rice: Abnormal grain induced by high temperature



- Occurrence of chalky and cracked grain are induced by high summer temperature
- In chalky part in endosperm, amyloplast development is incomplete

Effect of temperature on chalky grain



- Incidence of chalky grain such as milky white grain is widespread in the country.
- It increases with the increase in temperature during ripening stages and is aggravated by low solar radiation.

Projected climate change and its impacts on agriculture in Asia-Pacific (IPCC 2007)

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■ Climate change

- Elevated [CO_2] in the atmosphere; exceed 700 ppm within this century
- Global warming of 2 〜 4.5 ℃ at the end of this century
- Precipitation: Increase in high latitude regions, but decrease in most sub-tropic regions
- Sea level rise of 0.18 〜 0.59 m at the end of this century
- Increased intensity and frequency of extreme weather events (cyclones, typhoons, floods, heatwave etc.)

■ Climate change effects on agriculture

- CO_2 fertilization effects on crops and pastures (10 〜25 % yield increase in C3 and 0 〜10 % increase in C4 plants at 550 ppm)
- Increased temperature: generally, negative effects on agriculture and livestock production in warm-temperate to tropic regions, and positive effects in cool-temperate, provided water is available
- Increased frequency and intensity of droughts, especially in west and central Asia and west Australia
- Increased flood and sea-water intrusion in coastal area
- Increased pests and vector-borne diseases
- Increased soil degradation in fragile areas

Impacts of climate change on agriculture in Asia

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■ Without adequate adaptation to climate change, food insecurity and loss of livelihood are likely to be exacerbated in Asia

Adaptation opportunities of agriculture to global climate change

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■ Adaptation via altered genotypes and cropping seasons

■ Adaptation via management

■ Adaptation via altered crops and cropping systems

■ Adaptation via creation of innovative genotypes and technologies

■ Adaptation via infrastructure development

■ Adaptation via social correspondence

■ Integrated adaptation, or adaptation as an agro-ecosystem

Adaptation via altered genotypes and cropping seasons

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■ Avoid coincidence of crop stress-sensitive stage with short-term environmental stresses which bring crucial yield losses

- Heat stress at anthesis
- Cool temperature stresses during meiosis to flowering period
- Water stresses during reproductive development period

■ Safely complete crop life cycles with full use of environmental resources

- Escape early- and late-season environmental stresses

■ Avoid shortening of crop growth duration under increased temperature

- Use of long basic-vegetative period genotypes
- Use of photoperiod-sensitive genotypes where possible

■ Genotypes having higher resistances to environmental stresses

- Deeper root system to avoid droughts
- Higher tolerance to heat, drought and submergence stresses
- Higher resistances to insects and diseases

CO_2 and temperature effects on rice: TGC experiment

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Doubling CO_2 effect on rice biomass

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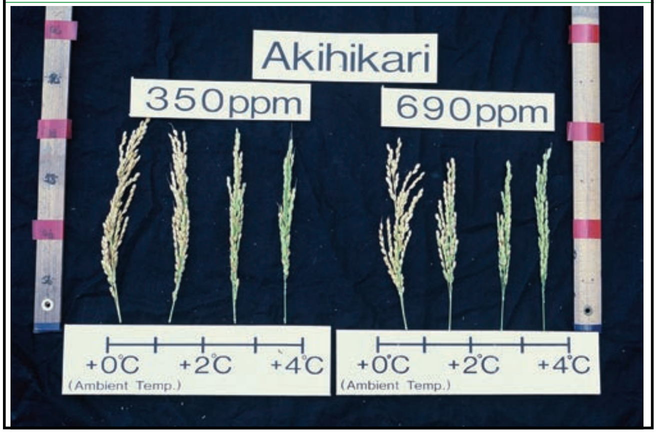
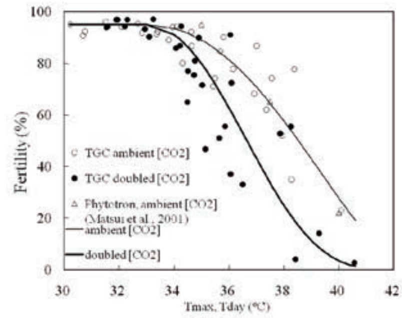
Rice heat stress during flowering period: spikelet sterility

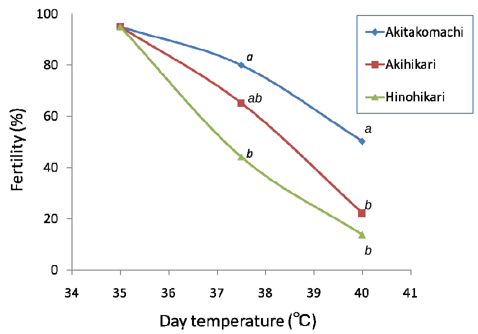


Rice spikelet fertility as affected by heat stress during flowering period and CO_2

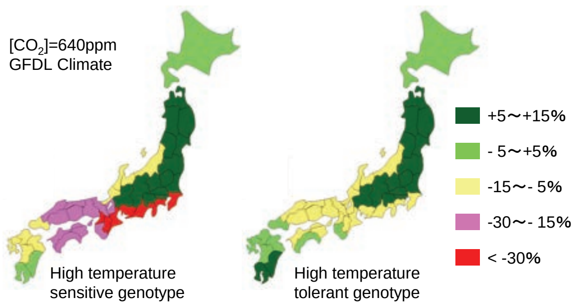


Relationship between average daily maximum temperature during the flowering period Tmax (for TGC experiment) or day time temperature Tday (for phytotron experiment) and spikelet fertility in a rice cultivar 'Akihikari' acclimated to ambient and doubled $[CO_2]$ (Nakagawa et al.,2003)

Rice genotypic difference in spikelet sensitivity to heat stress during flowering period

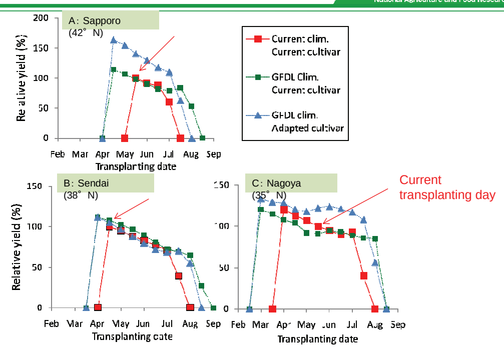


Effects of genotypes on regional rice yield under doubled CO_2 climate in Japan



Horie et al. (1996)

Effects of altered genotypes and cropping seasons on rice yield under doubled CO_2 climate in Japan



Relative yield change as a function of transplanting date for current and phenologicaly adapted rice cultivars under current and GFDL doubled CO2 climate conditions for three representative locations in Japan (Horie et al., 1996)

Adaptation via management

■ Water management for efficient water use

- Mulching to reduce surface run-off and soil evaporation
- Field incorporation of clay-rich soils, organic matters and water retention materials to increase soil water-holding capacity
- Hardpans by polymers infiltration into soil to suppress percolation
- Aerobic rice culture and system of rice intensification (SRI)
- Micro irrigation and drip trickle irrigation etc.

■ Nutrient management adaptable to global warming

- Organic matter application to maintain soil fertility
- Application of controlled-release fertilizers of which release pattern highly match temperature conditions
- Localized application of fertilizers to increase their use efficiencies

■ Management for heat stress reduction

- Spill-over irrigation to reduce canopy temperature for irrigated rice
- Localized temperature control: Crown Temperature Control System for Strawberry
- Fog cooling of greenhouse crops and barn-feed cattle

■ Pest and disease management

- Protections against new disease and pest invasions associated with global warming
- Early warning systems for efficient and timely control of pests and diseases
- Integrated pest management (IPM)

Adaptation via localized temperature Control: Strawberry crown temperature control system

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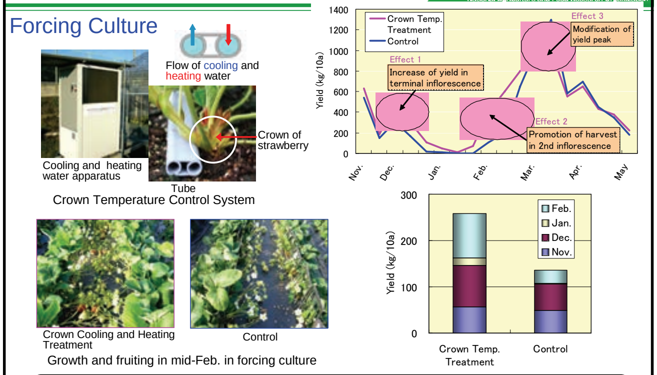

Growth of second inflorescence was promoted, early yield was remarkably increased by cooling at the temperature of 20 ℃ to crown in autumn high temperature period in forcing culture of strawberry.

Adaptation via localized temperature Control: Strawberry crown temperature control system

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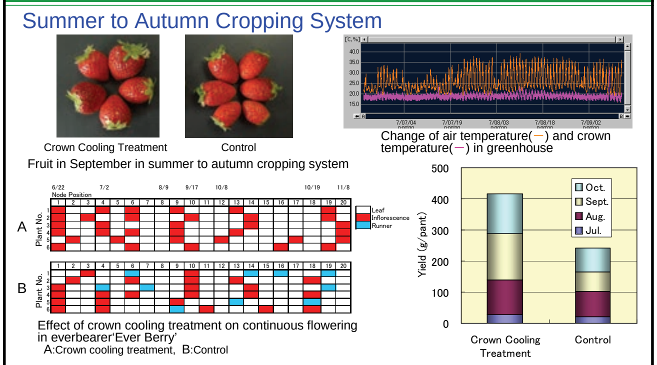

Continuous flowering, number of achenes, fruit weight and yield were increased by cooling at the temperature of 20 ℃ to crown in summer high temperature period in summer to autumn cropping system using everbearing strawberry.

Protection from pest invasion associated with global warming: Citrus greening disease

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Spread of citrus greening disease and Asian citrus psyllid with global warming

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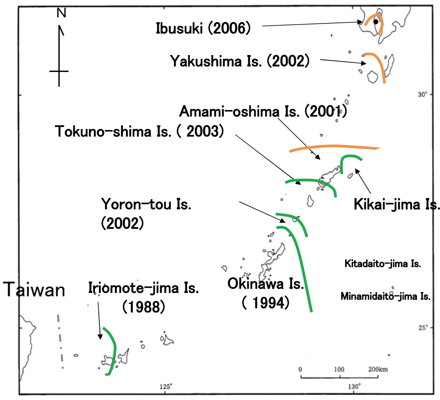

Protection from disease invasion: Control of Asian citrus psyllid, the vector insect

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Vector insects :*Diaphorina citri*

Adaptation via altered crops and cropping systems

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- **Alter crop species to those having higher tolerance to water and heat stresses**
  - ･Change C3 crop species with C4 species
- **Adopt cropping systems adaptable to global climate change**
  - ･From mono-crop to double crops to increase production where water is available
  - ･From double-crops of rice to upland-lowland rotations to save water and suppress insect and disease damages

Adaptation via creation of innovative genotypes and technologies

- ■ **Creation of highly resistant genotypes to abiotic and biotic stresses by conventional and maker-assisted breeding and gene transformation technologies**
- ■ **Creation of high yielding genotypes**
  - ・**Increased crop productivity under favorable conditions for food security**
  - ・**Do high-yielding crop genotypes under favorable conditions necessarily perform poor yield under adverse conditions?**
- ■ **Development of early warning and decision support systems for minimizing damages from drought, heat wave, flood, pest and disease.**

Adaptation via cultivar creation: Current status in the development of biotic-stress resistant rice genotypes

Disease and insect	Stage of cultivar development: Diversity study for resistance	Germplasm or breeding materials	Marker assisted selection using DNA markers	Cultivar (conventional breeding)	Multiline variety or combined cultivation	Genetic transformation	References
Tungro	○	○	◎	◎ (IR lines since IR20)	×	△	
Stripe Virus	○	○	◎ (*Stvb-i, Stva, Stvb*)	◎ (Aichinohikari SBL, Koshihikari-aichi SBL Japan)	×	△	Hayano-Saito et al. (2000)
Bacterial leaf blight	○	○	◎ (*Xa3, 4,5,7,13,21*)	◎ (IR lines since IR20)	×	◎ (Xa21) △ (Xa1)	IRRI web Song et al. (1995) Yoshimura et al. (1998)
Blast	○	○	◎ (*Pib, Pb1, Pita, Piz, Pik* alleles)	◎ (IR lines since IR20)	◎ (Koshihikari BL, Japan)	△	Ando (2006); Wang et al. (1999); Qu et al. (2006); IRRI-Japan collaborative
Sheath blight	Not enough	Not enough	△	×	×	△	Sato et al. (2004)
Rice stem borer	Not enough	Not enough		○		◎ (Bt, CpTI)	Lei (2004) Huang et al. (2005)
Brown plant hopper	○	○	○	◎ (IR lines since IR26)	×	×	Hirabayashi (2006)
Green rice leafhopper	○	○	○ (*Grh1, 2, 3, 4*)	◎ (IR lines since IR5)	○	×	

◎: Released or ready for release, ○: Promising line/method developed,
△: Promising line/method not yet obtained, ×: No positive result or not yet tackled

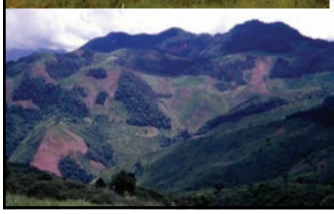
Adaptation via cultivar creation: Current status in the development of abiotic-stress resistant rice genotypes

Abioic stress	Stage of cultivar development: Diversity study for resistance	Germplasm or breeding materials	Recent cultivars by conventional breeding	Marker assisted selection using DNA	Cultivar by marker assisted breeding	Genetic transformation	References
Drought stress	○	○	NEICA1～18（WQRDA) Shusk Samrat (India) Hitachihatamoti (Japan)	△	×	△ ・DREB ・SNAC ・ostA, ostB ・P5CS ・CDPK	Ito et al.(2006); Hu et al.(2006) Grag et al. (2002)
Salt stress	○	○	PSCRc48 (Hagonoy), PSBRc50（Bicol), PSBRc84 (Sipocot),PSBRc86(Matnog), PSBRc88 (Naga), IRRI CSR21, CSR23, CSR28 (IRRI) →alkaline tolerant	○*Saltol*	×	△ ・DREB ・SNAC ・HTK1 (OsHTK1,8) ・AtNHX1 ・P5CS ・CodA ・CDPK	Ren et al. (2005) IRRI web Gregorio et al. (2002)
Submergence	○	○	Sudhi r(India) Prachinburi2 (Thailand)	◎*Sub1*	○ IR64+*Sub1*	△・*Sub1*	Xu et al.(2006) Fukao et al. (2006) IRRI web
Cold stress	○	○	Hexi34-36 (JIRCAS-China) Hitomebore Nanatsuboshi Norin-PL8, PL11 (Japan)	○	×	△ ・GST ・CodA ・DREB	Kuroki et al. (2007)

◎: Released or ready for release, ○: Promising line/method developed,
△: Promising line/method not yet obtained, ×: No positive result or not yet tackled

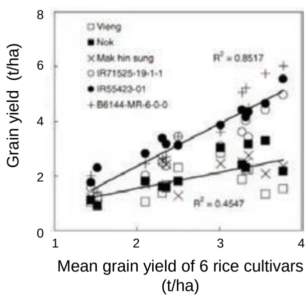
Adaptation via new genotype: A case study on slash-and-burn rice system in Laos





Do high-yielding crop genotypes under favorable conditions necessarily perform poor yield under adverse conditions?

Rice yield responses to soil fertility under slash-and-burn systems in Laos

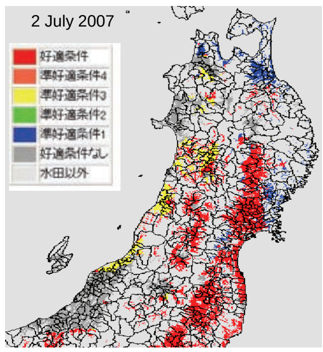


Improved cultivars

Traditional cultivars

Relationship between mean grain yield of 6 rice cultivars and grain yield of each cultivar in 12 environments (three locations × four fertilizer treatments) in Luang Prabang province, Laos (Saito et al, 2006)

Early warning system for cool temperature and blast damages of rice for Tohoku district, operating by NARO



Red regions indicate the conditions favorable for blast infection.

Blast Prediction

BLASTAM indicates when favorable conditions for leaf blast infection appear between tillering and heading stage.

↓

BLASTAM information helps farmers make decisions when to start applying fungicides, and whether they should repeat applications.

Hazard map for inundation area due to storm surge by typhoons in a costal region in Japan

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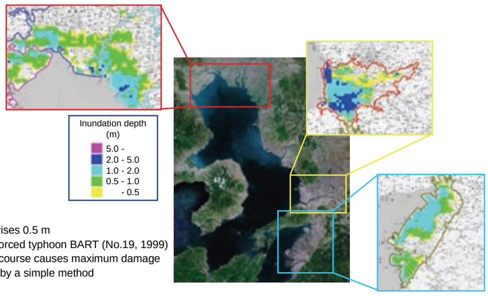

Case
- Sea level rises 0.5 m
- 15 % reinforced typhoon BART (No.19, 1999)
- Paths the course causes maximum damage
- Estimated by a simple method

Distribution of the inundation area due to a storm surge caused by the typhoon reinforced by Global warming

沿岸域の農地では，地球温暖化の影響が早期に現れ，深刻な被害が予想されている．この図は，温暖化後の有明海沿岸における高潮による浸水域の分布を示している．有明海沿岸域では，干拓により造成された農地が多く，詳細なシミュレーションによる被害予測が重要である．

The influence of Global warming appears at the early stage, and serious damage is expected in the coastal farmlands. This figure shows the distribution of the inundation area in the coastal area of the Ariake Sea after Global warming. More detailed estimation of damage by the simulation is important in this area because there are a lot of low-land farmlands that had been constructed by the land reclamation projects.

Adaptation via infrastructure development

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- **Water control**
  - **Water reservoirs, irrigation and drainage channels**
  - **Ring dikes to protect farm land from flood**
  - **Efficient field-water control systems such as underground irrigation and drainage system**
- **Coastal area protection from seashore recession and sea-water intrusion**
  - **Mangrove plantation**
  - **Tidal-wave protection dikes**
- **Soil-erosion protection**
  - **Contour terrace with hedge-row plants**
  - **Terrace channels**

Ring dike to protect farmland from floods in a river delta in Japan

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Ring dike to protect farm land from flood

出典　自然の中の人間シリーズ　地形が育む農業　農文教、片山秀策著

Infrastructural adaptation: Tidal wave protection dike

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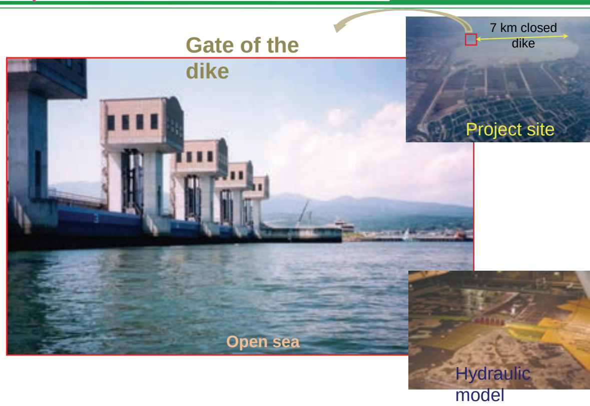

Infrastructural adaptation: Terrace channel to protect soil erosion

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Terrace channel collects runoff from the inter-terrace area in a farmland and conveys it along the contour line across the slope to a collection canal. The collection canal transports downslope the runoff into a drainage channel or a natural river.

Adaptation via social correspondence: Regional, national and international

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- **Consensus and policies for better use of water and other regional resources for reducing risks and increasing productivity**
- **Policies for infrastructure and technology development for agricultural adaptation**
- **Education and capacity building for better adaptation**
- **Increased accessibility to information and technologies for adaptation**
- **Policies for food stocks and trade for food security**

Integrated adaptation or adaptation as an agro-ecosystem

■ To minimize/maximize negative/positive effects of global climate change on agriculture and foods by integration of the adaptation measures which are available under given conditions

・Altered genotypes and cropping seasons

・Adaptive resource management

・Altered crops and cropping systems

・Innovative genotypes and technologies

・Infrastructure development

・Social adaptation

Adaptation opportunities to global climate change in agriculture in Asia-Pacific

Conclusions

■ Predicted global climate change will give enormous impacts on agriculture in Asia-Pacific. Without adequate adaptation to climate change, food insecurity and loss of livelihood are likely to be further exacerbated in Asia.

■ There are many opportunities for adaptation of agriculture in Asia-Pacific to global climate change: altered genotypes, cropping seasons and systems; better management of resources, pest and diseases; infrastructure development; and social correspondence.

■ Creation of crop and livestock genotypes with superior ability both in yield potential and biotic- and abiotic-stress resistance, and management technologies for efficient resource use with minimizing production risks needs to be accelerated to cope with ongoing global climate change and sustain food security and livelihoods in Asia-Pacific.

■ The specifically needed is information system development for,
・Monitor and prediction of climate effects on agro-ecosystems
・Agricultural hazard maps
・Early warning to biotic and abiotic stresses
・Decision support for adaptive management.

Adaptation Opportunities to Global Climate Change in Agriculture in Asia-Pacific

Thank you.

ご静聴に感謝いたします。