ICA-RUS REPORT 2013

Redefining the Climate Change Issue from a Risk Management Perspective

ICA-RUS
Integrated Climate Assessment - Risks, Uncertainties and Society

A Comprehensive Research on the Development of Global Climate
Risk Management Strategies
S-10 Strategic Research Project

Environmental Research and Technology Development Fund of the
Ministry of the Environment, Japan

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Preface

The Icarus of Greek myth attempted to fly across the sea borne on wings made from feathers held together by wax in order to escape the Labyrinth of the Minotaur with his father Daedalus. As we all know, though, he flew too high – the heat of the sun melted the wax, and he plummeted to earth as the feathers came away. What is perhaps less well known, however, is that Icarus also faced the risk of crashing if he flew too low, as the feathers would have absorbed the spray from the sea and become too heavy to fly. He thus faced a risk trade-off in that he may have fallen if he flew too high or too low.

This is similar to the situation now faced by humankind with regard to climate change. The trade-off in this case is that while sitting back and doing nothing to tackle the problem could increase the risk of adverse impacts, acting too drastically creates social, economic, and technological risks. In tackling climate change, it is not obvious which risks should be taken and to what extent. This is because, firstly, considerable uncertainties are associated with the risks on both sides of the equation, and, secondly, determining which risks are acceptable and to what extent enters the realm of value judgment.

In order to delineate the structure of risks associated with climate change (including uncertainties and trade-offs) and present society with a set of risk options for decision making, the "Comprehensive Study to Develop a Global Climate Change Risks Management Strategy" was launched as an S-10 Strategic Research Project funded by the Environmental Research and Technology Development Fund of the Ministry of the Environment of Japan. This involves 44 participants and approximately 40 collaborators from 15 bodies in Japan, and has an annual budget of approximately JPY 300 million and a research term of five years. While it is known as "Integrated Climate Assessment - Risks, Uncertainties and Society," or ICA-RUS for short, there is no intention of suggesting a tragic ending of the kind suffered by Icarus. Avoiding any preconceptions or pre-conclusions, our aim is to help contemporary society decide for itself how high to fly in the face of the complex risk trade-off now faced.

The present report is the first in what will be an annual series that presents selected outputs of the project for an interested readership, and the main focus this year has been placed on framing the issues faced and describing the findings of a qualitative analysis regarding the architecture of the problem.

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1 ICA-RUS in overview

1.1 Background and purpose of ICA-RUS

International negotiations taking place within the context of the United Nations Framework Convention on Climate Change (UNFCCC) have resulted in a recognition of the need to substantially reduce greenhouse gas emissions in order to keep the global average temperature rise to the target of 2°C or below from pre-industrial levels (referred to below as the "2°C target") being incorporated in the Cancun Agreements adopted at COP16 in 2010. At COP17 the following year, agreement was reached on a roadmap leading to the adoption in 2015 and implementation from 2020 of a legal framework that will be applicable to all parties. At the same time, it was decided to conduct a review of long-term targets between 2013 and 2015. Taking into consideration the views of small island developing states in particular, this review will also look at the possibility of adopting a stricter target of keeping the temperature rise to within 1.5°C.

Owing to the gap between the reductions in the greenhouse gas (GHG) emissions that will be required to achieve the 2°C target and individual countries' GHG emission targets, however, there appears no prospect of the reductions necessary to achieve this target being made. The World Bank (2012) reports that even with the current mitigation commitments and pledges fully implemented, there is roughly a 20 percent likelihood of exceeding 4°C by 2100.

As is evident from how this is expressed probabilistically, proper attention must be paid to the fact that there exists scientific uncertainty concerning the relationship between GHG emissions and temperature rise. Moreover, as well as similar uncertainty over assessments of the impacts of climate change and response options against it, the spillover effects of such response options (e.g. the large-scale use of biofuels resulting in competition between the production of food crops and biomass crops) are also not yet properly understood.

Even the question of whether or not the temperature increase is allowed to exceed 2°C cannot be answered on scientific grounds alone, as it also involves value judgments concerning what adverse impacts are unacceptable.

Thus while we do not contest the adoption of the 2°C target *per se* in current international negotiations, we believe that the question of setting targets to address climate change should be redefined as one of decision-making under uncertainty and that the issue be revisited in depth from a risk management perspective.

Risk management's definition is considered in detail in **2. ICA-RUS's research premises.** Suffice it to say that at this point this project is informed in particular by risk management's 1) explicit consideration of uncertainty, 2) use of the best available scientific knowledge, and 3) flexible revision in response to future changes in conditions. Learning from the Great East Japan Earthquake on March 11, 2011, and ensuing nuclear crisis, emphasis is also placed on 4) paying attention to all kinds of possibilities and 5) inclusion of social decision-making processes. (While "climate risk management" is often used to refer to the discussion of regional-scale adaptation, we should like to reemphasize that the aim here is to consider global-scale targets for response options to address climate change.)

Studies of global-scale climate change targets that adopt a risk management approach include those of the United Kingdom's Committee on Climate Change (2008), which recommends that the objective should be to limit our central expectation of temperature rise to 2°C, or as close as possible, and reducing the risk of extremely dangerous climate change to very low levels (e.g. less than a 1% chance of 4°C temperature rise), and the studies of Mabey *et al*. (2011), who propose aiming to mitigate to stay below 2°C, building and budgeting for resilience to 3°C-4°C and making a contingency plan for capability to respond to 5°C-7°C. However, research of this kind is still somewhat limited.

This project will therefore comprehensively examine the risks posed by the various impacts of climate change, an array of risk management options (including mitigation, adaptation, and geoengineering[1]), the interrelationships with water, food, and other issues, public perception of the risks, and value judgments. Taking all these factors into account, it will then consider a global climate risk management strategy. This will then be put to society with the aim of contributing to the building of international consensus and assisting policymaking in Japan.

In addition, progress has been made in recent years on reorganizing international research programs on sustainability, and an interdisciplinary initiative called "Future Earth" is to be launched. This recognizes that human activities on earth have begun to transcend the boundaries of safe operating space in several dimensions and seeks to produce a vision of a sustainable future through collaboration between science and society. ICA-RUS in some respects echoes these movements.

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1) Regarding geoengineering, see **Column 4: What is geoengineering?** on p. 13.

1.2 Structure of ICA-RUS

ICA-RUS consists of five themes of research that need to be pursued in order to produce global climate risk management strategies (**Table 1**).

Table 1 Overview of research themes

THEME 1 Synthesis of global climate risk management strategies (Leader: Kiyoshi Takahashi - Senior Researcher, National Institute for Environmental Studies)
● Proposal of risk management strategy for rationally determining the course of comprehensive response options against climate change (including climate stabilization targets). (Climate stabilization targets themselves will not be proposed).
THEME 2 Optimization of land, water and ecosystem uses for climate risk management (Leader: Yoshiki Yamagata - Principal Researcher, National Institute for Environmental Studies)
● Presentation of results of simulations to quantitatively assess (including uncertainties) the interactions of climate change impacts and response options against climate change with water, energy, food, ecosystems, etc., and analysis of co-benefits and trade-offs based on these results.
THEME 3 Identification and analysis of critical climate risks (Leader: Taikan Oki - Professor, The University of Tokyo)
● Comprehensive assessment (including uncertainties) of factors including levels of temperature rises at which the potential impacts of climate change that humankind should avoidbecome apparent, the scale and nature of their adverse impacts, and analysis of the risks at each climate change level.
THEME 4 Evaluation of climate risk management options under technological, social and economic uncertainties (Leader: Shunsuke Mori - Professor, Tokyo University of Science)
● Method and model development for the comprehensive assessment (factoring in uncertainties) of the potentials and costs of various options to deal with climate changes (including mitigation, adaptation, and geoengineering), analysis of their outcomes and rational ways of combining response options.
THEME 5 Interactions between scientific and social rationalities in climate risk management (Leader: Yuko Fujigaki - Professor, The University of Tokyo)
● Analysis of distribution of public opinion concerning the various value judgments impacting on the determination of climate stabilization targets, etc. ● Analysis of the social factors of public perceptions of climate change risks and their key attributes from scientific and risk communication perspectives.

For further details of these themes and their sub-themes, see the ICA-RUS website (http://www.nies.go.jp/ica-rus/en/index.html).

In order for ICA-RUS to fulfill its objective of producing a comprehensive risk management strategy, mutual collaboration in areas such as information and data sharing across the themes, as shown in Figure 1, is crucial. The ICA-RUS Climate Risk Management Strategy Synthesis Meeting ("Synthesis Meeting") was established to facilitate such inter-theme collaboration and general discussion on the project as a whole, and is held once a month to bring together some of ICA-RUS's participants and collaborators.

Cross-theme task groups are also being established to consider specific topics spanning more than one theme that deserve particular attention. Three such groups were established in fiscal 2012: 1) the Concepts Task Group set up to define concepts and establish a framework for deliberation required for the ICA-RUS project; 2) the Sequential Decision-Making Task Group assigned with considering means of successively revising decisions in light of information garnered with the passage of time; and 3) the Scenarios Task Group, whose mission is to consider the socioeconomic scenarios to be employed by ICA-RUS. The section in this report entitled **2. ICA-RUS's research premises** is based on the products of the Concepts Task Group. The products of other task groups will be included in reports from next year onward.

1.3 ICA-RUS principles

ICA-RUS's research is informed by three key principles: neutrality, comprehensiveness, and transparency.

"Neutrality" means that ICA-RUS should strive as far as possible to avoid bias toward particular value judgments or political standpoints. ICA-RUS's position is that the role of science in risk management is to develop and present to society frameworks of judgment, with the actual judgments themselves being left open to society. To ensure that no specific value judgments are implicit in the premises used at any stage of the research process, effort is made to ensure participants can check one another's work through mechanisms such as the Synthesis Meeting. Although ICA-RUS is funded by the Environment Research and Technology Development Fund of the Ministry of the Environment of Japan, the content and conclusions of its research are understood to be independent of the influence of the ministry's administrative position.

"Comprehensiveness" is essential given the principle that risk management should be based on the best available scientific knowledge. Research that lacks comprehensiveness in scope can at the same time produce biased findings that threaten the neutrality described above, and so

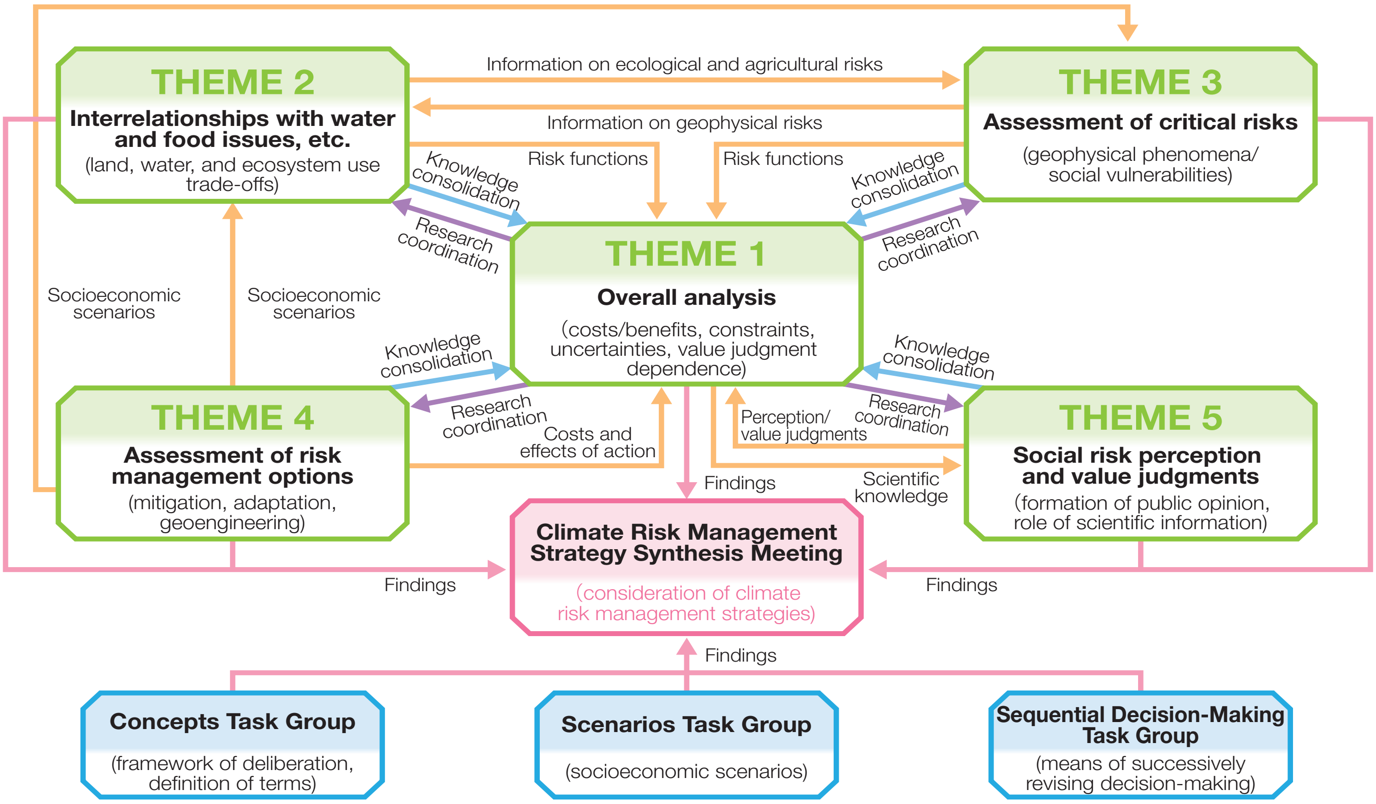


Figure 1 Information sharing across themes

must be avoided. ICA-RUS therefore endeavors to ensure comprehensiveness by paying attention to surveying existing knowledge at the same time as conducting its own analyses of a more limited range of topics. A particular focus of such work in the first year, fiscal 2012, was on developing the inventories and identifying the points at issue described in **3. Development of comprehensive inventories of climate change risks and identification of points at issue** in this report.

"Transparency" is a prerequisite to acquire society's trust in ICA-RUS's findings. Efforts are therefore made to publish as far as possible the minutes of the Synthesis Meetings and other materials and data on ICA-RUS's activities on its website. Contributing to neutrality and comprehensiveness as well as transparency, opportunities are also provided for dialogue with stakeholders to ensure that their views on, for example, possible important omissions or biases in ICA-RUS research, are heard.

1.4 ICA-RUS's remit and distinctiveness

A variety of frameworks are expected to be put forward by a wide range of bodies, both within and beyond the United Nations' forums for negotiation, in the lead up to an agreement being reached on a new framework by 2015 under the UNFCCC. ICA-RUS, however, does not intend to make any detailed proposals regarding such an international framework. This is because doing so requires consideration of international political realities such as various national interests and the potential for agreement, all of which are beyond ICA-RUS's remit. While various discussions may take place in the course of the review of long-term targets between 2013 and 2015, ICA-RUS will not be proposing any specific long-term targets either. The reason for this is that value judgments will need to be made by society in order to select specific long-term targets.

ICA-RUS's remit is instead to look at each of the international frameworks and long-term targets that are going to emerge from these various bodies, along with other possibilities yet to be put forward, from a risk management perspective in order to identify the kinds of decision-making that they each imply and to diagnose their scientific and social rationality. “Scientific rationality” here refers to the scientific validity of the grounds and logical reasoning that underlie decision-making, while “social rationality” refers to the appropriate reflection of value judgments by society following a decision-making process appropriate to its members.

ICA-RUS’s distinctiveness lies in that through its investigation of the scientific rationality of decision-making, it delineates the risk trade-off structure having first comprehensively identified the risks and opportunities generated by response options against climate change as spillover effects, as well as the risks of adverse impacts of climate change and costs of response options extensively studied in past studies. Another extremely distinctive feature of ICA-RUS’s approach is that it provides materials that are helpful in the examination of the social rationality of decision-making through which knowledge can be gained regarding the risk perception and value judgments exhibited by ordinary citizens once the risk trade-off is properly understood. ICA-RUS is further distinguished by the fact that neutrality and transparency are ensured by obtaining feedback from various kinds of stakeholders regarding the comprehensiveness of its framework of study and the risks and opportunities that should be taken into account.

The strategy adopted by ICA-RUS is to leave comprehensive analysis of international political realities to other research bodies or practitioners in Japan or abroad, and instead to contribute to actual decision-making in forums for international negotiation and so forth by providing them with the results of its research.

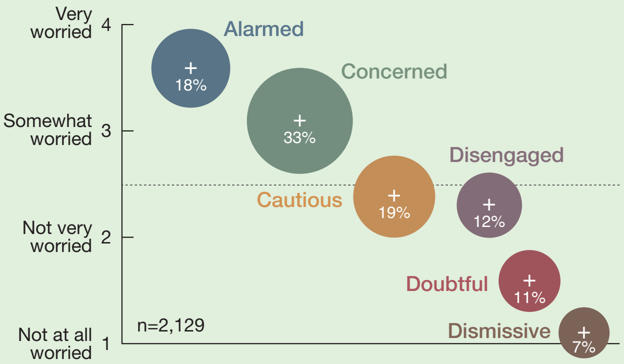
COLUMN 1 Value judgments on climate change trade-offs

Climate change and options against it entail various trade-offs. The issue of to what extent present-day society should bear the cost of mitigation to limit climate change 200 years hence, for example, involves trade-offs between the interests of current and future generations, and it is intrinsically impossible to objectively find a single solution to such problems. People’s approach to climate change, therefore, depends on value judgments. Identifying important trade-off relationships to decision-makers offers one practical answer to the question of what uncertainties and trade-offs should be clarified and delineated by the science of climate change.

The trade-offs extending across the spatial, temporal, and social dimensions that people and society face in regard to global environmental issues may be thought of in terms of the four core “survival dilemmas” of human society identified by Vlek and Keren (1992), namely: present versus future, anticipated loss versus anticipated gain, region versus other regions, and individual versus collective. Given that these dilemmas are internal to society, there remains scope for consideration of a further dilemma, that of the social versus the extra-social (such as natural ecosystems).

As no objectively optimal solution to these dilemmas exists, decisions have to be guided by value judgments. So what mechanisms may be posited to inform people’s value judgments, and specifically judgments on risk trade-offs involving major uncertainties? Douglas *et al*. argue that human risk perception is socially as well as individually constituted, and that this social element varies according to social outlook (hierarchical, egalitarian, individualist, or fatalist) (Douglas, 1970, 1978; Douglas and Wildavsky, 1982). Although considerable objections have been raised against this argument, research findings have begun to emerge that support it in relation to climate change. Social research on 1,000 individuals in the United States conducted by Malka *et al*. (2009), for example, shows that political attitude correlates with attitude to action on climate change. Similarly, the “Six Americas” survey of 1,000 citizens conducted annually since 2007 divides citizens’ attitudes toward climate change into six types, and it has been shown that these are related to political affiliation and the categories identified by Douglas *et al*. (Maibach *et al*., 2009, 2011).

Decisions on the risk trade-offs associated with climate change thus depend to a considerable extent on basic social outlook – in other words, what goals are shared by society and what obligations its members are considered to have in the first place. It is therefore important that the uncertainties of significance and appropriate methods of presenting them be identified on the basis of these main types of social outlook.



Source: Compiled with additions from Maibach *et al.* (2009)

Figure C1.1 Six types of attitude to climate change in the U.S.

2 ICA-RUS's research premises

2.1 Need for and significance of examination of premises

In order for the climate change risk management strategy considered and put forward by ICA-RUS to be able to contribute to actual decision-making in the form of the development of international consensus and domestic policymaking, the framework for investigation of this risk management strategy must itself be made quite explicit further to extensive discussion, and will also need to be repeatedly revised according to changes in conditions (such as available knowledge and countermeasures). By "framework of investigation" is here broadly meant the premises of the study, including the types and scopes of risks and response options taken against them to be analyzed (and how they are selected), the selection of risk assessment techniques, procedure of investigation of management strategy, and arrangements for reflecting the needs of stakeholders and decision-making authorities. Relatedly, the development of terminology is also included within the framework of investigation. This is an important prerequisite to ensure that discussion among the ICA-RUS participants involved in exploring management strategy, along with stakeholders and decision-making authorities with views on the shape of the framework of investigation and in a position to utilize management strategy, is not hindered by misunderstandings over the usage of terms.

If research proceeds and a risk management strategy is developed in the absence of discussion or agreement on the framework of investigation, decision-making authorities will be unable to properly assess the premises of the management strategy with which they are presented and may as a result be unable to use it as a basis for decision. An even more undesirable outcome might be that decision-making authorities adopt the management strategy presented uncritically and indifferently to the premises of the research (especially its neutrality and comprehensiveness), resulting in the failure of risk management.

Ideally, a framework of investigation should be intensively discussed, research undertaken, a management strategy presented, and the framework of investigation revised, and then the process repeated. As the priority must be to produce results within a limited five-year research period, however, discussion of the framework of investigation and pursuit of individual studies must proceed side by side. Discussion regarding the framework of investigation commenced in fiscal 2012 with definitions of key terms and consideration of the applicability of existing generic frameworks. These two tasks are summarized below.

2.2 Current framework of investigation

Definitions of key terms

The summary for policymakers of the Synthesis Report of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) spells out the message that "responding to climate change involves an iterative risk management process that includes both mitigation and adaptation taking into account climate change damages, co-benefits, sustainability, equity, and attitudes to risk" (IPCC, 2007a). However, studies that treat the problem of climate change as a question of risk management are still not widespread, and the terms used are also variously defined. It was therefore decided that the definitions of key terms used by ICA-RUS should be documented and shared to facilitate communication both within and without ICA-RUS. As ICA-RUS had no intention of creating new definitions, however, the approach adopted was to use the definitions established by the International Risk Governance Council (IRGC) for risk management-related terms (IRGC, 2005), and the definitions given in the IPCC's latest report, entitled "Special Report: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC-SREX)" (IPCC, 2012a) for terms relating to climate change. Excerpts from these are included below. (For reasons of space, only risk management-related terms are given in this report. For details of climate change-related terms, see the summary materials of the IPCC-SREX)

■ Risk

An uncertain consequence of an event or an activity with respect to something that humans value. Such consequences can be positive or negative, depending on the values that people associate with them.

■ Risk Appraisal

The process of bringing together all knowledge elements necessary for risk characterisation, evaluation and management. This includes not just the results of (scientific) risk assessment but also information about risk perceptions and economic and social implications of the risk consequences.

■ Risk Assessment

The task of identifying and exploring, preferably in quantified terms, the types, intensities and likelihood of the (normally undesired) consequences related to a risk. Risk assessment comprises hazard identification and estimation, exposure and vulnerability assessment and risk estimation.

Risk Characterisation

The process of determining the evidence based elements necessary for making judgements on the tolerability or acceptability of a risk.

Risk Evaluation

The process of determining the value-based components of making a judgement on risk. This includes risk-benefit balancing or incorporation of quality of life implications and may also involve looking at such issues as the potential for social mobilisation or at pre-risk issues such as choice of technology and the social need of the particular operation giving rise to the risk.

Risk Governance

Includes the totality of actors, rules, conventions, processes, and mechanisms concerned with how relevant risk information is collected, analysed and communicated and management decisions are taken. Encompassing the combined risk-relevant decisions and actions of both governmental and private actors, risk governance is of particular importance in, but not restricted to, situations where there is no single authority to take a binding risk management decision but where instead the nature of the risk requires the collaboration and co-ordination between a range of different stakeholders. Risk governance however not only includes a multifaceted, multi-actor risk process but also calls for the consideration of contextual factors such as institutional arrangements (e.g. the regulatory and legal framework that determines the relationship, roles and responsibilities of the actors and co-ordination mechanisms such as markets, incentives or self-imposed norms) and political culture including different perceptions of risk.

Risk Management

The creation and evaluation of options for initiating or changing human activities or (natural and artificial) structures with the objective of increasing the net benefit to human society and preventing harm to humans and what they value; and the implementation of chosen options and the monitoring of their effectiveness.

Stakeholder

Socially organized groups who are, or are expected to be, affected by the outcome of the event or the activity from which the risk originates and/or by the risk management options taken to counter the risk.

Usages and definitions of terms are considered by ICA-RUS as the need arises, to confirm and ensure that participants all share the same understanding of the usage of terms which require particular care. Among the processes encompassed by the framework of investigation, for example, we consider it important to consciously distinguish between processes for organizing knowledge that eliminate value judgments and processes that involve value judgments. Thus "risk assessment" is an example of the former type of process, while "risk evaluation" belongs to the latter type.

Framework and procedure of investigation

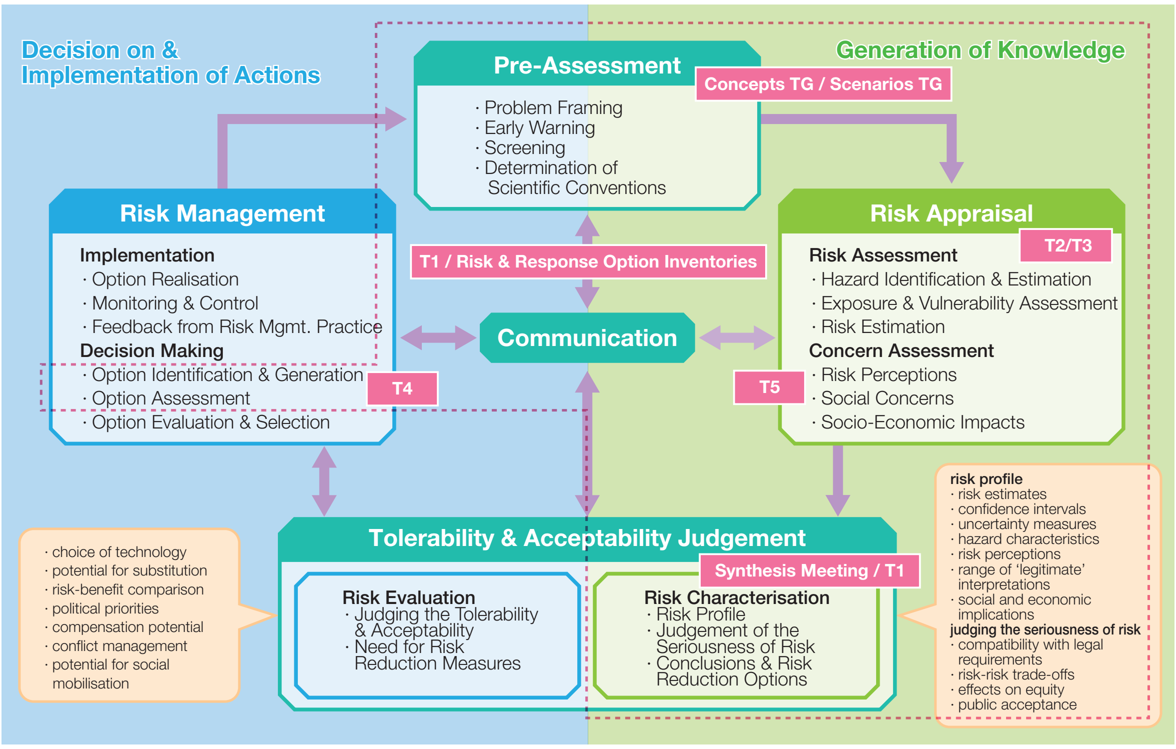
ICA-RUS does not include taking response options against climate change (mitigation or adaptation) or monitoring them within the scope of its activity, and in this sense it does not aim to practice risk management processes in their entirety. At the same time, its task is not to perform simply the risks assessment component of an externally given framework of risk management. Starting from the position that a framework of global climate change risk management has yet to be definitively proposed, ICA-RUS's mission is to investigate and suggest what form such a framework should take, and at the same time to practice risk assessment where it is decided that risk management should be practiced following the proposed framework.

Although there exist virtually no instances of climate change risk management being considered on a global scale, risk management concepts themselves have been widely applied in relation to chemicals, disasters, ecosystems, business, and so on, and generic frameworks have been put forward. In fiscal 2012, therefore, a study was made of the potential for application of an existing generic risk management framework to the realm of global climate risk management being addressed by ICA-RUS.

As a first step, a study was made of the ISO 31000 risk management framework, whose utility in the assessment and implementation of adaptation options has been noted in the literature. During the process of investigation, however, it was observed that ISO 31000 framework's supposition on the presence of a small organization (such as a business), a single strong organizational leader, and risk managers to whom authority is delegated makes its application to ICA-RUS problematic. If it were a question of regional climate change risk management by means of adaptation, a risk management framework that identified an organizational leader or other head as a single decision-making authority could be applied. In the case of global climate change management of the kind envisaged by ICA-RUS, however, there would be no self-evident decision-making authority; instead, multiple decision-making authorities with different values would have to be anticipated. Global climate change risk management involving multiple decision-making authorities is more appropriately considered as a form of governance that allows mutual accommodation of interests and implementation of agreements and methods of management.

The IRGC's risk governance framework was therefore considered and ultimately adopted, as this provides explicitly for governance. In conjunction with this, it was decided, as a rule, to use the IRGC's definitions of the terms described above. **Figure 2** locates ICA-RUS's composite modules (themes and task groups) within the IRGC framework. The processes enclosed in the red box constitute ICA-RUS's scope of activity. As ICA-RUS will not itself engage in decision-making or the implementation of measures pertaining to risk management, as previously noted, its remit largely consists of the assessment sphere (generation of knowledge) shown on the right side of the figure. The identification and assessment of options that are the main concerns of Theme 4, on the other hand, are located within the management sphere on the left side of the IRGC's framework. ICA-RUS, however, regards them rather as comprising part of the expanded risk appraisal to be undertaken in parallel with risk assessment and concern assessment.

Every process can be expected to reflect stakeholders' perceptions of the risks and values in risk assessment paired with risk management through communication with them, and the risk management strategy arrived at by following this procedure should as a result be fit for actual use in risk management practice. For example, while the development of inventories of risks and response options and identification of points at issue described in **3. Development of comprehensive inventories of climate change risks and identification of points at issue** in this report could be considered preliminary screening work under pre-assessment, communication with stakeholders will be incorporated when screening is conducted (judgment on the need for quantitative and qualitative risk estimation by ICA-RUS). ICA-RUS aims to engage in communication and consultation by means including the publication of materials such as ICA-RUS reports and the minutes of Synthesis Meetings, the questionnaires conducted for Theme 1 to coincide with publication of ICA-RUS reports and meetings for dialogue with stakeholders, and the risk perception research conducted for Theme 5.



Source: Compiled with additions from IRGC (2005).

Figure 2 Relationship between IRGC framework and ICA-RUS's component modules

Development of comprehensive inventories of climate change risks and identification of points at issue

3

3.1 Development of inventories and identification of points at issue through review of the literature

As noted in **1. ICA-RUS in overview**, one of ICA-RUS's distinguishing features is its engagement in comprehensive research making use of the best available scientific knowledge. In the first year especially, therefore, focus was placed on gathering and organizing scientific knowledge by conducting various surveys of the literature, the findings of which enabled us to identify the main points at issue concerning risk and response option inventories and research on each theme.

The risk inventory is a comprehensive inventory of climate change risks, and inventorying work in 2012 consisted of identifying the individual forms of damage caused by climate change. The response option inventories bring together the spillover risks and opportunities of response options against climate change based on a comprehensive listing of response options in four categories: mitigation options, socioeconomic options, adaptation options, and geoengineering options. These inventories of risks and response options are used to confirm the comprehensiveness of research on climate change risk management strategy and as a means of facilitating information sharing between researchers working on different themes. These inventories are also seen as having a part to play in assisting communication beyond ICA-RUS by eliciting comment from outside parties, such as readers of this report, who can use them to check for omissions of risks and so forth. The inventories of risks and response options and points at issue described in this report will be continuously revised and updated as necessary as ICA-RUS's research progresses. We plan to publish the latest editions of these inventories on the ICA-RUS website (http://www.nies.go.jp/ica-rus/inventory.html in Japanese), and opinions and comments received from outside parties on these materials will be used to produce more useful data (both within ICA-RUS and beyond).

As each inventory is improved, they will be compared and contrasted to draw out concerns and correlations so that they can be used not simply to confirm comprehensiveness, but also to help identify the trade-offs between different risk categories and the relations between risks and response options in research on climate change risk management strategy.

3.2 Development of risk inventory

Climate change poses various risks on human life, ecosystems, and biodiversity. In 2012, a comprehensive inventory of such risks was developed through surveys of the literature. The purpose of this was to assist research on the nature and scale of damage in each area, the effects of response options against such damage, and other related concerns.

The risk inventory was drawn up by identifying the impacts in each area in which it appears that "damage should be avoided" in light of various value judgments in society, and we began by broadly dividing risks into three main (first-level) categories: human life, ecosystems and biodiversity, and geophysical systems. Human life was then divided into six second-level categories: energy, safety, health, economy and services, food, and freshwater resources, which were in turn broken down into even more detailed (third-level) categories where necessary. Similarly, the ecosystems and biodiversity category was divided into northern forest, temperate forest, tropical forest, grasslands and desert, low-lying land and shore regions, uplands, inland water, oceans, fauna, insects, and microorganisms. Risks were categorized based on the classification of protection categories described in LIME2 (Itsubo and Inaba, 2010).

When possible, ICA-RUS takes diverse value judgments into account in its research, although it must be borne in mind that each category of damage implies the value judgment "this damage should be avoided." Thus while the risks associated with "ecosystems and biodiversity" and "geophysical systems" may entail the value judgment that it is sufficient to avoid the negative impacts on human life arising from them, they are shown alongside "human life" to allow for the value judgment that the impacts on those systems should themselves be avoided. (Note that ICA-RUS itself avoids considering any of these value judgments of greater priority than another.)

Next, individual climate change risks were identified. While climate change risks are interpretable in numerous ways, the risk inventory described here was developed by identifying the individual forms of damage that could cause damage in a specific first-, second-, or third-level category in light of a broad and diverse range of value judgments in society regarding potential future damage and dangers, and physical phenomena arising from nature or human activity capable of causing individual forms of damage were excluded.

To illustrate this, below we take an example from the abridged version of the developed risk inventory shown in **Table 2**. Next to "northern forest" (third-level category) under "ecosystems and biodiversity" (first-level category), "reduction

COLUMN 2 Tipping elements

"Tipping elements" are the elements of climate change that have thresholds or "discontinuities" beyond which rapid discontinuous changes with catastrophic consequences may arise. Among the tipping elements identified by Lenton *et al*. (2008) are:

Ⓐ (Loss of) Summer Arctic Sea-Ice ➡
Acceleration of temperature rise, impact on ecosystems
Ⓑ (Melting of) Greenland Ice Sheet ➡ Increase of sea level
Ⓒ (Destabilization and melting of) West Antarctic Ice Sheet ➡
Increase of sea level
Ⓓ (Slowing of) Thermohaline Circulation in the Atlantic Ocean ➡
Regional cooling, sea level changes, movement of
Intertropical Convergence Zone
Ⓔ (Amplification of) El Niño-Southern Oscillation ➡
Droughts in Southeast Asia
Ⓕ (Weakening of cycle of) Indian Summer Monsoon ➡
Decreased rainfall, drying, drought
Ⓖ (Increase in proportion of vegetation in) Sahel/West African
Monsoon region ➡ Wetting
Ⓗ (Decrease in proportion of vegetation in) Amazon rainforest ➡
Loss of biodiversity, decline of rainfall
Ⓘ (Decrease in proportion of vegetation ratio in) Boreal forest ➡
Shift of plant communities

Of these, Ⓐ and Ⓑ are highly likely to reach critical points during the 21st century, and sudden changes may also be observed when Ⓒ to Ⓖ approach their tipping points too. While some changes, such as Ⓐ, Ⓕ, and Ⓖ, may take just a decade to occur, others, such as Ⓑ and Ⓒ, are expected to occur over a period of around three centuries. All, however, are "sudden" on a geophysical timescale.

Tipping elements came into the picture because, given that it is conceivable in the physical science area of climate change research for the climate system to transition from one steady state to another in a comparatively short period in a manner analogous to mathematical bifurcation (of solutions to non-linear equations), researchers felt uncomfortable with emissions, climate change, and expected damage being treated as changing comparatively continuously and smoothly in, for example, the integrated assessment models used to calculate the gains and losses associated with climate change. Tipping elements often appear to imply changes that cannot be reversed once the climate has changed to another stable state, even if the level of climate change is reduced somewhat. However, tipping elements are not necessarily irreversible.

Tipping elements are also sometimes known as "critical phenomena," and there exists the impression that, having occurred, they will give rise to unprecedented catastrophes that spell the end of the world. Assuming one of the items to the right of the arrows in the list above may occur, however, even faster sea level rises and more frequent extreme droughts than conventionally anticipated would not be completely without parallel in the 10,000 year history of humankind.

Instead of seeing tipping elements as simply too terrifying to contemplate, therefore, the aim of Theme 3 of the ICA-RUS project is to estimate what climate changes will have what impacts, on what regions, and to what extent at the time a tipping element occurs. Like disaster prevention education, which is evolving from threat to knowledge to approach, tipping element research could be described as having just reached the knowledge stage.

of soil organic matter and carbon emission due to melting of tundra" is given as one specific example of the kind of damage that may arise. The individual forms of damage that directly harm ecosystems and biodiversity are "reduction of soil organic matter" and "carbon emission." "Melting of tundra" is classified as a physical phenomenon that gives rise to such individual forms of damage, and so is not given its own category as an individual form of damage in the risk inventory. As in this instance, causal relationships are spelled out for some of the individual forms of damage shown in the table to facilitate understanding. Note that although in **Table 2** no more than three individual forms of damage are given for each category, the full version lists more. Additionally, while the risk inventory lists individual forms of damage as described above, the "geophysical system" category is limited to selected "tipping elements[2)]," which represent climate change elements with the potential to give rise to "discontinuous" changes with potentially catastrophic consequences once climate change goes beyond a certain point. Although tipping elements in the geophysical system category were identified in 2012, this does not mean that tipping elements are the only individual forms of damage considered to impact on geophysical systems, and individual forms of damage other than tipping elements may be added in subsequent years.

Climate change risk management strategy needs to be considered drawing on this risk inventory to factor into account the uncertainties surrounding the points that it raises, such as to what extent what impacts can be tolerated, and what is the probability of what impacts occurring on what scale in the event that air temperature increases by a certain number of degrees. Work will continue on the risk inventory to improve it by clarifying causal relationships and adding opportunities as well as damage.

Note that although the individual forms of damage are all listed alongside one another in the risk inventory, it must be remembered that they differ considerably from one another in several respects, including their probability and scale of occurrence, the possible timing of their occurrence, and uncertainty over projections of them. ICA-RUS will therefore analyze and evaluate the distinguishing features of these forms of damage, and will use the findings to inform its research on risk management strategy.

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2) Regarding tipping elements, see **Column 2: Tipping elements** on p. 9.

Table 2 Risk inventory (abridged version)

First-level category	Second-level category	Third-level category	Specific examples of damage
Human life	Energy		Shortage of power station cooling water due to decline of river flow
			Electric power shortages due to damage to hydroelectric plants caused by flooding
			Destabilization of wind power generation due to changes in circulation fields
	Safety		Drowning due to storm surge flooding
			Drowning due to flooding
			Deaths by crushing caused by collapse of homes in landslides
	Health		Malnutrition due to food shortages
			Gastrointestinal diseases due to rise in air temperatures
			Heat-related deaths due to rise in air temperatures
	Economy and services		Flood damage to buildings
			Loss of buildings/houses destroyed or swept away by high tides
			Disruption of transport and community functions by snow
		Forestry	Changes in forest productivity and increased cost of adaptation
			Increased fire damage to planted forests
			Increased damage to planted forests caused by pests and disease
	Food	Food crops Cereals (rice, wheat, soybeans, maize, others) Livestock feed, vegetables, fruit, fruit trees, flowering plants, stem and root vegetables	Decline in cereal yields, production, and quality due to rise in air temperatures, droughts, flooding, etc.
			Change in land suitable for cultivation and growing periods due to rise in air temperatures and changed rainfall patterns, etc.
		Pasture, livestock production	Decline in pasture and livestock production due to rise in air temperatures, drought, flooding, etc.
			Decline in livestock production efficiency due to increase in pest and disease damage
		Wild fisheries, aquaculture	Change in marine yields due to changes in marine fish habitats
			Negative impact on shellfish production due to rise in sea levels in low-lying coastal regions
			Damage to fishery facilities due to extreme phenomena
		Food production in general	Destabilization of food production due to increased frequency of abnormal weather with climate changes
	Freshwater resources	Surface water, groundwater	Change in water-stressed population due to changes in river flow and water intake
			Decline in summer water resources due to melting of snow and ice
			Groundwater depletion in irrigated land in arid and semi-arid areas
		Water quality	Changes in quality of river water
			Changes in salination of groundwater in coastal areas due to sea-level rise
			Deterioration of water quality due to overgrowth of algae, etc. in rivers, wetlands, and reservoirs
Ecosystems and biodiversity		Northern forest	Reduction of soil organic matter and carbon emission due to melting of tundra
			Decrease/decline of tundra ecosystems due to northward movement of northern tree line
			Increase/intensification of forest fires due to drying
		Temperate forest	Increase in severe pest outbreaks due to rise in winter temperatures
			Damage to fauna and flora due to heat waves
			Loss of diversity due to increase in epidemics (chytridiales, etc.)
		Tropical forest	Decline and death of forests due to drying
			Intensification of windfalls and leaf litter due to tropical cyclone
		Grasslands, desert	The shrub invasion of grasslands and decline of biodiversity due to increase in atmospheric CO_2
			Increase in frequency and intensity of fires due to drying
			Increase in wind erosion of soil due to decline of plant cover through drying
		Low-lying land, shore regions	Submergence of low-lying marshland and mangrove forests due to sea level rise
		Uplands	Adverse impact of wintering of plants and animals due to decline of winter snow
		Inland water	Impact on ecosystems of changes in river flow and intake
			Impact on ecosystems of temperature rise and acidification of wetlands
		Oceans	Increase in volume of oxygen-deficient water due to decline of oxygen solubility
			Change in production and dissolution of calcium carbonate due to ocean acidification
			Change in marine biogeography due to rise in water temperature
		Fauna	Decline of migratory bird nesting grounds due to decline in marshlands
			Increase in animal heatstroke due to temperature rise
		Insects	Expansion of pest habitats due to temperature rise
			Increased frequency of major pest outbreaks due to temperature rise
			Decline of beneficial insects due to temperature rise
		Microorganisms	Change in soil microflora and impact on matter cycle due to environmental change
Geophysical systems (tipping elements)			Shrinkage of Greenland ice sheet
			Collapse of West Antarctic ice sheet
			Disappearance of Amazon rainforest

Note: The full version lists more individual forms of damage.

COLUMN 3 Assessing the impacts of climate change on health

Climate change impacts are often expressed in monetary terms. As this makes it possible to calculate the sum of all kinds of impacts—be it the destruction of homes by typhoons or the loss of wheat to drought—the net cost of scenarios for lowering CO_2 emissions, taking into account the resulting reduction in the impact of climate change, can thus be estimated. Although the comprehensive estimation of impacts is difficult in practice, this approach does make their integrated assessment theoretically possible.

But while economics techniques can thus be extremely effective, they also present serious problems. Economically speaking, human life is assigned a lower value in developing countries than in developed countries. Although there may be some validity to this approach in a situation where the aim is to provide compensation for the income that might have been earned had there been no impact, it is debatable whether such an approach is appropriate to assessing the impacts of climate change. Another method of assessment is to concentrate on the impacts on health. In the case of a typhoon, this means calculating the number of people who drown and the number of people who die as a result of contracting cholera from drinking unsanitary water. There are also people who, although they may not die, fall sick or experience worsened health as a result of the typhoon. Thus in the case of an increase in droughts due to climate change, the scale of the impact is assessed by counting not only the number of people who die from malnutrition or commit suicide because they can no longer earn a living from farming, but also the number of those whose growth is stunted by malnutrition or who have to abandon cultivated land and become refugees (also experiencing malnutrition and psychological problems as a consequence).

While deaths can be categorized together whatever their cause, there are several ways of assessing non-fatal conditions. One is through the use of “disability-adjusted life years” (DALYs), which allows loss due to ill health and early death compared with a theoretical life span to be calculated based on the proportion of life “lost” as a result of a given degree of ill health.

In order to consider how to tackle climate change given the existence of various value judgments, it is therefore also important to assess the impact using health as a metric.

3.3 Development of response option inventories

Response options on climate change can take various forms. Broadly speaking, however, they can be divided into mitigation options, which cut emissions of GHGs, and adaptation options, which consist of options against the impacts of climate change that have arisen. Here, we draw up comprehensive inventories encompassing as far as possible all response options now known in order to provide an overview of the response options and spillover risks from four perspectives: (1) technological mitigation options against mainly GHG emission sources, (2) socioeconomic options to promote reductions in GHG emissions, (3) adaption options focused on reducing the damage caused by climate change impacts, and (4) geoengineering options to directly influence climate change as well as reduce GHG emissions.

Technological mitigation options are mainly energy-related. However, they are extremely diverse in nature as they span every stage from energy extraction to conversion, transportation, and consumption (including options specific to each sector of industry and users of energy to heat water or power air conditioning, etc. in the commercial and residential sectors). The obstacles and risks of adoption also differ in each case. The inventory of mitigation options contained in this report breaks these responses down to a second level of categorization, but the full report breaks them down even further to a more detailed third level. Like technological mitigation options, adaptation options are proposed for each sector affected by climate change, such as health and agriculture. The abridged version of the inventory of adaptation options shown in **Table 5** does not state the risks associated with each individual adaptation option for reasons of space. However, these risks are included in the full version.

Set against these are socioeconomic mitigation options, which consist of options that users most efficiently choose of their own volition from among several options, including in some cases adaptation options as well as technological mitigation options, as a result of financial incentives and institutional design. This inventory was therefore developed from a different perspective from that for technological mitigation options, with information being compiled on the scopes of entities affected, positives and negatives, and scopes of effects as these constitute the main points at issue. In this report, we present the opportunities and risks at the time of introduction and following adoption. The full version, however, additionally includes information on each of the entities affected.

Differing slightly in approach from the above responses, geoengineering is intended to act directly on the mechanisms of climate change, such as radiative forcing and GHG absorption. The options are limited and are additionally all at the theoretical or experimental level. In the geoengineering inventory, therefore, the row headers are the areas of research that need to be pursued to develop concrete technologies and the points at issue revolve around the uncertainties that exist over their effects and possible side effects.

The inventories of response options thus reflect the distinguishing features of the options in each field.

COLUMN 4 What is geoengineering?

While emissions of CO_2 and other greenhouse gases continue to rise, there is a growing recognition among experts, despite some uncertainty about the climate system, of the risk that climate change impacts may reach dangerous levels unless the sufficient international options of mitigation and adaptation are taken. For example, research shows that if the Antarctic or Greenland ice sheets melt, sea levels may rise 5-7 meters, although this will take several hundred years. Given this possibility, some scientists are considering a type of option called "geoengineering," artificial climate intervention of the kind depicted in the figure below.

Although the concept of geoengineering itself is an old one, it was not actively discussed owing to concern that it could reduce the incentive to take mitigation. Since the 2000s, however, the subject has attracted renewed interest, as evidenced by a comprehensive report on geoengineering published by the Royal Society of the United Kingdom in 2009. The Meeting Report of the IPCC Expert Meeting on Geoengineering in 2011 (IPCC, 2012b) defines geoengineering as a "broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate the impacts of climate change," and it was included within the scope of review of the IPCC's Fifth Assessment Report.

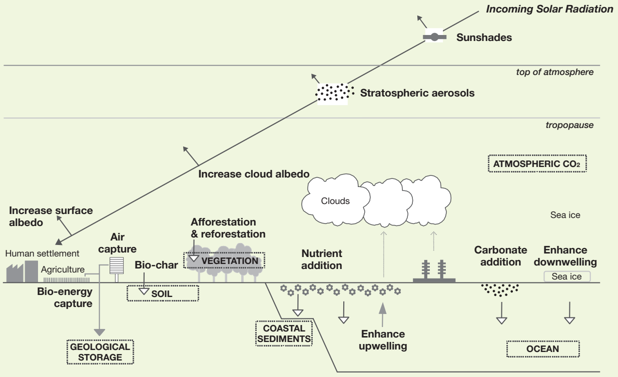
There are basically two approaches to geoengineering. The first is to negate air temperature increases by intervening in the energy balance of the climate system, and almost all the suggestions that have been made along this line involve directly or indirectly reflecting solar radiation, which is called solar radiation management (SRM). The second approach is to reduce the amount of substances in the atmosphere that have a greenhouse effect, and most of the methods that use this approach revolve around "carbon dioxide removal" (CDR) to directly or indirectly remove CO_2 from the atmosphere.

SRM and CDR are very different in character. SRM is typically cheap and immediate in effect, but comes with side effects. In comparison, CDR takes longer for its effects to become apparent and is more expensive, but it is thought to have fewer side effects. Naturally, though, these characteristics differ considerably according to the specific method and conditions of implementation involved.

The concept of CDR overlaps with conventional mitigation, and it needs to be defined so that it is delineated by scale of implementation and side effects. Normally, carbon capture and storage (CCS) of CO_2 from fossil fuels is considered a form of mitigation. Among the CDR strategies that have been suggested, direct removal of CO_2 from the air and bio-energy with carbon capture and storage (BECCS$^{3)}$), are considered to have much potential. Some very low emission scenarios for keeping the rise in air temperature to within 2°C of the pre-industrial level see total world CO_2 emissions become negative following large-scale adoption of BECCS in the latter half of the 21st century.

There does not appear at present to be a consensus in the global environmental research community on whether the geoengineering option should be actively adopted. The Meeting Report of the IPCC Expert meeting on Geoengineering observes that there exist environmental risks on the scientific side and concerns regarding ethical issues, governance in an international framework, governance of research and development, and the social acceptability on the social side, and it recognizes that this is a field of research in which implementation should be considered with care.

Heightened interest in geoengineering should be regarded as an extension of research on the options for tackling climate change impact risks, and this in itself points to the need for a profound and comprehensive reconsideration of climate change risks and the risks associated with options against them.



Source: Lenton and Vaughan (2009)

Figure C4.1 Forms of geoengineering

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3) Regarding BECCS, see **Column 5: Use of bio-energy with carbon capture and storage (BECCS)** on p. 18.

○ Mitigation options

Mitigation options aim to reduce emissions of GHGs focusing on their sources, and are a concrete and natural approach to tackling climate change. The specific options that immediately spring to many people's minds when they think of mitigation options may include switching from coal to natural gas for the thermal power stations and adopting photovoltaic power generation. Some also no doubt think of options such as recycling and implementation of energy-saving technologies, by switching from conventional vehicles to more fuel-efficient ones, and heat-insulating building walls. However, two points must be borne in mind here. Firstly, there are no options that are perfect cure-alls. Secondly, expanding adoption of these options too rashly can result in their effects cancelling or causing new risks.

The inventory of mitigation options was therefore prepared by first exhaustively identifying such options on the basis of the IPCC Fourth Assessment Report WG3 (IPCC, 2007b) and then summarizing the anticipated risks when they are extensively adopted. The resulting inventory of mitigation options is outlined in **Table 3**. It is thus evident that when adopting mitigation options, factors including the opportunities and risks associated with adoption and obstacles likely to be encountered, as well as the development of economic and institutional infrastructure, must all be comprehensively taken into consideration.

Table 3 Inventory of mitigation options (abridged version)

Technological mitigation options			Economic mitigation options	Regulatory institutional mitigation options	Opportunities for adoption	Co-benefits with sustainable development	Response risks	Constraints on wider adoption	Risks of obstacles	Entities subject to risks
First-level category	**Second-level category**	**Third-level category**								
Energy supply	Fuel conversion and power generation efficiency	(Concrete options)	Online electricity prices	Mandatory use of renewable energies	Creation of markets for new technologies	Improvement of environment (air pollution, etc.)	Increased GHG emissions due to use of unconventional fossil fuels	High investment risk	Price fluctuation risk	International, national, regional (countries/ provinces), sub-regional (municipalities), buildings, individuals
	Energy-efficient supply		Reduction of subsidies for fossil fuels	Easing of environmental regulations			Energy security	Land use constraints	Competition with vested interests	
	Early CCS use		Subsidization of early demo units				Competition with food supply			
Transportation	Mode of transport (road, rail, etc.)		Subsidies, tax incentives	Fuel efficiency regulation	Instability of fossil fuel supply	Improvement of social infrastructure	Decline of effects due to income growth	Geographical conditions	Pricing risk	
	Land use and transport plans		Development of infrastructure							
Building	Lighting		ESCO, tax system	Standardization	Government sector procurements	Improvement of health impacts	Free-riding on subsidies	Relations with behavior of inhabitants	Finance, poverty, increase cost of reliable information	
	Heating devices			Demand management						
Industry	Energy-intensive industries		Business permits and other incentives	Standardization	Technology transfers/ knowledge acquisition	Decline of air pollution	Reduced effects due to economic growth	Existing low-efficiency facilities	Financial and technological resource constraints	
	Foods									
Agriculture	Soil		Financial policy to encourage management	Regulatory systems	Co-benefits with sustainable development	Improvement of production environment	Competition with water resources and nitrogen pollution	Competition with bio-energy	Friction with macroeconomic policy	
	Livestock industry						Disease risk due to single crop cultivation			
Forests and forestry	Afforestation									
	Management									
Waste	Waste disposal								Technological sustainability	
	Expansion of waste recycling									

Note: The full version provides more detailed information by breaking down each item in the table into more detailed first, second, and third level categories.

○ Socioeconomic options

There are basically two types of socioeconomic options: options that incentivize economic entities to reduce GHG emissions through economic means and provision of information (economic options and social options), and options that work directly to reduce GHG emissions (regulatory options).

Table 4 summarizes the available socioeconomic options based on the IPCC Fourth Assessment Report (IPCC, 2007b) and Stern (2007). As can be seen, every option has its spillover opportunities and risks. Formulating individual options to reduce GHG emissions necessitates minimizing the risks for little expenditure. As GHG emissions derive from our economic activities, however, options often involve economic loss (such as a decline in GDP). It is therefore particularly important to adopt an approach that avoids or lessens this economic loss while still reducing GHG emissions.

The need for options to be taken on a global level if climate change is to be actually mitigated additionally means that even where a country develops and implements appropriate options to reduce GHG emissions, their effects will inevitably be limited. Attention must also be paid to the problem of “free rider” countries that do not take such options, and the fact that the cost of options regarding GHG emissions will differ according to country and region. According to the IPCC (2007b), the factors that should be taken into account in international policy coordination are GHG emission reduction effects, the cost effectiveness of policy coordination, the fairness of the cost burden, and feasibility. Agreement on policy coordination that satisfies these factors is also an important socioeconomic option that will contribute to the reduction of GHG emissions in the future.

Table 4 Inventory of socioeconomic options (abridged version)

Category of socioeconomic options			Opportunities		Risks	
First level	Second level	Third level	Before adoption	After adoption	Before adoption	After adoption
Economic options	Taxes, charges	• Carbon tax, etc.	• Low cost of options	• Improvement of energy security • Promotion of innovation	• Non-price elasticity of energy demand • Setting of tax points • Political difficulty of adoption • Consistency with fossil fuel subsidies	• Unclear volume of reduction in GHG emissions • Consistency with innovations having reverse effect • Uses of revenues from taxes and charges • Regressivity • Loss of competitiveness and leakage • Decline of output • Monitoring system design and cost
	Emission permits	• Emission permits	• Certain reduction of GHG emissions	• Income from sale of emission credits (auction) • Securing of fairness (auction) • Improvement of energy security • Promotion of innovation	• Methods of initial distribution • Scope of application of emission credits • Points of application of emission credits	• Fluctuations in emission credit prices • Use of revenues from sale of emission credits • Possibility of companies exercising pricing power • Regressivity • Loss of competitiveness and leakage • Decline of output • Monitoring system design and cost
	Subsidies Other incentives	• R&D subsidies • Investment tax credits • Price support (e.g., feed-in tariff system)	• Fairness of subsidy cost burden • Political ease of • introduction	• Promotion of innovation • Spread of low-carbon technologies • Increased competitiveness • Promotion of international cooperation on development of technologies	• Financial costs • Consistency with fossil fuel subsidies	• Difficult to abolish • Technological spillover (protection of intellectual property) • Monitoring system design and cost
Regulatory options	Regulations, standards		• Adaptability to individual cases	• Comparatively certain reduction of GHG emissions	• Cost of GHG emission reductions and cost of access to information on technologies	• Cost burden of regulatory options • Tendency not to lead to innovation • Revision of regulations and standards to keep abreast of times • Monitoring system design and cost
	Self-regulation	• Businesses	• Familiarity to specific cultures	• Improvement of image • Contribution to society • Low cost of options		• Cost burden of regulatory options • Uncertain effects • Potential for linkage with central government policy • Monitoring system design and cost
		• Society		• Encouragement of action by enterprises that have yet to adopt		
Social options	Information policy	• Information disclosure system • Education, etc.		• Promotion of consumer choice based on better information • Maintenance of corporate environmental awareness • Synergies with other options		• Uncertain cost effectiveness • Cost of information disclosure • Monitoring system design and cost

Note: The full version describes the opportunities and risks at each of the following levels: world, state/government, business, individual/household.

○ Adaptation options

Adaptation options are options adopted to lower the risks of climate change. Conversely, however, there are also risks that may arise as a result. A multidimensional study was therefore made of such options, including summarization of the spillover risks. (Regarding the risks of climate change themselves, see **Table 2**. The inventories of adaptation options and risks have yet to be correlated with each other, and this remains an area for further study.)

The inventory of adaptation options was developed focusing on the fields of introduction of adaptation options described in the Report of the Ministry of the Environment (MOE, 2008) and drawing also on World Bank report (World Bank, 2010) and other sources.

While the risks of adaptation options differ depending on the specific types of options taken, they basically fall into two categories: (1) risks to human society (including economic activity), and (2) risks associated with changes in natural ecosystems. When going forward with adaptation options, it is also necessary to take into account the risks associated with over- or underestimation of the anticipated climate changes. Thus, overestimating climate change can increase the cost burden, for example, while underestimating can result in the actual effects of climate change exceeding the capacity of the adaptation options adopted.

The constraints on and obstacles to introduction of adaptation options exist along several dimensions—(1) physical and ecological, (2) technological, (3) economic and financial, (4) social and cultural, (5) institutional, (6) informational and perceptive, and (7) human resource related—with (1) and (2) in particular limiting adaption. As well as the financial question of how to fund adaptation options, issues stemming from society, culture, tradition, and so on (which come under (4) to (6) above) also pose numerous challenges that have to be overcome. Although some attempts have been made to estimate the cost of adaptation options, as in the case of the estimates provided by the World Bank (2010), they have yet to be fully explored and further study is required in this area.

Table 5 Inventory of adaptation options (abridged version)

First-level category	Second-level category	Third-level category	Adaptation options	Constraints/ obstacles	Risks for human society	Risks for ecosystems
Food sector	Agriculture	Grains, fruit	Improvement of tolerance and avoidance of high temperatures	Physical/ecological Technological Economic/financial Social/cultural Institutional Information/ perception Human resource development	• Risks associated with cost burden (adoption expenses, develpopment expenses) • Development potential as an industry • Risks associated with changes in land use • Risks associated with changes in local infrastructure • Risks associated with growth in energy demand	• Impact on ecosystems of selective breeding and changes in tree species, etc. • Risks associated with ecosystem changes
	Livestock farming	Livestock, fodder	Avoidance of high temperatures and migration to more suitable locations			
	Fisheries	Migratory fish, coastal fish, aquaculture	Adaptation to changes in ecosystems and movement to more suitable locations			
Water environment and water resources	Water supply		Securing of reservoirs and groundwater use			
	Water demand options		Improvement of efficiency			
	Water environment management		Options against eutrophication and salt water			
	Flood control Options					
Natural ecosystems (vegetation/land)	Forest ecosystems	Natural forests, planted forests, community woodland	Revision of sanctuaries			
	Coastal ecosystems	Oceans, freshwater, tidal flats	Reduction of environmental load and riparian forest preservation			
Disaster prevention and coastal sector	Changes in land use	Changes in land use/ architectural styles	Development of buffer zones/dykes, changes in architectural styles			
	Enhancement of disaster prevention systems	Information provision and support	Development of evacuation routes, disaster drills			
	Monitoring		Observation			
Health	Summer heat		Public health guidance			
	Infectious diseases		Vaccination, improvement of sanitation			
National/ urban life	Safe living	Houses, inhabited areas	Strengthening/movement of buildings			
	Healthy living	Heat, water environment	Heat stroke options, maintenance of health			
	Economically affluent living	Heat, diet	Use of weather derivatives, development of new industries			
	Comfortable living	Heat	Renovation and pest extermination			
	Culture	Ecosystems	Tree planting and preservation			

Note: The full version also lists the risks associated with each adaptation option.

○ Geoengineering options

Options and potential risks were compiled based on studies covering a wide range of techniques (Royal Society (2009), Secretariat of the Convention on Biological Diversity (2012)), with stress placed on the comprehensiveness of options conceivable as geoengineering. These options may first be broadly divided into carbon dioxide removal (CDR) methods and solar radiation management (SRM) methods, as shown in **Table 6**. These are then subdivided into smaller categories of specific technical options along with their corresponding risks.

There are several methods of indirect CDR, including land use management of forests and biomass (biochar and BECCS). Other options over much longer timescales are “chemical weathering,” where the earth absorbs CO_2 in the atmosphere, and “ocean fertilization,” which involves introducing iron, phosphorus, or nitrogen into the ocean to promote photosynthesis. One method of direct removal, on the other hand, is direct CO_2 capture from the atmosphere, which involves capturing CO_2 with alkaline substances and storing it underground. The pursuit of CDR options such as these on a sufficiently large scale could lead to competition with other land use needs, ecological impacts on biodiversity and the oceans, and risks associated with CO_2 storage.

SRM risks are broadly divided into those concerning SRM as a whole and those relating to specific technologies. Failure to resolve ocean acidification, concerns over the continuation of regional temperature increases (and localized changes in rainfall especially) despite the global average being brought under control, and the danger of a sharp temperature increase occurring if SRM is suddenly halted while the concentration of CO_2 is still high have all been identified as risks of the former type. While virtually all the concrete technologies in this field aim to increase the earth’s albedo (solar reflectance), they can be subdivided into, for example: land surface technologies used in cities, homes, grasslands, arable lands, deserts, and so on; cloud technologies to increase the reflectance of naturally existing low-level cloud by generating sea salt aerosols, etc.; stratospheric aerosol injection, which aims to mimic the earth’s cooling after a major volcanic eruption; and space-based solar shields, which involve placing substances that reflect or scatter sunlight in space. Of these, stratospheric aerosol injection and increasing the reflectance of clouds provide effective means of reducing temperatures and also appear cost efficient. However, they also have side effects in the form of potential impacts on inhabited areas, agriculture, and ecosystems, and meteorological impacts (in terms of the water cycle, destruction of the ozone layer, acid rain, and atmospheric circulation).

The above summary of the risks also does not take into account such risks of implementation that are discussed in contexts of social science, including the ethical aspects, the international frameworks that will be necessary when full-scale SRM is implemented, or the issue of societal acceptability. We therefore intend to examine these issues further in the future.

Table 6 Inventory of geoengineering options (abridged version)

Geoengineering response categories			Main risks (including latent)
First level	Second level	Third level	
CDR	Land use management	Afforestation, reforestation, options against forest decline	Land use competition, alteration, impact on biodiversity
		Biochar storage	Additional energy consumption, impact on soil
		Biomass CCS	CCS risks (leakage, triggering of earthquakes, impact on marine ecosystems)
	Weathering promotion	Land, ocean	Environmental destruction due to mining/transportation, impact on marine ecosystems
	Direct CO_2 capture from air		CCS risks (leakage, triggering of earthquakes, impact on marine ecosystems)
	Marine fertilization		Uncertainty over amount of CO_2 absorbed, impact on ecosystems
SRM	General		Global/regional climate changes, problem of termination
	Increase of albedo	Earth's surface	Impact on crops, communities, ecosystems
		Cloud	Changes in ocean currents, etc., changes in interhemispheric circulation
		Stratosphere aerosol	Changes in global water cycle, ozone layer destruction, acid rain
		Solar shield in space	Decline of north/south temperature gradient and change in atmospheric circulation

Note: The risks are described in more detail in the full report.

COLUMN 5 Use of bio-energy with carbon capture and storage (BECCS)

In order to keep the temperature rise below 2°C or a similar target above pre-industrial levels, past studies have noted the need for CO_2 emissions from fossil fuel combustion to be net negative by the end of the 21st century (Obersteiner *et al*., 2001). Projections of climate change simulated by the latest Earth System Models also indicate that about half of the models, despite considerable variations among them, require CO_2 emissions from fossil fuel sources to be negative (i.e., removal of CO_2 from the atmosphere by some means) from 2080 if the global average temperature rise is to be kept below 2°C (Jones *et al*., 2013).

Using bio-energy with carbon capture and storage, or "BECCS", is considered to be one potentially important way of achieving the negative emissions (van Vuuren *et al*., 2007; Azar *et al*., 2010). As the figure below shows, BECCS ultimately produces a negative CO_2 balance by capturing and storing the CO_2 generated during energy use of biofuel based on carbohydrates produced by plant photosynthesis. To give an example of the sort of impact it might have, one study estimates that annual carbon uptake by BECCS using wood biofuel could be 8.8 Pg C yr^{-1} in 2100 (Fuss *et al*., 2013).

However, numerous uncertainties currently surround future use of BECCS, including the feasibility of large-scale BECCS, the kinds of biofuels that might be used, and the cost of facilities at use, transport and storage sites (IPCC, 2005). The possible consequences of increased use of biofuel with large-scale BECCS also need to be analyzed taking into account the diverse interactions of a variety of factors, including land-use, biodiversity, carbon emissions, water resource consumptions, and competition with food production.

Researchers working on Theme 2 of the ICA-RUS project are using a process-based global terrestrial ecosystem model and a global crop model to estimate the following, assuming the land-use required by scenarios for the large-scale adoption of BECCS: the amount of biofuel that can be practically produced; the quantity of fertilizer and area of irrigated land required to produce biofuel crops; and the amount of carbon emissions generated by deforestation resulting from expansion of land necessary for the biofuel crop productions. As part of this analysis, a study is being made into the possibility that more land than expected might be needed to produce biofuel crops under scenarios to keep the global average temperature increase to not more than 2°C assuming the first-generation biofuel use, and the possibility of further deforestation as a result of competition with land used to produce food crops. The integration of terrestrial ecosystem, water resource, crop, and land use models being pursued under ICA-RUS Theme 2 makes an important contribution to the analysis of the consequences of such interactions.

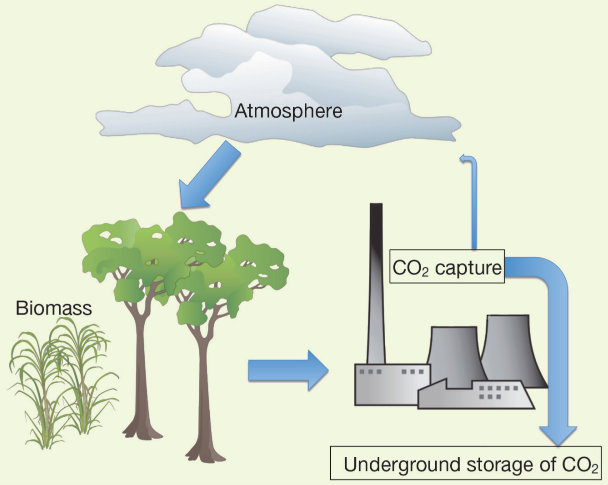

Figure C5.1 Carbon flow with BECCS

3.4 Identification of points at issue concerning climate change risk management

Alongside developing inventories, ICA-RUS has identified the points at issue concerning its themes of research based on its findings of surveys of the literature on each theme. These "points at issue" constitute the focal points of research ICA-RUS's research on each theme, the findings of which will inform its examination of climate change risk management strategy. Below, we summarize the points at issue that have been identified for each theme.

Theme 1:Synthesis of global climate risk management strategies

The purpose of research on Theme 1 is to put forward a risk management strategy for rationally determining the course of comprehensive response options against climate change. As a practical step toward achieving this task, teams were set up to tackle sub-themes of Theme 1. These are: development of an integrated assessment tool incorporating the quantitative findings generated by each of the other themes and quantitative analysis of climate change risk management strategy using this tool; examination of global climate change risk management strategy applying the results of this analysis and the scientific findings on the risks and response options produced separately by each theme; incorporation into this of research findings concerning decision-making under uncertain conditions; and reflection of the views of stakeholders in the framework of ICA-RUS's risk management strategy through forums for dialogue. Below we identify the points at issue concerning, respectively, integrated assessment tool development and risk management strategy.

<Development of an integrated assessment tool>

An integrated assessment tool was developed by first surveying the current state of development and application of the simplified climate models that are a standard component of integrated assessment models. This revealed the points at issue having a strong impact on the results of analysis of risk management strategy to include taking into account the uncertainties over factors having a strong effect on global average temperature (such as climate sensitivity, ocean heat uptake, aerosols, and the carbon cycle), constraints on model uncertainties using observed data, and improvement of the sophistication of land carbon cycle modules. Regarding decision-making under the conditions of uncertainty being considered for incorporation into the integrated assessment tool, the main areas to pursue were found to be improved handling of expected utility theory and discount rates by the integrated assessment model, and modeling of irreversible investment decisions applying options theory, etc.

<Research on climate change risk management strategy>

A survey of past studies showed the main points at issue in research on climate change management strategy to be: linkage of regional and localized impacts to global stabilization targets; factoring in of irreversible and non-linear climate change impacts; assessment of changes in the probability of occurrence of extreme events resulting from mitigation; allowance for the results of risk management options themselves and for spillover risks; and determination of the scope of risks to assess. A survey was also made of the forums for dialogue on climate change that have seen actual use, both in Japan and in other countries, as a means of building stakeholders' views into climate change risk management strategy. These were found to consist mostly of committee-based hearings of views on local action policies and plans hosted by local governments, and research and experiments designed to formulate recommendations for government and other bodies organized mainly by research institutions. It was confirmed, however, that these forums had different goals from ICA-RUS, whose focus is on climate change risk management on a global scale, which means that mechanisms of this kind will have to be specially tailored to meet ICA-RUS's needs.

Theme 2: Optimization of land, water and ecosystem uses for climate risk management

For Theme 2, the following models were developed and analyzed: integrated land model, ecosystem model, water resource model, land use model, and agriculture model. The points at issue identified regarding each of these models are as shown below.

<Integrated land use model>

Many of the low-carbon scenarios to mitigate climate change involve use of BECCS. Important points at issue are the kinds of biofuels to be used, types of land to produce them, and assessment measures of greenhouse gases throughout the entire lifecycle.

<Ecosystem model>

Temperature increases give rise to changes in biological phenology, and this can disrupt the balance between organisms and reduce biodiversity unless interspecies synchronization occurs. Deterioration of habitats can also lower productivity and create a risk of worsened damage caused by insect pests and fires, and accelerated climate change caused by increased emissions of CO_2 and nitrous oxide from the soil and the release of methane from melting tundra.

<Water resource model>

Climate change is expected to affect the earth's water cycle (precipitation, evaporation, and runoff), thus changing the discharge of rivers (a fundamental water resource) and increasing variability from year to year and season to season. There are already concerns about the sustainability of some aquifers as water is being taken from them more rapidly than it can be replenished. The effects that an increased concentration of CO_2 in the atmosphere exerts on the water cycle through plant activity are also not properly understood.

<Land use model>

The main points at issue concern the amount of land available, the quantities of inputs (including fertilizer, water, and labor) required for land to be used, and the value of output produced by land used. These are closely related issues and it is important to understand their geographical distribution in today's globalized world.

COLUMN 6 The discounting approach

Commonly used concepts in the discussion of reductions in greenhouse gas emissions and their timing are "discounting" and "discount rate," and the results of analysis of reductions and timing of reductions are often affected by their values. Below we explain the nuts and bolts of the thinking behind discounting.

Economic activity basically consists of people ("economic agents") consuming goods and feeling happy (obtaining "utility") as a result. These goods are extraordinarily diverse in practice. Imagine something, then, like a fruit basket filled with every kind of goods imaginable. Utility (happiness) is also a quite nebulous concept, so let us imagine the happiness that might be experienced by a single economic agent—one person—through consumption during the course of his or her entire life. Our imaginary individual is thus carrying a basket of fruit that he or she consumes throughout life, enjoying happiness as a result.

The various fruits (goods) contained in the basket can be used (eaten) not just now but also in the future, whether tomorrow, the day after tomorrow, one year's time, or 10 years' time. If the types of goods are expressed as $j = 1 \sim N$ and time as $t = 0 \sim T$, then there are $N \times (T+1)$ goods in this world. Here, the present point in time is $t=0$. Writing the amount of each item consumed as $X_{j,t}$, then utility throughout a person's life may be written in the form of the following function:

$$U(X_{1,0}, X_{2,0}, \ldots, X_{N,0}, X_{1,1}, X_{2,1}, \ldots, X_{N,1}, \ldots\ldots, X_{1,T}, X_{2,T}, \ldots, X_{N,T})$$

In an actual economic system, consumption of goods can be recombined for future points in time as well as the present. The function may thus be rewritten by separating utility into each time period:

$$u_0(X_{1,0}, X_{2,0}, \ldots, X_{N,0}) + u_1(X_{1,1}, X_{2,1}, \ldots, X_{N,1}) + \ldots + u_t(X_{1,t}, X_{2,t}, \ldots, X_{N,t}) + \ldots + u_T(X_{1,T}, X_{2,T}, \ldots, X_{N,T})$$

To make this easier to read, the basket of consumption at a given point in time may be aggregated and written simply as Ct, which gives us the following:

$$u_0(C_0) + u_1(C_1) + \ldots + u_t(C_t) + \ldots + u_T(C_T)$$

In economics, this is called a "time separable utility function," which takes instantaneous utilities at each point in time and adds them together. Here, let us further assume that an agent's preferences regarding consumption choices at each point in time are unchanging. The above utility may then be written as follows:

$$D_0 \times u(C_0) + D_1 \times u(C_1) + \ldots + D_t \times u(C_t) + \ldots + D_T \times u(C_T) \qquad (1)$$

This is based on the unchanging instantaneous utility functions at each point in time, which are weighted and added together. This weighting is expressed as D_t and is called the "discount factor."

Almost without exception around the world, economic analysis of climate change takes as its starting point a utility function in the form of (1). There is not, however, complete consensus on how specifically D_t should be envisaged. Being essentially a hypothesis on top of a hypothesis, it can be set out in all manner of ways. What has been accepted to a degree is that D_t should take the form $(1+\rho)^{-t}$ using some kind of positive constant ρ. This is called "exponential discounting." As ρ is taken to be a positive constant, D_t decreases as t increases. This means that the instantaneous utility obtainable from consumption in the future has relatively less value in the context of total utility over a lifetime than the instantaneous utility obtainable from the same consumption in the present. To put it the other way around, economic agents consider it better to consume the same amount now than in the future. The value of future consumption is therefore "discounted" relative to that in the present. The further consumption is in the future, the greater this discount is.

As ρ is constant, the discount is $1/(1+\rho)$ at one remove ($t=1$) from the present, $1/(1+\rho)$ at two removes ($t=2$), and so on, so that the discount at a given number of removes ($t=s+1$) from a given point in time ($t=s$) is always $1/(1+\rho)$. No matter how much time elapses, an economic agent's thinking about the future is assumed to be unchanged. That is the basic thinking behind exponential discounting, and we may safely say that it is on exactly this point that a certain degree of agreement has been reached. Nevertheless, major questions that are hard to settle will need to be answered before ρ can be given a concrete value. In the absence of a consensus on exponential discounting, D_t can be assumed to take a form such as $(1+t)^{-\alpha}$. This is called hyperbolic discounting. In this case, too, deciding what value to give to the constant α is a difficult problem.

As is easily imaginable, analysis findings and policy recommendations vary considerably according to how these values are set. In the case of public policy analysis, such as climate change policy, the above utilities enjoyed by each individual throughout their life are aggregated to define utility for society as a whole. T is therefore at least 100 years and may in some cases be in the order of 1,000 years. For example, if in exponential discounting $T=100$, then $(1+\rho)^{-T} = 0.37$ where $\rho=0.01$. This means that instantaneous utility 100 years hence is regarded as having approximately 40% of its value in today's terms. Conversely, 1/0.37 times (=2.70 times) current instantaneous utility would be required to obtain the same instantaneous utility as now 100 years in the future. If $\rho=0.05$, then $(1+\rho)^{-T} = 7.6\times10^{-3}$, and if $\rho=0.1$, then $(1+\rho)^{-T} = 7.3\times10^{-5}$. When the value reaches $\rho=0.1$, then $1/7.3\times10^{5}$ times (approximately 14,000 times) current instantaneous value would be required to obtain instantaneous utility on a par with today 100 years in the future, Economic analysis of climate change may appear objective and scientific, but actually much remains open to debate regarding the fundamentals.

<Agriculture model>

As crop yields govern food supply, it is necessary to identify the factors that have constrained the rate of growth in yields in recent years (air temperature and precipitation) and gain a better understanding of the effects of fertilization on rising concentrations of CO_2, composite effects and responses to environmental factors, attainable yields, responses to extreme phenomena, and so on. Estimating the impact of changes in market structure and growth in the urban poor on food access are also key concerns affecting food demand projections.

Theme 3: Identification and analysis of critical climate risks

Interest in tipping elements (outlined in Column 2 on p.9) in relation to climate change risk management stems from the supposition that, despite their low probability, they would have profound and far-reaching negative impacts were they to occur.

While academic discussion of rare phenomena occurring below a certain frequency may be possible using expected values obtained by multiplying their anticipated impacts (the cost of damage) by their probability of occurrence, such discussion will remain limited to the realm of theory as long as human society in practice only weighs its interests a decade at most into the future. In the case that a certain rare phenomenon occurs completely randomly and independently, for example, the probability that a phenomenon that occurs once in T years does not occur at all in T years and the probability that it will occur exactly once (if T is sufficiently large) will both be approximately 37%, and there will also be a remaining 26% probability of its occurring at least twice. Even if the statistically expected frequency is 1, there will likely be a feeling that action was redundant if the phenomenon does not occur at all during the period, and that the forecast was overly optimistic if it occurs twice or more. In order for the frequency of occurrence to exactly equal the expected value, several times the average recurrence period T will be required. Hence in the case of a phenomenon whose probability of occurrence with climate change is 1%, a timescale of several thousand years will need to be adopted if it is to occur as frequently as expected. A cost-benefit analysis along insurance lines may therefore not necessarily be the best approach.

If a phenomenon that is feared to be a tipping element causes catastrophic damage on the scale exaggeratedly depicted in movies, on the other hand, this raises the question of whether adaptation is even possible and whether the risks are manageable. However, researchers engaged in Theme 3 are working on the assumption that the tipping elements being considered may not cause major damage to all the earth's oceans and atmosphere. In this case, balancing the interests of different regions emerges as a problem. Another important concern of Theme 3 is whether there exist phenomena associated with climate change that might be considered tipping elements but have not yet been identified.

A further goal of research on Theme 3 concerns assessment of the impacts of climate change health and economic costs as end points after taking into account flood damage, drought, food shortages, epidemics, and so on, as well as simply the frequency and changes in intensity of climate hazards such as torrential rain, flooding, water shortages, and high temperatures.

Theme 4: Evaluation of climate risk management options under technological, social and economic uncertainties

Points at issue were identified in each category of options; namely, mitigation options, adaptation options, and geoengineering options.

<Mitigation options>

Various mitigation options have been proposed and developed, as outlined in the inventory of mitigation options (**Table 3**), which all contribute indirectly to mitigating the impacts and damages caused by climate change. The points at issue that concern all these forms of option include (A) uncertainties over costs and effects, (B) interactions with other options, (C) estimation of spillover risks, and (D) estimation of ancillary benefits.

The fact that the agents and entities assessing these options vary widely according to region and point in time, also poses a major obstacle to reaching a consensus. For example, the agents that actually implement mitigation options are not the same as those that experience the benefits of curbing climate change. The effects of climate change mitigation options will be felt by future generations. Additionally, different damage (and sometimes benefits) can be experienced depending on region, time, and category of climate change impact. The consequent conflicts of interests between agents when options are taken mean that the optimal action at the macro-level according to a cost-benefit analysis may not necessarily be favorable for everyone. As the participating agents must compromise to reconcile their geographically and temporally conflicting interests, the option selected may not necessarily be effective overall (even if natural scientific uncertainties have been eliminated). It may be preferable to adopt a fairness-based approach rather than efficiency-oriented ones. However, as the concept of fairness is governed more by value judgments than efficiency, questions of fairness are less susceptible to resolution through scientific discourse.

<Adaptation options>

Some of the points at issue concerning mitigation options apply similarly to adaptation options. As they consist of individual options to combat the impacts of global warming at the regional level, however, costs and benefits are easier to consider. On the other hand, their more localized implementation means that conflicts with overall efficiency, social and cultural obstacles, and securing the necessary funding for implementation are more likely to emerge as issues.

<Geoengineering options>

As geoengineering is still at the proposal and experimental stage, there remain considerable scientific and technological uncertainties regarding elements of geoengineering itself, such as the effects and side effects of implementation. As geoengineering involves direct intervention in geophysical systems, there are also several social questions to consider. Those that have been noted include the ethical acceptability of geoengineering, whether an effective international framework can be created, how global benefits can be reconciled, and how R&D should be pursued in the future. Discussion of these issues has only just begun, however, and there is practically no consensus at present except for that regarding the insufficiency of the international framework for dealing with geoengineering.

Theme 5: Interactions between scientific and social rationalities in climate risk management

Theme 5 examines the significance of demonstrating to the public how risks are constituted, and explores appropriate methods of communication. Focusing on categorization by characteristics of risk phenomenon, personal traits, and method, the key points were identified as follows

<Categorization by characteristics of risk phenomenon>

Uncertainties are inherent in risk issues, and are not limited to climate change. What then distinguishes climate changes from other risk issues? The key points are summarized below.

1) Of the six risk phenomena involving high uncertainties (genetic engineering technologies (genetically modified foods and crops), genetic testing, mobile phone handsets, mobile phone masts, radioactive waste, and climate change), people tend to conceive that the responsibility for risk management rests with the individual in the case of mobile phones, genetic testing, and genetically modified foods. People, however, tend to conceive that actions by individuals to manage risks of climate change, mobile phone masts, radioactive waste, and genetically modified crops are of practically no use, suggesting that responsibility should lie with the government (Bickerstaff *et al.*, 2008).

2) The issues specific to the communication of climate change risks include: (1) the invisibility of its causes; (2) the remote nature of causes and impacts (both temporally and geographically); (3) the insulation of urban populations from environmental changes; (4) the imperceptibility of the effects of any action taken; and (5) the difficulty of instinctively believing that humans are affecting the environment (Moser, 2010).

<Categorization by personal traits>

When presenting risk management options to the public for them to decide, the key points to broadly categorize personal traits are examined as follows.

1) The key trade-offs which people need to consider are the dimensions of (1) risks and benefits, (2) present and future, (3) local and global, (4) individual and community, and (5) society and nature. The appropriateness of these dimensions was reviewed.

2) While the differences in attitudes to the trade-offs specified in 1) are considered in terms of the four classical world-views—hierarchical, egalitarian, individualist, and fatalist—whether a more refined classification would be required or not was examined.

<Categorization by method>

An analysis was made of methods of engaging citizens in discourse on risk choice and matching them with issues. The points at issue here are as follows:

1) The issue of "biodiversity" is well suited to public participation and in particular to the WWViews Citizen Forum method. The reasons for this include (1) visibility of the issue to the public (e.g., extinction of species, etc.), and (2) visibility of both action and effects (protection of coral reefs, etc.)

2) From the above, the factors making climate change risks harder to perceive are: (1) tendency to be diverted by more immediate issues, and (2) difficulty of creating topics for public engagement.

4 Future direction of research

In fiscal 2012, the project's first year, ICA-RUS's overall focus was on framing the problem based primarily on a survey of existing knowledge, and the present report concentrates on reporting the resulting findings. Alongside this, preparations are underway to develop the models and other apparatus required to conduct the analyses specific to each theme. Next year will see work begin in earnest on examining a quantitative risk management strategy, with the aim being to present the first edition of a comprehensive product during fiscal 2014 (ICA-RUS Global Climate Risk Management Strategy Ver. 1).

Socioeconomic scenarios of the future will play a key role at this stage. Keeping abreast with the development of scenarios in the international research community, ICA-RUS will establish a set of scenarios for shared use by ICA-RUS as a whole. These will be quantified during the next fiscal year and progressively used in a consistent manner in research on subjects such as the impacts of climate change, scenarios of climate change response options, and the spillover effects of the response options, and in social surveys that explore citizens' value judgments.

As the range of topics susceptible to independent analysis by ICA-RUS is limited, the comprehensiveness of research will be ensured by continuing to survey and apply existing knowledge in quantification too. Work will continue from next year onward on the development of inventories of risks and actions and identification of contentious points in order to enhance and organize their content.

Additionally, further attention will be paid next year to publicizing the project's results through such channels as online publication, presentation at academic conferences in Japan and abroad, and dialogue with stakeholders.

Request for Feedback

Thank you for your interest in this report. ICA-RUS welcomes any and all feedback, so please do not hesitate to email us at the address below if you have any requests regarding future reports or comments or criticisms (however brief) concerning this year's report.

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We hope that you will continue to follow ICA-RUS's reports in the future.

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