futurearth
research for global sustainability

Draft initial design report

17th April 2013

This report sets out the initial design of Future Earth, comprising a research framework and governance structure, preliminary reflections on communication and engagement, and capacity building and education strategies, and implementation guidelines.

This report was developed by the Future Earth Transition Team, a group of more than 30 researchers and experts from many countries and representative of the natural sciences, social sciences, and humanities, as well as from international organisations, research funders and business. Earlier drafts of its main sections have been circulated and presented for consultation in the process of designing Future Earth. Future Earth is expected to develop and evolve through a wider consultation process as the transition is made to its fully operational phase.

These recommendations suggest a direction for the Alliance of sponsors and the initial governance bodies of Future Earth to take the design and implementation forward.

Acknowledgments

The transition to Future Earth has been a complex, difficult and inspiring task – trying to capture the urgency, seriousness and breadth of the future of our planet and its inhabitants, engaging a broad international community of scientists, and building on the decades of research and collaboration that have already made important contributions to our understanding. We were humbled when Future Earth was included as one of the commitments that science and the research community made to the world at Rio+20. We wish to sincerely thank the many people and organisations that contributed to this report and the work of the transition team.

Foremost are the staff of ICSU and the Belmont Forum who organized our meetings, phone conferences, and helped to draft the report – most especially our Science Officer Roberta Quadrelli, but also Anne Sophie Stevance, Vivien Lee, Rohini Rao, Peter Bates, Owen Gaffney, Leah Goldfarb, Maureen Brennan, David Allen, Carthage Smith, Maria Uhle, Andrew Wei-Chih Yang, Gisbert Glaser, and Denise Young. We are also very grateful to the members of the Transition Team who volunteered their time and energy to create this report and to participate in consultations and presentations around the world. We are especially grateful to the working group leaders Martin Visbeck and Karen O'Brien, Rik Leemans and Peter Liss, and Rohan D'Souza who drafted sections of the report and to other members of the Executive Group – Joseph Alcamo, Gretchen Kalonji, Tim Killeen, Jakob Rhyner, Albert van Jaarsveld, Patrick Monfray, and Paul Rouse – who guided our work over the last two years. We are also grateful to specialist advice from Roberta Balstad and Roberta Johnson (for input on data and education sections respectively). The Transition Team was selected in the spirit of co-design of a new research agenda, and thus included researchers, funders and private and public sector stakeholders from many different countries and disciplines. We learned a lot from each other over the two years of discussion.

Steven Wilson and Deliang Chen, the current and former Executive Directors of ICSU were critical to the success of this project, travelling the world to ensure its success, and we are also particularly grateful to Heide Hackmann, Executive Director of ISSC who provided a sustained representation of the social science community throughout our work.

We are particularly thankful for the constructive engagement and invaluable contributions of the current leadership of the Global environmental change programs and their associated projects (the International Geosphere and Biosphere program, IBGP; the International Human Dimensions Program, IHDP; the World Climate Research Program, WCRP; Diversitas - biodiversity science; and the Earth System Science Partnership, ESSP). Without the strong engagement from GEC program directors, chairs of science committees and project leaders, Future Earth would not have emerged with such a strong potential of global scientific engagement and scientific integration. The staff, science committees and projects of the current global environmental change projects provided important insights to the process and we hope that this report reflects their hopes and concerns.

The Transition Team emerged as a result of the ICSU visioning process on Earth system research for global sustainability and the strategic dialogues on future research priorities developed by the Belmont Forum. We would, apart from the Belmont Forum, like to thank the Task team that led the ICSU visioning process, including Walt Reid (co-chair), Anne Whyte, Heide Hackmann, Kari Raivio, John Schellnhuber, Elinor Ostrom, K. Mokhele, Yuan Tse Lee, and Deliang Chen, who laid the foundation for the work of the transition team.

With tasks that include solving some of the most urgent challenges facing our society the transition team struggled with identifying priorities, themes and governance structures. This report reflects both consensus and compromise, and responds to inputs from many different constituencies. It is the start of what should be a step change in international collaboration in the service of all people on our planet – a major new effort to further raise our understanding of the dynamics of the Earth system, provide new knowledge and solutions for human prosperity and global sustainability, and identify transformations that create a better future for humankind.

Johan Rockstrom and Diana Liverman

Co-chairs, the Transition Team for Future Earth

Executive Summary

The need for a step change in Earth system research

Human activities are altering the Earth system with significant impacts on the environment at the local, regional and global scale. Changes in the Earth's climate and loss of biodiversity are undermining improvements in human wellbeing and poverty alleviation. The challenge of achieving a transition to global sustainability is urgent given the potentially catastrophic and irreversible implications for human societies. On one hand, this is a threat to human prosperity on Earth, on the other hand, it provides incentives to exploit and develop new opportunities for innovation that supports sustainable development.

Future Earth is a 10-year international research programme launched in June 2012, at the UN Conference on Sustainable Development (Rio+20) that will provide critical knowledge required for societies to face the challenges posed by global environmental change and to identify opportunities for a transition to global sustainability.

Future Earth will answer fundamental questions about how and why the global environment is changing, what are likely future changes, what are risks and implications for human development and the diversity of life on Earth, and what the opportunities are to reduce risks and vulnerabilities, enhance resilience and innovation, and implement transformations to prosperous and equitable futures.

Future Earth will deliver science of the highest quality, integrating, as necessary, different disciplines from the natural and social sciences (including economic, legal and behavioural research), engineering and humanities. It will be co-designed and co-produced by academics, governments, business and civil society from all regions of the world, encompass bottom-up ideas from the wide scientific community, be solution-oriented, and inclusive of existing international Global Environmental Change projects and related research activities.

Connecting research and responses to societal challenges

Future Earth will address issues critical to poverty alleviation and development such as food, water, energy, health, and human security and the nexus between these areas and the over-arching imperative of achieving global sustainability. It will provide and integrate new insights in areas such as governance, tipping points, natural capital, the sustainable use and conservation of biodiversity, lifestyles, ethics and values. It will explore the economic implications of inaction and action and options for technological and social transformations towards a low-carbon future. Future Earth will explore new research frontiers and establish new ways to produce research in a more integrated and solutions-oriented way.

Recent foresight exercises on the challenges facing Earth system research converged on the need for a step change[1] in both the conduct and support of such research. More disciplines and knowledge fields need to be engaged, bringing together both disciplinary and interdisciplinary excellence. Close collaboration between the scientific community and stakeholders across the public, private and voluntary sectors to encourage scientific innovation and address policy needs is essential. More financial support for these collaborations is required. Together, these changes will help realise a new 'social contract' between science and society to accelerate the delivery of the knowledge that society needs to address pressing environmental changes (Lubchenco 1998, ICSU 2011).

At the Rio+20 UN Conference on Sustainable Development in June, 2012, governments agreed to develop a set of Sustainable Development Goals (SDGs) that will integrate environment and development goals for all nations. Future Earth will provide integrative scientific knowledge needed to underpin the SDGs and sustainable development more broadly.

Future Earth will build upon and integrate the existing Global Environmental Change (GEC) Programmes – the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP), DIVERSITAS – biodiversity science, and the Earth System Partnership (ESSP). It will also have to expand significantly beyond the existing global networks and engage new institutions and researchers. It must ensure research excellence by being open and inclusive, attracting the brightest minds from a broad range of disciplines and countries.

The research and complementary capacity building and outreach activities of Future Earth will be co-designed by the broad community of researchers (including natural and social sciences, engineering and humanities) in partnership with governments and business and other stakeholders, in order to close the gap between environmental research and policies and practices. Future Earth will deliver a step-change in making the research more useful and accessible for decision-makers.

The conceptual framework

The conceptual framework for Future Earth (Figure 1), which will guide the formulation of research themes and projects, recognises that humanity is an integral part of the dynamics and interactions of the Earth System and that this has important implications for global sustainability. It recognises that many of those socio-environmental interactions occur across different spatial and temporal dimensions.

---

[1] "Towards a 10 year Earth System Research initiative for Global Sustainability - A joint statement of intent from the Belmont Forum1, ICSU2 and the ISSC" 2011 http://www.icsu.org/general-assembly/programme/general-assembly/documentation-for-delegates/30th-general-assembly-file-of-documents/8-earth-system-sustainability-initiative.pdf

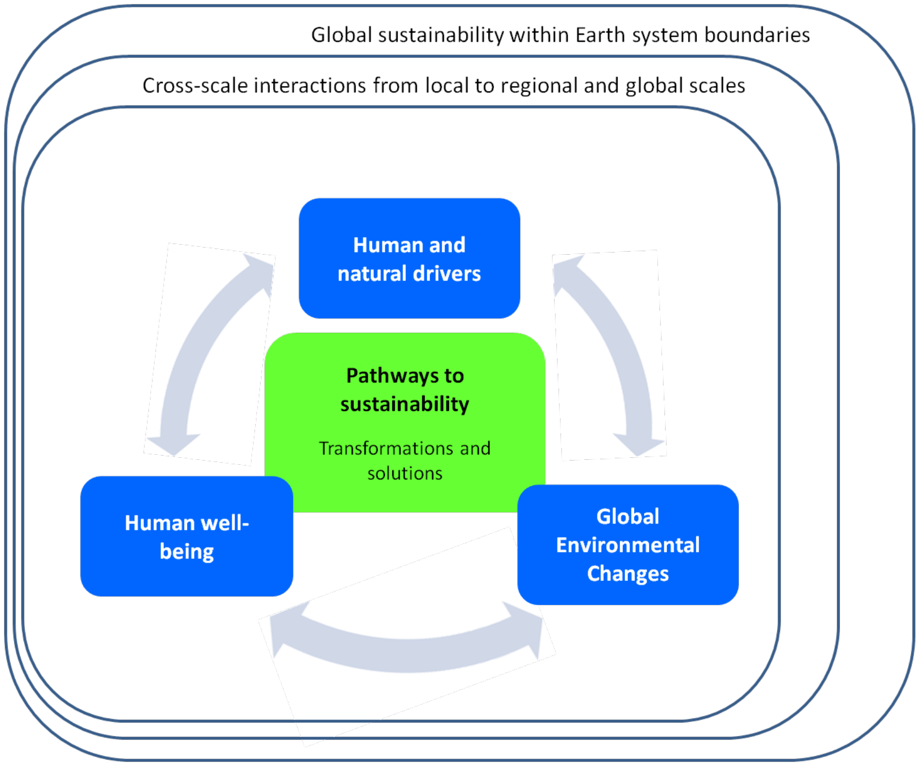


Figure 1: Schematics of the Future earth conceptual framework

The conceptual framework illustrates the fundamental interconnections between natural and human drivers of change, the resulting environmental changes and their implications for human well-being. These interactions take place across a range of time and spatial scales, and are bounded by the limits of what the Earth system can provide. It emphasises the challenge of understanding and exploring avenues for human development within Earth system boundaries. This fundamental, holistic, understanding is the basis for developing transformative pathways and solutions for global sustainability.

The initial research themes

The conceptual framework guides Future Earth research towards addressing key research challenges, expressed as a set of three broad and integrated research themes:

(i) **Dynamic Planet** - understanding how planet Earth is changing due to natural phenomena and human activities. The emphasis will be on observing, explaining, understanding, projecting Earth environmental and societal trends, drivers and processes and their interactions as well as anticipating global thresholds and risks. Building on existing knowledge, there will be a particular focus on interactions between social and environmental changes across scales

(ii) **Global Development** - providing the knowledge for addressing the most pressing needs of humanity including sustainable, secure and fair stewardship of food, water, biodiversity, energy, materials, and other ecosystem functions and services. The emphasis of this Future Earth research theme will be on understanding the impacts of human activities and environmental change on the health and well-being of people and societies and on the interactions of global environmental change and development.

(iii) **Transformations toward Sustainability** – providing the knowledge for transformation toward a sustainable future: understanding transformation processes and options, assessing how these relate to human values and behaviour, emerging technologies, and economic development pathways, and evaluating strategies for governing and managing the global environment across sectors and scales. The emphasis of Future Earth research will be on solution-oriented science that enables fundamental societal transitions to global sustainability. It will explore what institutional, economic, social, technological and behavioural changes can enable effective steps towards global sustainability and how these changes might best be implemented.

These research themes will be the main priorities for Future Earth research.

Cross-cutting capabilities

Addressing the proposed integrated research themes will depend on progress in and access to a number of core capabilities including observing systems, Earth system models, theoretical developments, data management systems and research infrastructures. Future Earth will also support and deliver scoping and synthesis activities, communication and engagement, capacity development and education, and effective interactions at the science-policy interface. These capabilities are essential to advance the integrated science of global environmental change and translate it into useful knowledge for decision making and sustainable development. Many of these capabilities lie beyond the boundaries of the Future Earth initiative per se, residing in national and international infrastructures, training programmes, and disciplines. It will be important that Future Earth works in partnership with the providers of these capabilities for mutual benefit.

The governance structure

The governance structure of Future Earth (Figure 2) embraces the concepts of co-design and co-production.

The Science and Technology Alliance for Global Sustainability is responsible for establishing Future Earth and will promote and support its development as the programme's sponsors. Its members consist of the International Council for Science (ICSU), the International Social Science Council (ISSC), the Belmont Forum of funding agencies, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the United Nations University (UNU), and the World Meteorological Organization (WMO) as an observer. Future Earth is led by a Governing Council, and supported by two advisory bodies: an engagement committee and a science committee.

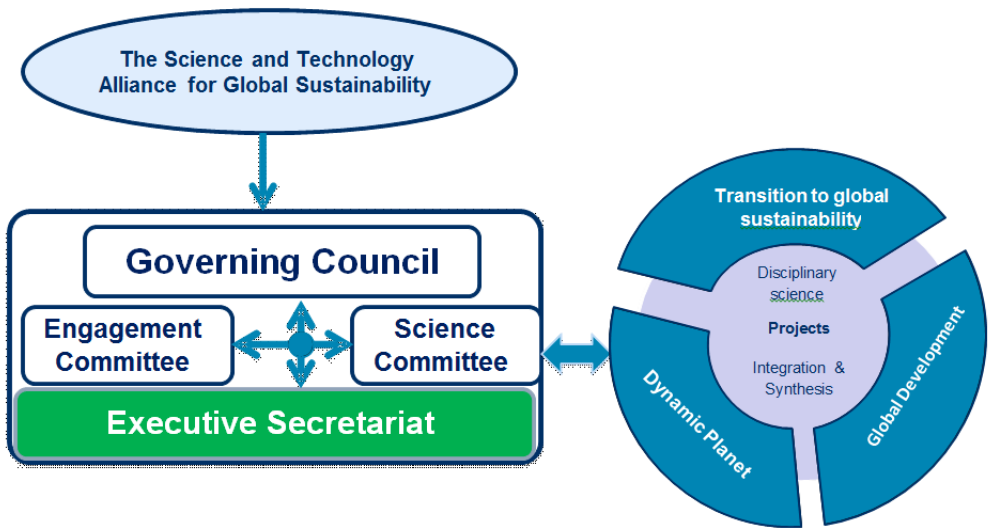


Figure 2: Schematics of the organisational structure of Future Earth

The Governing Council and its subsidiary bodies will, as appropriate, involve representatives from the full range of stakeholder communities (academia, funders, governments, international organisations and science assessments, development groups, business and industry, civil society, and the media).

The Governing Council is the ultimate decision-making body and is responsible for setting Future Earth's strategic direction and policies. The science committee will provide scientific guidance, ensure scientific quality and guide the development of new projects. The engagement committee will provide leadership and strategic guidance on involving stakeholders throughout the entire research process from co-design to dissemination, ensuring that Future Earth produces the knowledge society needs. The Executive Secretariat will perform the day-to-day management of Future Earth, ensuring the coordination across themes, projects, regions and committees, and liaising with key stakeholders. It is expected that the secretariat will be regionally distributed. The development of National Future Earth committees will also be actively encouraged.

Towards a funding strategy

Future Earth will require both innovative funding mechanisms and enhancement of existing support. The success of the programme will depend on continued support for essential disciplinary research and infrastructures and a substantial strengthening of the funding bases for trans-disciplinary research and coordination activities. The Alliance will work with the Governing Council and Future Earth secretariat to secure new and enhanced sources of funding. Already the Belmont Forum has launched in 2012 a new open and flexible process to support international collaborative research actions through annual multi-lateral calls. Members of the Belmont Forum and of the International Group of Funding Agencies for global change research (IGFA), will need to proactively engage with other funders at national and regional levels to create adequate support. Strengthened engagement with development donors, the private sector and philanthropic foundations will be part of a diversified Future Earth funding strategy.

Towards a new model of Communications and Engagement

Future Earth will position itself as a lead provider of independent and innovative research on global sustainability. It will provide a vibrant, dynamic platform that encourages dialogue, accelerates knowledge exchange, and catalyses innovation. Future Earth will develop a comprehensive flexible communications strategy to engage all relevant users, at regional and global level, working with regional partners to engage locally, combining the traditional top-down expert information sharing approach with more inclusive iterative dialogue and exploratory participatory and bottom-up approaches. New social media and web technologies provide exciting opportunities and the expertise to take full advantage of these must be embedded in the Future Earth secretariat.

Education and capacity building

Future Earth will partner with programmes and networks that already work in the educational sector to ensure rapid dissemination of research findings and their implications for global sustainability to support formal science education at all levels. The identification of effective partners is critical to the success of Future Earth in the complex arena of formal education, with its diversity of local and national mechanisms, cultures and languages. The strengthening of existing partnerships with networks of science and technology centres also provides a valuable mechanism for contributing to the 'informal' education sector.

Future Earth has identified capacity building as a basic principle of all its activities and will adopt a multi-tiered approach to scientific capacity building, with both dedicated capacity building actions and capacity building embedded across all its activities and projects. Dedicated capacity building actions will include building a strong international network of scientists committed to international interdisciplinary and trans-disciplinary research, a particular focus on early-career scientists and the development of institutional capacity. There will be a strong emphasis working on enhancing science capacity in lesser developed countries, with regional partners playing an important role.

1. Overview

1.1. Why Future Earth?

Human activities are altering the Earth system in ways that threaten well-being and development (Steffen et al., 2004; Steffen et al., 2011). We have entered a new geological epoch, the Anthropocene (Crutzen 2002; Zalasiewicz et al., 2010), in which our activities significantly impact many global processes in the Earth system, and together with natural variations, are leading to dangerous global environmental changes. There is growing evidence that a transformation to global sustainability is necessary to secure global prosperity in the future, and this will require important shifts in governance and development paradigms (Galaz et al., 2012; Kanie et al., 2012). Human knowledge and ingenuity in an increasingly interconnected world offer many possibilities for innovation to respond to these changes and to create new opportunities for individuals, communities, firms and countries to thrive (WBGU, 2011).

Global environmental changes have regional and local impacts, undermining natural resources and ecosystem services. The cross-scale interactions between human activities, large scale changes in the Earth system, and local impacts have important implications for human development and create many of the sustainability challenges facing society. Evidence increasingly suggests that global sustainability is a prerequisite for human wellbeing at local as well as global scales (IPCC 2007; UNEP 2012a; MA, 2005). Failure to move towards global sustainability will likely cause more global environmental changes, with their consequent regional and local impacts, such as flooding, drought, land use change, biodiversity loss and sea-level rise. Prosperity is likely to be limited to those that can afford to adapt while others could suffer disproportionately. However, in today's globally connected world, local conditions and crises can magnify across scales and societies with effects on perceptions, mobility, trade, economics and political stability. Knowledge-based solutions are needed to provide food, water, and energy security for all, and to allow humanity not just to survive, but to thrive, as we resolve the sustainability challenges of economic development, demographic change, climate change and the loss of biodiversity.

The terms sustainability and sustainable development have become common currency in the international science and policy community. The most frequently cited definition of sustainable development is that of the Brundtland Commission that in 1987 wrote that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". For many scholars and practitioners there are three pillars of sustainability: environmental (or ecological), social, and economic with others seeing sustainable development as based in a respect for nature, human rights, and economic justice. The 2012 report of the High-level panel on global sustainability wrote "sustainable development is fundamentally about recognizing, understanding and acting on interconnections — above all those between the economy, society and the natural environment. Sustainable development is about seeing the whole picture —

such as the critical links between food, water, land and energy. And it is about ensuring that our actions today are consistent with where we want to go tomorrow" (Bruntland, 1987; Brown et al. 1987; GSP, UN, 2012).

The challenge of achieving a transition to global sustainability is not only large in scale - it is also urgent. There is growing evidence that the climate is changing and critical environmental services are degrading, and that there are risks of crossing critical tipping points in the Earth system. These changes can have potentially catastrophic and irreversible implications for human societies (Lenton et al., 2008; Schellnhuber 2009; Rockström et al., 2009). There are also many important, unanswered questions relating to the global environmental change, sustainability and the basic functioning of the Earth system that need to be addressed.

Evidence to date indicates that little progress is being made towards sustainability. For example, UNEP's recently published Global Environmental Outlook-5 (2012a) assesses the state of the environment in different regions, for different sectors and for the world as a whole, and concludes that we are not moving towards sustainability, with only 3 of 90 indicators showing significant improvement. Development indicators have shown some improvement, yet about a billion people remain poor and hungry (UNMDG, 2012) and many more experience chronic threats to their livelihoods, health, and well-being.

At Rio+20, the nations of the world agreed to develop Sustainable Development Goals that integrate environmental and development indicators to set targets for the future, and discussed other options and opportunities for environmental stewardship and equitable development. There are calls for science to provide the knowledge base for these and other efforts to build a sustainable, just and prosperous future for current and future generations. *The Future We Want*, as the outcome document of the Rio+20 UN Conference on Sustainable Development, provides a clear statement in this direction:

> *"We recognize the important contribution of the scientific and technological community to sustainable development. We are committed to working with and fostering collaboration among academic, scientific and technological community, in particular in developing countries, to close the technological gap between developing and developed countries, strengthen the science-policy interface as well as to foster international research collaboration on sustainable development". (Paragraph 48)*

Future Earth can play a key role in providing scientific advice and expertise to the United Nations post-Rio+20 and post 2015 processes, including the definition and monitoring of Sustainable Development Goals, a UN 'high level political forum' on sustainable development, the science-policy interface within UNEP, and ongoing assessment processes such as the IPCC.

The international research community has a number of organisations and networks that promote international science coordination and collaboration to understand the causes and consequences of global environmental change. Notably, these include the existing Global Environmental Change programmes – the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), DIVERSITAS, and the International Human Dimensions Programme (IHDP). Together with their numerous research projects, these programmes have delivered essential advances in understanding global environmental change and they have created important networks of researchers and connections to decision makers.

In 2001 the global change research programmes (WCRP, IGBP, IHDP and DIVERSITAS) issued the Amsterdam Declaration on Global Change calling for a new system of global environmental science that would draw upon the disciplinary base of global change science and integrate across disciplines, environment and development, natural and social sciences, and international boundaries[2]. They jointly established the Earth System Science Partnership (ESSP). A 2008 review of the ESSP recommended stronger engagement with policy and development, greater scientific focus and more resources, a greater commitment to an integrated approach to global environmental change and governance options that included a consolidated secretariat or a fusion of the parent programmes.[3] Subsequent reviews of individual programmes confirmed the need for change. ICSU and ISSC then initiated a wide consultation to explore options for a holistic strategy for earth system research. The report of this Earth System Visioning process for the next decade of Earth system research (ICSU/ISSC, 2010) identified grand challenges that addressed the intersection of global environmental change and sustainable development. These challenges included forecasting future environmental changes and their consequences, enhancing observations, anticipating disruptive change, changing behaviour, and encouraging innovation for sustainability (Reid et al, 2010).

The Visioning process called for both disciplinary and interdisciplinary research, and new partnerships between researchers, research funders and users to coordinate and co-design research. At the same time a consortium of research funders issued the Belmont Challenge with the goal of delivering knowledge needed for action to avoid and adapt to detrimental environmental change including extreme hazardous events. They identified priorities that included the assessment of risks, impacts and vulnerabilities, advanced observing systems and environmental information services, interaction of social and natural sciences and effective international coordination (Belmont Forum 2011).

The potential and urgency of a coordinated scientific and societal response to global environmental change was highlighted at the 2012 Planet under Pressure conference, organized by the global environmental change programmes. The conference declaration called for a new approach to research that is more integrative, international and solutions oriented; reaching across existing research programmes and disciplines, north and south, and with input from governments, civil society, local knowledge, research funders and the private sector (Planet under Pressure 2012). This call was echoed

---

[2] The Amsterdam Declaration on Global Change 2001, see http://www.essp.org/index.php?id=41.

[3] ICSU-IGFA Review of the Earth System Science Partnership 2008, see http://www.icsu.org/publications/reports-and-reviews/essp-review.

in the Rio+20 declaration and the UN Secretary General's Global Sustainability Panel report with the latter calling for a major global scientific initiative to strengthen the interface between policy and science (UNCSD 2012; UNEP 2012b).

1.2. What is Future Earth?

Future Earth is the response to calls for international, integrated, collaborative and solutions-oriented research to respond to the urgent challenges of global environmental change and sustainable development.

Future Earth is conceived as a 10-year programme that builds upon Earth system science and brings together global environmental change researchers to further develop interdisciplinary collaborations that address critical questions. Future Earth will develop research to better understand changing natural and social systems; observe, analyse and model the dynamics of change and especially human-environment interactions; provide knowledge and warnings of risks, opportunities and dangers; and define and assess strategies for responding to change, including through the development of innovative solutions. It provides the opportunity for scientists from within and outside existing international programmes, projects and initiatives to work together under a unifying framework.

The following questions represent some of the sustainability challenges where Future Earth research is expected to make a major contribution:

- How can freshwater, clean air, and food be sustainably secured for the world population today and in the future?
- How can governance be adapted to promote global sustainability?
- What risks is humanity now facing as global growth and development place unprecedented pressures on ecosystems? What are the risks of crossing tipping points with serious implications for human societies, and the functioning of the Earth system, and the diversity of life on earth?
- How can the world economy and industries be transformed to stimulate innovation processes that foster global sustainability?
- In a rapidly urbanizing world, how can cities be designed to sustain a high quality of life for more people, and have a sustainable global footprint that considers the human and natural resources they draw on?
- How can humanity succeed in a rapid global transition to a low-carbon economy that secures energy access for all?
- How can societies adapt to the social and ecological consequences of a warming world, and what are the barriers, limits and opportunities to adaptation?
- How can the integrity, diversity and functioning of ecological and evolutionary systems be sustained so as to sustain life on earth and ecosystem services, and to equitably enhance human health and well-being?

- What lifestyles, ethics and values are conducive to environmental stewardship and human welfare and how might these contribute to support a positive transition to global sustainability?
- How does global environmental change affect poverty and development, and how can the world alleviate poverty and create rewarding livelihoods which help achieve global sustainability?

There are many areas where Earth system research can contribute to better understanding these challenges and help identify solutions. For example, observing, documenting and forecasting the dynamics and interactions of Earth system components, including social elements, will provide the knowledge needed to assess the state of the planet, understand the risks and opportunities in where we may be heading, and explore alternative scenarios for the future. Understanding the relationships between biological diversity and ecosystem function will play a critical role in sustaining the services provided by nature (e.g. healthy soils, clean water, fresh air, genetic variation). Evaluating the potential and risks of new technologies can identify new options for human development and environmental restoration. Analysing the effectiveness of different response options to environmental change, and identifying the longer term social transformations associated with the responses, will help identify pathways to sustainability.

1.3. What is the added value of Future Earth?

Future Earth intends to add value to existing research activities by emphasising:

Co-design of research and activities: Future Earth aims to close the gap between environmental research and current policies and practices. Future Earth invites the broad community of researchers working within the natural and social sciences, engineering and the humanities to engage in developing knowledge that is co-designed with those who use research in governments, business, and civil society. Such co-design means that the overarching research questions are articulated through deliberative dialogues among researchers and other stakeholder groups to enhance the utility, transparency, and saliency of the research. This approach embraces the concept of a new 'social contract' between science and society (Lubchenco 1998, ICSU 2011).

International and regional emphasis: Future Earth prioritises research that requires international cooperation to succeed because the research and solutions are difficult to implement at the national level only. In this context, it will include national or locally placed and comparative research that has international implications. Future Earth must be inclusive, involving researchers from countries around the world and building capacity where needed, especially in the least developed countries. Future Earth recognizes the added value of regional research collaborations where common questions, challenges, projects and solutions are best designed and implemented within and between clusters of countries and among researchers that share common problems, regional concerns, and cultural perspectives.

Decision support and improved communication: Future Earth intends to deliver a step change in making research more useful and accessible for decisions and solutions that can be made by governments, business and civil society regarding environmental change and sustainable development. In addition to the principle of co-design, this means that Future Earth should develop best practices in integrating user needs and understanding of the research, making research accessible to all parties, communicating risks and uncertainty, developing and diffusing useful tools for applying knowledge, resolving conflicts, respecting and including local knowledge and supporting innovation.

Support for intergovernmental assessments: Future Earth will also respond to the research needs identified by major global and sectoral assessments such as the Intergovernmental Panel on Climate Change (IPCC 2007), the Millennium Ecosystem Assessment (2005), and the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, McIntyre et al 2009). The new Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), the Assessment of Assessments (AOA) on the oceans, and the emerging process to develop Sustainable Development Goals (SDGs) provide other important opportunities for researchers to contribute and collaborate through the mechanisms and networks of Future Earth. Alliances with major international agencies that regularly provide reports on environment and development, such as WMO, UNEP and UNESCO, provide opportunities to ensure that Future Earth research responds to and informs stakeholder needs for up to date information and indicators of high scientific quality.

In the wake of Rio+20, Future Earth can enhance the contribution of the scientific community to sustainable development by increasing scientific collaboration between countries, disciplines and sectors. It should provide the basis for a more effective interface between science and policy (see Annex 2 for further details).

1.4. Key principles of Future Earth research and governance

Future Earth will be guided by the strategic research framework set out in this document and its research will operate according to the following principles. Future Earth will:

- *Promote scientific excellence:* An overarching element to these key principles is Future Earth's commitment to support science of the highest quality.
- *Linking earth systems research to global sustainability:* Future Earth does not encompass all environment and development research but focuses on integrated earth systems research and global sustainability.
- *Be international in scope*: Future Earth focuses on areas where international research co-ordination is needed.
- *Promote integration*: Future Earth should draw on expertise in natural and social science, as well as engineering, the humanities and professions such as planning and law.
- *Encourage co-design* and co-production: the research agenda and programmes should be co-designed and, where possible, co-produced by researchers in collaboration with various stakeholders in governments, industry and business, international organisations, and civil society.

- *Be bottom-up driven*: the Future Earth approach will emphasize the importance of 'bottom-up' ideas from the research community and other stakeholders in designing the projects that respond to sustainability challenges.
- *Provide solution-oriented knowledge*: Future Earth will provide foresight of changes and risks, evaluating the effectiveness of responses and providing a knowledge base for new innovations and policies.
- *Be inclusive*: Future Earth will include existing international Global Environmental Change programmes and projects and related trans-national and national activities in a framework that strengthens existing endeavours and provides new opportunities. Attention will be given to regional engagement, geographic and gender balance, capacity building and networking.
- *Be responsive and innovative*: The governance and organisational structure for Future Earth must be fit-for-purpose, leave room for adaptation as the programme develops, and especially enable step-changes in the delivery of research for sustainability.
- *Be sensitive to Future Earth's own environmental footprint*: Special consideration will be given to the environmental impacts resulting from the implementation of Future Earth. For instance, greenhouse emissions related to operations (travel for meetings etc.) will be tracked and minimised wherever possible.

1.4.1. Building Future Earth's approach to co-design

One of the most innovative and challenging aspects of Future Earth is the idea of co-design and co-production of relevant knowledge. This requires an active involvement of researchers and stakeholders during the entire research process. Such co-design is also endorsed by the UN Conference on Sustainable Development (Rio+20, June 2012) in its 'Future we want' document (United Nations 2012). This document clearly states the importance of enhanced involvement of stakeholders.

Integrating global environmental change issues with development and sustainability issues involves many complexities and uncertainties and must incorporate understanding of societal norms, values and perspectives (Kates 2011). Under such conditions, science has up-to-now tended to provide mainly understanding but not answers or comprehensive solutions (e.g. Funtowicz and Ravetz 1990, Klein 2004b). Co-design is one way to address this, and it has already shown its value and utility in fields where science and policy meet. Experiences with co-design and co-production of knowledge are discussed at length in the scientific literature (e.g. Alcamo et al. 1996, Lemos and Morehouse 2005, Scholz et al. 2006, de la Vega-Leinert et al. 2008, Pohl 2008, Brown et al. 2010, Scholz 2011, Lang et al. 2012). In development research participatory approaches are common (e.g. Chambers 2002) and in science-policy research different dialogue approaches have evolved (e.g. van den Hove 2007). Co-designed and co-produced research is also sometimes referred to as 'transdisciplinary' (e.g. Klein 2004a and b).

Co-design and co-production of knowledge include various steps where both researchers and other stakeholders are involved but to different extents and with different responsibilities (Figure 1). Whilst researchers are responsible for the scientific methodologies, the definition of the research questions and the dissemination of results are done jointly. Co-design and co-production also recognises that researchers, information and models are now based in many different types of organisation and the great benefits from research collaborations between, for example, universities, NGOs, and the private sector. One of the main challenges is how to build trust among all stakeholders, and to ensure continuous engagement. The challenges of co-design and particularly co-production are not underestimated by the Transition Team, and it is recognised that the programme will need to support the research community and stakeholders to develop and share the necessary skills. It is also recognised that the focus for this way of working should be on where the research and stakeholder community feel that it will bring the greatest benefits.

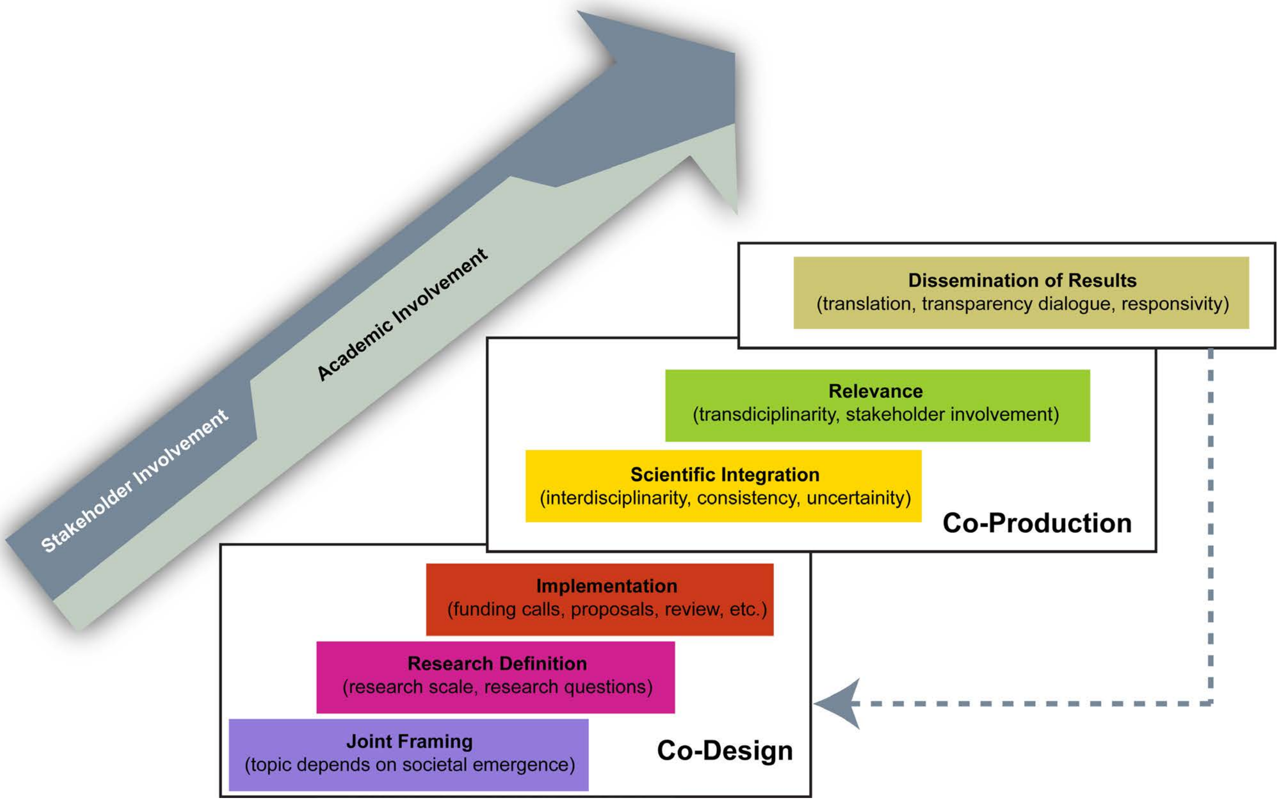


Figure 1: Steps and involvement in co-design and co-production of scientific knowledge[4]

---

[4] Mauser W, Klepper G, Rice M, Schmalzbauer BS, Hackmann H, Leemans R, Moore H: Transdisciplinary global change research: the co-creation of knowledge for sustainability. Current Opinion on Environmental Sustainability 2013, (Submitted)

1.4.2 Future Earth major stakeholder groups

The major stakeholder groups identified so far as relevant to Future Earth are shown in Figure 2.

Figure 2: Future Earth's main stakeholder groups

The stakeholder communities that could potentially be interested in Future Earth knowledge are heterogeneous. It is therefore difficult to unambiguously classify them into distinct groups. However, eight major categories of stakeholders can be distinguished:

- *Academic Research*: This essential stakeholder group includes individual scientists, research institutes and universities, who provide both the scientific knowledge necessary to accomplish the ambitions of Future Earth, as well as scientific expertise, methodology and innovation. Individual researchers and their students, and internationally oriented research institutes should all be able to contribute to and benefit from Future Earth.
- *Science-policy interfaces*: Organisations at the interface between science and policy assess the status of scientific evidence and 'translate' it into policy-relevant information. These include integrated assessments such as the Ozone Assessment, IPCC, the Millennium Assessment, and more recently, IPBES. They also include a variety of other 'boundary' organisations and structures such as the Sustainable Development Solutions Network. There are also other bodies that undertake this role.
- *Research Funders*: National research funding organisations are important catalysts of innovative disciplinary and interdisciplinary research. They are often relatively independent parts of governments or private foundations. Funders support peer-reviewed research projects and

research infrastructures. They also support the training and career development of researchers and work with them to inspire young people and engage the wider public with research. Some trans-national research funders, most notably the European Commission, play a similar role at the regional level. Funders are important stakeholders as intermediaries between researchers, governments, and other stakeholders.

- *Governments (national, regional and international)*: Governments are responsible for managing and balancing the short and long-term well-being of their citizens, business, environments and resources. Governments operate at many different levels (e.g. municipalities, states, nations and internationally). Future Earth should work at supra national and international levels and work with regional partners to support more local needs. Key stakeholders include the various UN-organisations and programmes, and the international conventions such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD).

- *Development groups*: Some of these organisations (e.g. World Bank) focus on promoting social and economic development in less developed countries. Others play a role in amplifying the voices of the poorest people in the decisions that affect their lives, improving development effectiveness and sustainability and holding governments and policymakers to account. Many organisations (see e.g. http://www.devdir.org) share in such development work, including civil society organisations, academic and research institutions, governments, faith-based organisations, indigenous peoples' movements, foundations and the private sector.

- *Business and industry*: This sector supports the majority of the world's research and development and is a critical group of stakeholders to be engaged in Future Earth. There are many different industry sub-sectors with different interests, including: primary and secondary productive industries (e.g. mining, manufacturing, agriculture and construction), a wide variety of financial, health and other services and consultancies, and consumer focused business such as retail and media. Some industry organisations (e.g. the World-Business Council for Sustainable Development - WBCSD) do cover a broad range of interests and could potentially represent these in Future Earth at the global level.

- *Civil society*: These are groups organised independently from governments and governmental institutions. Civil society groups have organised themselves to represent their interests with governments or other influential actors. The non-governmental organisations (NGOs) have nowadays taken over some roles that traditionally have been the responsibility of local or national governments. NGOs have also been instrumental in national and international policy negotiations and in producing research reports. All these accomplishments increase the relevance of these actors to Future Earth. Civil society in this document includes indigenous communities, recognising the important knowledge that these groups can offer and the important role they can play in Future Earth.

- *Media*: Media here refers to communication intermediaries and organisations that use both traditional and electronic means to gather and distribute information, and are central to the broader influence of any network or concern - scientific, corporate, financial, cultural, industrial, political or technological. The media represent a fast changing landscape, which will continue to evolve rapidly during the lifetime of Future Earth. It is not just an outlet for communication, but also a stakeholder group that does its own research and can help broker messages between the local and global scales and different stakeholders.

1.5. The Science and Technology Alliance for Global Sustainability

Future Earth is a programme of the Science and Technology Alliance for Global Sustainability. The 'Alliance' is an international partnership based on a shared commitment to address the needs of global sustainability through the application of science and technology. The Alliance vision is: a sustainable world where decision-making is informed by the best available scientific evidence, and in which its mission is to encourage and facilitate the co-design, co-production and co-delivery of knowledge with relevant stakeholders in order to address and create solution pathways for global sustainability problems. Future Earth is the Alliance's first initiative.

The Alliance operates as an informal body comprising stakeholders from the research and education community, research funders, operational service providers and users. The present members include:

- International Council for Science (ICSU)
- International Social Science Council (ISSC)
- Belmont Forum / IGFA (groups of major research funders)
- UN Educational Scientific and Cultural Organisation (UNESCO)
- UN Environment Programme (UNEP)
- UN University (UNU)
- World Meteorological Organization (WMO) as an observer.

Other organizations have also expressed interest in joining the Alliance as Future Earth moves into an implementation phase.

More generally, the Alliance partners collaborate on:

- Promoting and monitoring the vitality of the international science, technology and innovation system
- Marshalling resources needed to support a successful Future Earth programme
- Incentivizing the cooperation of natural, social (including economic and behavioural), engineering and human sciences in developing integrated solution pathways.
- Fostering the use of science, technology and innovation in equitable, sustainable decision making and practice at all levels, taking into account environmental, societal, cultural and geographic diversity.

2. Research framework

This chapter presents the conceptual framework for Future Earth, and a set of research themes which follow. It identifies a set of cross-cutting capabilities, such as observing, modelling and assessment which will require important partnerships with other organisations. The framework is intentionally broad, to encourage the inspiration and innovation of the science community, working with other stakeholders.

2.1. A Conceptual Framework for Future Earth

Overall framing

The conceptual framework for Future Earth, which guides the formulation of its research themes and projects, takes as its starting point the recognition that humanity is an integral part of the dynamics and interactions of the Earth system[5] and must operate within its boundaries. From the local to global scales, human activity is influencing environmental processes, whilst at the same time, human well-being depends on the functioning, diversity and stability of natural systems. The overall framing of Future Earth focuses on social-environmental interactions and their implications for global sustainability. The Transition Team agreed to use a simple conceptual framework, illustrated in Figure 3 and described below.

Human activities and development generate environmental impacts at the local, regional and global scales that interact with natural drivers of change. Global environmental change (e.g. climate change, land use change) is a result of complex social-environmental interactions between components of the Earth system, in which local to regional impacts on the environment can generate feedbacks, sometimes with unexpected outcomes.

Human well-being depends on many ecosystem functions and services (including regulating, supporting, provisioning and cultural services). The sustainable delivery of food, water, energy and materials, and the regulation of natural hazards, diseases, pests, pollution and climate all depend on the functioning and interactions among the components of the Earth system; in the biosphere (the diversity and

---

[5] The Earth System includes the coupled human-environment processes that determine the state and operations of planet Earth. It is defined as the integrated biophysical (e.g., the climate system and the hydrological cycle) and socio-economic processes (e.g., our globalised economy) and interactions (e.g., the carbon and nitrogen cycles) among the atmosphere, hydrosphere, cryosphere, biosphere, geosphere and the anthroposphere (human enterprise) in both spatial - from local to global – and temporal scales, which determine the environmental state of the planet within its current position in the universe. The human enterprise is a fully coupled interacting component of Earth System (Steffen et al., 2004).

abundance of life on land and in the oceans), the atmosphere (the climate system, weather patterns, ozone layers), the geosphere (natural resources and material flows) and cryosphere (ice sheets providing climate regulation and ecological habitats).

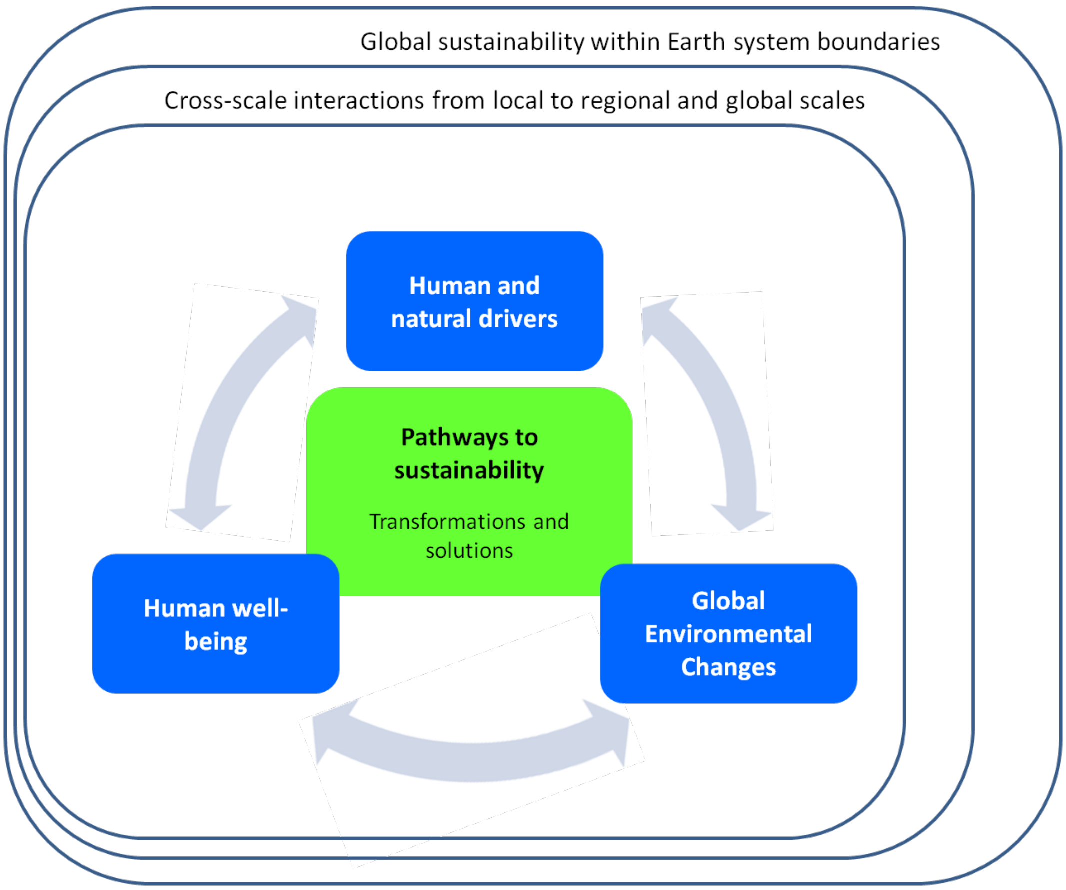


Figure 3: The conceptual framework illustrates the fundamental interconnections between natural and human drivers of change, the resulting environmental changes and their implications for human well-being. These interactions take place across a range of time and spatial scales, and are bounded by the limits of what the Earth system can provide. It emphasises the challenge of understanding and exploring avenues for human development within Earth system boundaries. This fundamental, holistic, understanding is the basis for advancing transformative pathways and solutions for global sustainability.

The impacts of global environmental change on people and societies in turn depend on their social and environmental vulnerabilities and resiliencies. Understanding impacts on societies thus requires knowledge of the resilience of local to regional ecological and evolutionary systems and societies, to both natural variability and human-induced changes in the global environment.

Humans respond to impacts of global environmental change through a wide spectrum of strategies for mitigation, adaptation, innovation and transformation. The way societies respond to observed impacts or forecasts of environmental change depend on a complex mix of political, cultural, economic, technological and moral dimensions. Knowledge plays a critical role in informing all aspects of societal change, both in terms of providing insights of risks and opportunities, and in providing new solutions for adaptation and transformation in the face of global environmental risks.

Human responses and changes in development, can contribute to new drivers of change. These may reduce the risks of environmental change and help identify trajectories towards sustainability, or create additional challenges. Achieving global sustainability will require fundamental, innovative and long-term transformations. This will call for new scientific research on the environment, economics, social dynamics and governance of global change.

While the conceptual framework emphasizes the Future Earth focus on global environmental change and global sustainability, it also recognizes cross-scale interactions, interdependencies and feedbacks across its components.

2.2. Initial Research Agenda

Introduction

In line with the conceptual framework presented above, Future Earth will answer fundamental questions about ***how and why the global environment is changing, what are likely future changes, what are the implications for human development and the diversity of life on earth, and what the opportunities are to reduce risks and vulnerabilities, enhance resilience, and create transformations to prosperous and equitable futures.***

The transition team proposes that Future Earth research is organized around three broad and integrated research themes: *Dynamic Planet*; *Global Development*; and *Transformations toward Sustainability*. These themes are derived from the conceptual framework (Figure 3) and respond to the needs to: 1) understand how the Earth system is changing, 2) provide knowledge to support human development priorities, and 3) implement transformations that move us towards sustainability.

The proposed research themes build upon and integrate existing research agendas and science plans, and incorporate new areas of investigation. The themes and questions are intended to promote discussion, consultation, user engagement and research planning in a co-design mode. They will be addressed by a number of existing and new research projects, with some projects contributing to more than one research theme. Each research theme addresses a series of cross-cutting research questions that build on the overall conceptual framework of Future Earth.

The science within the research themes will be underpinned by a set of crosscutting capabilities that are necessary to carrying out the research agenda. In many cases these required crosscutting capabilities—such as observations, models and theoretical frameworks—will be brought into Future Earth through partnership arrangements. The Transition Team also identified important crosscutting activities that will support Future Earth communications and engagement activities, research infrastructures, observation systems, capacity building and education, science-policy interactions and contributions to assessments. The description of these technical capabilities such as model and data management, is provided in section 2.1.2. while communication and engagement, education and capacity building are discussed respectively in sections 4 and 5.

2.1.1 Research themes

Research themes constitute the most general organisational units for research under Future Earth, and will function as broad platforms for strategic and integrated Earth system research. The themes are broad and each calls for collaboration across a range of research areas and disciplines.

The proposed themes below were developed by the Transition Team and have been revised in response to initial consultations. Supported by the set of crosscutting capabilities, these themes propose an initial structure for the implementation of Future Earth. There are many options for organizing research priorities and themes – for example around basic human development needs (water, food, energy, genetic diversity) or by earth system components (climate, land, oceans). The proposed research themes are designed to 1) build on the agenda set out by the ICSU/ISSC Visioning process and Belmont Forum 2) provide opportunities for existing GEC projects[6] to become associated with Future Earth and 3) respond to new and urgent calls for research to inform development and to identify the social, technological, economic and other transformations towards sustainability.

	Proposed Research themes
1	**Dynamic Planet**: Observing, explaining, understanding, and projecting earth, environmental, and societal system trends, drivers and processes and their interactions as well as anticipating global thresholds and risks.
2	**Global development:** Knowledge for the pressing needs of humanity for sustainable, secure and fair stewardship of food, water, biodiversity, energy, materials and other ecosystem functions and services.
3	**Transformation towards Sustainability**: Understanding transformation processes and

[6] While specific projects are mentioned in the description of the themes, they do not provide a comprehensive list of all the GEC projects associated to the GEC programmes or their partnership, but rather provide examples to illustrate how current activities have inspired the Future Earth research agenda and how these activities could be continued and strengthened within Future Earth. Annex 7 provides a more comprehensive list of GEC programmes and projects.

	options, assessing how these relate to human values and behaviour, emerging technologies and social and economic development pathways, and evaluating strategies for governing and managing the global environment across sectors and scales.

Table 1: Future Earth research themes

A description of the three themes follows. While some current GEC projects are mentioned in the description of the themes, this should not be considered as an exhaustive analysis of all existing activities. The Transition Team hopes that many more projects, inside and outside of the framework of the current GEC programmes (IGBP, IHDP, Diversitas, WCRP and ESSP) will connect and contribute to these themes.

(See annex 7 for a listing of existing GEC projects sponsored by IGBP, IHDP, Diversitas, WCRP and ESSP).

Theme 1: Dynamic Planet

Observing, explaining, understanding, projecting earth, environmental and societal system trends, drivers and processes and their interactions as well as anticipating global thresholds and risks.

The Dynamic Planet research theme will provide the knowledge needed to understand observed and projected trends in the Earth system, including both natural and social components, variations and extremes, and interactions globally and regionally. It encompasses research questions and projects that seek to observe, monitor, explain, and model the state of the planet including its societies and the potential for abrupt and potentially irreversible changes. The Dynamic Planet research theme has a particular goal of providing the science base for reports and assessments of the state and trends of the planet and providing early warnings of extreme events, vulnerabilities, and thresholds.

The global change research community has a continuing role to contribute to knowledge about our changing planet – understanding how and why the planet is changing and forecasting likely futures. Working with other critical partners (such as United Nations and national data and information agencies) the research community provides observations, models, analyses and projections that help society and decision-makers understand past, present and future changes and interactions in global climate, air quality, ecosystems, watersheds, oceans, ice cover, and the natural and human drivers of environmental changes. The human drivers include production and consumption, land use, natural resource exploitation, population dynamics, trade, technology and urbanization, as well as the values and policies that influence these drivers.

Assessments such as the IPCC and the Millennium Ecosystem Assessment, the periodic Global Environment Outlook (GEO) reports from UNEP, the Global Biodiversity 3 Outlook (GBO-3, Pereira et al. 2010) and 4 of the Convention on Biological Diversity (GBO-4), and annual reports of organizations such as the World Bank, United Nations Development Programme (UNDP) and FAO make extensive use of such knowledge but also reveal important gaps in geographic and temporal observations, understanding of system processes, and confidence in observations and projections. This knowledge also contributes to establishing and monitoring indicators and objectives such as the Millennium Development Goals (MDGs) and future Sustainable Development Goals. The information in assessment reports is widely used to build awareness about global environmental change, to provide future scenarios, to inform negotiations about environment and development, and to guide action on environmental issues. Global environmental change researchers have provided important forecasts and warnings of risks associated with extreme geophysical events, social vulnerabilities to environmental change, biodiversity loss, newly emerging risks (such as the ozone hole, ocean acidification, or infectious diseases), critical zones, and potential tipping points and thresholds. The risk that human activity will trigger rapid or irreversible changes in the Earth's key systems, highlights the need for more research to understand the risk of tipping points, and explain, map and predict vulnerability.

Future Earth will place a particular emphasis on research related to the development of early warning systems for abrupt and irreversible change that would be of use to decision makers, resource managers and business. Climate change is only one focus of such warning systems, which might also anticipate and warn of rapid changes in forest cover, ocean conditions, biodiversity, or water quality. A focus on vulnerability and resilience within this Future Earth theme is an excellent opportunity for the disaster risk reduction research community to come together with global environmental change researchers - especially those who focus on forecasting extreme events and anticipating thresholds with those who work on vulnerability and adaptation[7]. Historical analysis also offers important insights into past global environmental changes and their interactions with social systems and ecological regimes (e.g. Costanza et al 2012).

Although Future Earth focuses on research with an international scope, the shared challenges of particular places and regions are also a relevant priority. Some regions, people and ecosystems are more vulnerable than others to global environmental change because they are located in places where changes are most extreme, where biodiversity is the greatest, where populations are especially sensitive, concentrated or poorer, or where parts of the Earth system or local ecological systems are closer to thresholds. Global environmental change programmes have focused attention on particular regions and biomes that play important roles in the Earth system or are particularly vulnerable to environmental change. These include Monsoon Asia and the Arctic, Antarctic, Island and Mountain ecosystems, which are vulnerable to global warming (e.g. Hare et al 2011; Gurung et al 2012; Messerli 2012; www.mountainbiodiversity.org) — and are also important controls on the atmospheric and oceanic system. A biome of particular concern is the tropical forests, which exert an important influence on global and regional biogeochemical and hydrological cycles and are reservoirs of biodiversity and cultural diversity under pressures from agriculture, logging, mining and infrastructure (Malhi and Phillips

---

[7] For example, disaster risk reduction is a focus of the ICSU-ISSC-UN Integrated Research on Disaster Risk (IRDR) programme and climate risks and vulnerability are a focus of the Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA) with UNEP, UNESCO and WMO as partners (www.unep.org/provia).

2004; Gardner et al 2010). Deltas are another critical zone (Foufoula-Georgiou et al 2011). Cities are another important area for research on the dynamics of global environmental change (e.g. Seto and Sanchez 2010; Seto and Satterthwaite 2010; Seitzinger et al. 2012).

What types of research questions and projects might the Dynamic Planet research theme address? The Future Earth Transition Team identified the following over-arching questions to illustrate potential research priorities that can be addressed by current, updated or new collaborative international efforts:

- What approaches, theories, and models allow us to explain the functioning of Earth and socio-ecological systems, understand the interactions between these mechanisms, and identify the role of feedbacks and evolution within these systems?
- What are the states and trends of key environmental components such as climate, soils, the cryosphere, biogeochemistry, biological diversity, air quality, freshwater, and oceans, and in the human drivers of change, such as population, consumption, land and sea use, and technology. How do these relate to the states and dynamics in the social foundations of sustainable development, including well-being, equality, health, education, human security? How and why do these vary across time, space, and social context?
- What changes are predicted under the most likely scenarios of natural and social driving forces and Earth, social and biological system responses?
- What are the risks of rapid or irreversible changes, of crossing regional to global thresholds and planetary boundaries and inducing tipping points and social-environmental crises due to global environmental change?
- What can be understood and anticipated about the condition and future for critical zones and biomes such as coasts, tropical forests, arid zones or polar regions?
- What kind of integrated global and regional observing systems and data infrastructures are needed to document and model the coupled earth system and the anthropogenic drivers and impacts of change? Can we develop reliable monitoring systems, models and information systems and services that anticipate and provide early warnings of large scale and rapid change?

Many projects within the existing global environmental change programmes bring together observations and models to monitor and predict how key aspects of the Earth system are changing. Future Earth hopes to draw on and add value to these existing international projects (e.g. Analysis, Integration and Modelling of the Earth System – AIMES, Past Global Changes – PAGES, Climate Variability and

Predictability - CLIVAR, Global Energy and Water Exchanges Project - GEWEX, Stratospheric Processes And their Role in Climate - SPARC, Climate and Cryosphere - CliC, Global Carbon Project - GCP, bioGENESIS, bioDISCOVERY). These projects focus on key sectors – such as oceans, climate, carbon, biodiversity, or land – or critical zones such as coasts, mountains, or the Arctic. Others come together around input into key assessments such as IPCC and IPBES.

In addition to measuring change, some ongoing projects analyse the human driving forces of change including demography, consumption, industry and land use. However, integrated monitoring and modelling remains a challenge, especially with regards to including the full range of biological and social processes and cross scale dynamics. Responding to Future Earth those projects that use case studies and local analysis to understand Earth and social system dynamics could collaborate in initiatives that allow for rigorous comparative methods, identification of common drivers and feedbacks, and identification of distinctive regional patterns and problems. Future Earth also recognizes the importance of research agendas that have emerged from regional initiatives (e.g. the Inter-American Institute for global change research, the Asia-Pacific Network for Global Change Research, START) that seek to understand and forecast phenomena of particular regional concern – such as the state and fate of critical ecosystems and watersheds, the dynamics of the monsoon or El Niño Southern Oscillation, the degradation of soils, or rapid urbanisation.

There is a critical need for basic science to underpin this theme especially if we are to move towards prediction and informed management. Accurately observing and modelling our dynamic planet relies on the fundamental Earth, biological and social science undertaken by global environmental change projects and their partners. For example, an understanding of genetics and evolution is of practical importance in predicting how biodiversity will respond to rapid environmental change (Hendry et al 2010, Candry et al 2010). A comprehensive assessment of regional air quality and atmospheric composition is important to understanding health and climate at a variety of scales (Monks et al, 2009), linked biosphere-atmosphere models based on ecological studies across a range of vegetation types are needed to understand the biotic positive or negative feedbacks on anthropogenic climate change (Arneth et al 2010). Scientific evidence of human impact on ocean environments has led to calls for improved understanding of ocean systems and their significance to the Earth and social system (Halpern et al 2008). The fundamental geophysical, biological and social research needed to understand the dynamics of the planet must remain an essential component of Future Earth.

In summary, the Dynamic Planet research theme brings together existing strengths of global environmental change researchers, and other stakeholders, in continuing and new efforts to understand, document and anticipate how the Earth system and its socio-ecological interactions are changing and recommits the research community to communicate this knowledge to the full range of stakeholders.

Theme 2: Global Development

Knowledge for the pressing needs of humanity for sustainable, secure and fair stewardship of food, water, energy, materials, biodiversity and other ecosystem functions and services.

The research theme on Global Development will provide the knowledge needed to understand the links between global environmental changes and human well-being and development. In proposing this major research theme, Future Earth recognises a new 'social contract' between science and society that focuses global environmental change knowledge on the most pressing problems of human development – providing safe and adequate food, water, energy, health, settlements and other ecosystem services for all without degrading the environment, losing biodiversity or destabilizing the earth system.

This theme focuses on the more immediate challenges of sustainable development and meeting basic needs in contrast to theme 3, which addresses more fundamental and long-term transformations that are needed for global sustainability. It is important to emphasize that Future Earth focuses, here, on the intersection of human development with global and regional environmental change and the ways in which environmental research can help address development goals. Future Earth also recognizes the distinctive contributions of researchers who are already part of networks that address development issues at the local and regional scale and that development priorities and research needs vary by region and country. This is reflected in the missions of partners such as UNEP and UNESCO within the Alliance sponsoring Future Earth. In the consultations on Future Earth in the Asian, African, Latin American and Caribbean regions, a range of regional research priorities were highlighted that included coastal ecosystems and urban problems in Asia, food and water security in Africa, and biodiversity and disaster risks in Latin America and the Caribbean. The regional workshops also highlighted the challenges that Future Earth faces in responding to multiple goals, a variety of decision makers and diverse types of knowledge needs within an international research programme.

Global environmental change affects human well-being and social and economic development, just as development strongly influences the global environment. Human development in the Anthropocene is closely linked to the management of land, water, energy, materials, and natural resources; agricultural, forest and marine ecosystems; and the atmosphere and ocean. The international community has called for science to contribute to sustainable development agendas and most development institutions now recognize the importance of basic and applied environmental research. There is also a need, strongly emphasised in the Future Earth conceptual framework, to link sustainability in regions with changes at the global scale. These cross-scale interactions among complex social and environmental dynamics need to be understood in the pursuit of human development, reflected e.g., in the regional environmental change research of the Inter-American Institute for Global Change Research (IAI), the IRDR (Integrated Research on Disaster Risk) programme and PECS (the Programme on Ecosystem Change and Society) which focus on how local, regional and global changes interact. Future Earth will add value with research that shows how global environmental changes (e.g. in climate, air quality, biodiversity, oceans or soils) link to and underpin development, how development efforts can in turn add to global environmental problems, and how global environmental change relates to issues of human security, gender equity, indigenous cultures and justice.

In combining international expertise, data and insights from both the global change and development communities, this theme will be particularly responsive to societal needs; it will contribute to a better understanding of the human dimensions of environmental change, and it will contribute to solutions in areas such as agriculture, water, and economic and technological innovation.

The Global Development theme builds on some of the efforts of the GEC Earth System Science Partnership (ESSP with its projects that include food, water, and health) and of other organizations in the Future Earth Alliance such as UNEP, UNU and UNESCO. For example, research on climate change risks to food systems has revealed many opportunities for reducing the vulnerabilities of tropical and temperate agriculture to climate change and for mitigating greenhouse gas emissions in the food system (e.g. Ingram et al 2010; ccafs.cgiar.org). Research-based innovations in governance and technology have shown how to increase water supplies across society through water reuse, markets, legal rights, behavioural change and social support systems (e.g. Bogardi et al 2011, UNESCO 2012). Knowledge about the environmental impacts and distributional effects of different energy sources can inform decision making about investments, locations and policies for providing safe and secure energy (e.g. GEA, 2012). Research shows that air pollution and the incidence of vector-borne diseases are influenced by interactions between climate variability, health interventions, infrastructure, and poverty, and that numerous points for intervention exist (Kovats and Butler 2012; Ramanathan and Feng 2009).

Extreme events pose significant threats to development, especially as the risks shift as a result of climate, land use and other global environmental changes. By better connecting global environmental change research to the disaster risk reduction research community and their stakeholders, Future Earth can inform efforts to reduce disaster vulnerabilities and damages and plan for safer settlements. The climate community has much to contribute in terms of forecasting extreme events and providing climate services, and ecologists, social scientists and engineers have knowledge essential to understanding changing patterns of vulnerability and options for reducing it (e.g. Asrar et al 2012; Schipper 2009; Thompson et al 2011).

An increasingly globalized trading system means that products are consumed in complex supply chains that transfer embodied carbon, water, genes, species, mineral resources and waste around the world, with implications for the global environment, well-being and human security that can be addressed through, for example, policies and governance interventions (e.g. Bradley et al 2011; Canadell et al 2010; Cordell et al 2009). Global commodity chains and price volatility also can translate climate or disaster impacts in one region to many others, contributing to new types of vulnerability (e.g., wheat price shocks in the global food supply chain following regional or local drought) that call for more innovative approaches to enhancing resilience to shock (Vermeulen et al 2012). The political and social driving forces for land use change also can have distant origins in commodity trade and conservation policies that have, for example, moved deforestation from one region to another or resulted in new demand for biofuels (e.g. Banse et al 2011; Foley at al 2011; Meyfroid and Lambin 2011; LUCC/GLP).

Biodiversity is a key to development, in that it provides the basis for fully functioning ecological and evolutionary systems, important for human well-being and economies, with the loss of biodiversity shown to undermine development (e.g. Cardinale et al 2012; Perrings et al 2011; and the freshwaterBIODIVERSITY and agroBIODIVERSITY projects). Increasing scientific evidence shows that stewardship of the atmosphere, biosphere, land and water is central to avoiding disastrous risks from global environmental change.

What types of research questions and projects can contribute to the Global Development research theme? The Future Earth transition team identified the following over-arching questions to illustrate potential research priorities that can be addressed by current, updated or new collaborative international efforts:

- What insights and innovations in basic earth, biological and social sciences are most important to the environmental bases of sustainable development?
- What are the patterns, trade-offs and options for equitable and sustainable use of resources and land, and how can we ensure sustainable access to food, water, clean air, land, energy, genetic resources and materials for current and future populations?
- What are the implications of global environmental change including climate change for food, water, health, human settlements, biodiversity and ecosystems? How can climate services, ecosystem management and disaster risk assessment reduce these impacts and build resilience?
- What are the links between biodiversity, ecosystems, human well-being and sustainable development?
- How socially and environmentally effective, efficient and equitable are alternative approaches for conceiving, measuring and implementing development projects and initiatives?
- How should Sustainable Development Goals be defined in order to enable the twin-goals of world development and global sustainability?
- What options are available to provide energy for all with reduced environmental impacts, and what are the social implications of these energy choices?
- How can the business and industrial sector contribute to development, prosperity and environmental stewardship through the management of their production and supply chains?
- How does global environmental change affect distinct groups in society such as Indigenous people, women, children, subsistence farmers, business, the poor or the elderly? How does their environmental knowledge contribute to solutions for sustainable development?
- What options are available in terms of ecosystem restoration to restore the environmental bases of sustainable development?

Although there are several global environmental change projects already focused on issues such as food and water security, ecosystem services, disaster reduction, health, and energy, Future Earth provides the opportunity to connect these projects to broader efforts within the Science and Technology Alliance for Global Sustainability and for projects that have not yet considered the sustainable development implications of their research to do so. Existing and new projects might come together to address the challenges of disaster risk reduction through climate services, ecosystem based adaptation and social vulnerability; to examine the interactions and trade-offs between land, biodiversity, energy, and water in ensuring food security; to provide the integrated knowledge required for major assessments and intergovernmental processes such as IPBES and CBD; and to create scientifically credible indicators of sustainable development. Other example areas where projects could cluster include a focus on the needs of particularly vulnerable populations in the context of the multiple environmental stresses or on methods and models for rigorous comparison, evaluation and systemic analysis of the environmental basis of development.

The Global Development theme will have the principle of co-design at its core with extensive discussions with international development organizations as well as regional and local groups to ensure a research agenda that is focused and solution oriented and that respects the knowledge that already exists in these communities. Cooperation with development agencies and communities can bring benefits to Future Earth that include international networks of field research and practitioners and experience with participatory approaches, vulnerable populations, local innovation, and project evaluation.

In summary, the Global Development theme brings together global environmental change researchers in existing and new partnerships with the development community and other stakeholders to identify and solve the basic needs for human development and security.

Theme 3: Transformation towards Sustainability

Understanding transformation processes and options, assessing how these relate to human values and behaviour, emerging technologies and social and economic development pathways, and evaluating strategies for governing and managing the global environment across sectors and scales.

The proposed theme on Transformation towards Sustainability goes beyond assessing and implementing current responses to global change and meeting gaps in development needs to consider the more fundamental and innovative long-term transformations that are needed to move towards a sustainable future. There are major knowledge gaps in this area, in particular as to how such transformations can be developed, designed and achieved.

Future Earth will develop knowledge to understand, implement and evaluate these transformations which might include significant shifts in political, economic and cultural values, changes in institutional structures and individual behaviours, large-scale systems changes and technological innovations that reduce the rate, scale and magnitude of global environmental change and its consequences. In selecting this major research theme Future Earth signals the need and willingness of the global environmental change research community to engage with the challenges of innovation, new technologies, global governance and alternative solutions that will bring society and the Earth system towards more sustainable futures.

Understanding the many feedbacks from human responses and governance to Earth system processes requires close collaboration between natural and social scientists, economists and engineers in, for example, projecting the impacts of energy policy or ecosystem management on biogeochemical cycles and biodiversity or understanding how policy and international agreements shape demands for on-going monitoring of greenhouse gas emissions or species. Assessing the costs or benefits of different management and governance choices is another important arena for international collaboration and also an important opportunity to partner with the private sector. Another research challenge is to connect trends and policies in engineering, technology and business to their impacts on efforts to foster more sustainable individual and institutional behaviours through innovation and consumption choices. Identifying the social and cultural consequences of different response strategies, including real or perceived winners and losers and how these change over time, is an important focus. Evaluating the potential and risks of new technologies and approaches from developments in areas such as synthetic biology, geo-engineering, analysis of massive datasets, or new energy systems is another important area for research.

The GEC research community has a number of past and on-going projects that have addressed issues of transformation and governance for a sustainable earth system. For example, the Industrial Transformation (IT) project studied interactions between technology, society and industry as they related to the causes of environmental change and alternative solutions (e.g. Berkhout et al 2012; Elzen et al 2004). The Institutional Dimensions of Global Environmental Change (IDGEC) sought insights into the multi-scale governance of the environment with work continuing within the Earth System Governance (ESG) project to explore political solutions and novel, more effective governance systems to cope with the current transitions in the biogeochemical systems of our planet (Young et al 2008, Biermann et al 2010). The Global Environmental Change and Human Security project (GECHS) examined how diverse social processes such as globalization, poverty, disease, and conflict combine with global environmental change to affect human security (Matthew et al 2009). These projects show how responding to global environmental change is not just a matter for national governments but also for local governments and international organizations, civil society, the private sector, and individuals. Building on this experience and combining it with the work of other projects and institutions across the globe, Future Earth will have major emphasis on developing transdisciplinary insights for solutions.

What types of research questions and projects can contribute to the Transformation towards Sustainability research theme? The Future Earth transition team identified the following over-arching questions to illustrate potential research priorities that can be addressed by current, updated or new collaborative international efforts:

- How can governance and decision-making be aligned across different levels, issues, and places to manage global environmental change and promote sustainable development? What is known about the successes and failures of different actors in managing global environmental change, at different scales, and using different strategies?
- Can technologies provide viable solutions to global environmental change and promote sustainable development? What are the opportunities, risks and perceptions associated with emerging technologies such as geo-engineering or synthetic biology? How can technology and infrastructure choices be combined with changes in institutions and behaviours to achieve low carbon transitions, food security and safe water?
- How do values, beliefs and worldviews influence individual and collective behaviour to more sustainable and mindful lifestyles, patterns of trade, production and consumption? What triggers and facilitates deliberate transformations at the individual, organizational, and systems levels; what socio-political and ecological risks does it entail?
- What do we know about past transformations of the Earth System, as well as in ideas, technology and economy and how can the knowledge and lessons learned guide future choices?
- What are the longer-term pathways towards sustainable urban futures and landscapes, successful and sustainable 'blue societies, and a green economy?
- What are the implications of global environmental change for conservation of species and landscapes including the possibilities for restoration, reversal of degradation and relocation?
- How can the Earth and social system adapt to environmental changes that could include warming of more than 4°C over the next century?
- Can our present economic systems, ideas and development practices provide the necessary framework to achieve global sustainability and if not, what can be done to transform economic systems, measures, goals and development policies for global sustainability?
- What are the implications of efforts to govern and manage the Earth system for sustainability for scientific observations, monitoring, indicators and analysis? What science is needed to evaluate and assess policies and facilitate and legitimise transformation?
- How can the massive volume of new geophysical, biological, and social data, including local knowledge and social media be managed and analysed so as to provide new insights into the causes, nature and consequences of global environmental change and to facilitate the identification and diffusion of solutions?

Research projects under this theme might examine the ethical and environmental implications and technical challenges of new economic models, species relocation or climate engineering and could investigate new approaches to deliberative decision-making, participation, economic valuation and business management. Insights into past transformations, such as mass extinctions or the industrial and green revolutions and how and why notions of a successful, good, ethical and sustainable life have developed over time and across cultures are also relevant research areas. These activities can draw on existing and former GEC projects that have studied past transformations and abrupt changes or proposed new approaches to economic thinking (e.g. Past Global Change - PAGES, Integrated History of People on Earth- IHOPE, Industrial Transformation – IT, IHDP Inclusive Wealth). Research into innovation pathways, from institutional and engineering design options to strategies for stimulating growth of new ideas in support of global sustainability, will also be central to this theme.

Under this theme Future Earth can investigate the effectiveness and risks of new technologies that are designed to provide solutions to global sustainability, such as geo-engineering and new energy sources. It aims to engage with researchers who are rethinking economic systems and indicators in the context of sustainability, who are contributing to new thinking on politics and approaches to democracy, and who are exploring the links between social practices and human behaviour. Research on the communication of change and the development of new narratives and cultural stories can contribute to improved understandings of transformation. Pathways to transformation can benefit also from scenario and visioning exercises that provide understandings of alternative futures, as well as the trade-offs and co-benefits involved in different choices. Scenarios work can make important contributions to assessments such as the IPCC together with research that uses models to investigate longer term futures. Imagining possible futures can also engage the humanities and arts in shaping cultural responses to global environmental change (Robinson K. S., 2012).

The Transition Team discussed several areas where research into transformation for sustainability is particularly timely and urgent, and the clustering of existing with new projects could be particularly beneficial. These areas include:

- *Transition to a low carbon society*. Future Earth has the opportunity to provide more integrated approaches to energy and climate assessments such as IPCC, through research on the interactions between energy, land and climate systems, the implications of policy choices and alternative scenarios for greenhouse gas emissions, and the co-benefits and trade-offs between different energy and land use options such as biofuels and between climate change mitigation and adaptation.

- S*ustainable 'blue' societies*. Future Earth could advance integrated research on the urgent challenges of understanding global change and the oceans including the dynamics of oceans within the Earth system, the impact of humans on coastal and marine ecosystems, and the dependence of global and regional societies on ocean resources. How can "blue societies" live in greater harmony with oceans and achieve transformations that support ocean sustainability?

- *New media and sustainable transformations*. The explosion of new forms of communication, networking and amount of information associated with computing, the Internet and new media is one of the biggest contemporary transformations in information, technology and scientific research. How this wealth of information and new options for collaboration can be harnessed in monitoring and seeking pathways to sustainability is a research priority. For example, understanding how to analyse and share this mass of data and information to improve our understanding of society, to provide observations of environmental change, and to identify, scale up and communicate solutions will be critical to transformation processes.

Other examples of areas where new collaborations are needed include: the development of new approaches to economics that incorporate broader measures of sustainability and wealth; research that analyses proposals for a 'green economy'; research needed to support the design of cities and infrastructure that reduces the risks of global environmental change while adapting to the changes that cannot be avoided; research to understand geo-engineering solutions to global change, research around consumption patterns and production systems and how changes could affect or contribute to global sustainability.

The Transformations for Sustainability research theme will require partnerships that engage a wide range of stakeholders who are working on sustainable futures, including communities, businesses, humanitarian and conservation groups, spiritual and cultural leaders, and citizens who are re-evaluating their lifestyles and legacies for their descendants.

2.1.2. Crosscutting Capabilities

The ICSU-ISSC Visioning process and the Belmont challenge identified several core capabilities needed to respond to the grand challenges of global environmental change including modelling and observations. The Future Earth Transition Team has identified additional cross cutting capabilities needed to advance the science of global environmental change and translate it into useful knowledge for decision making and sustainable development. Many of these capabilities lie beyond the boundaries of the Future Earth initiative per se, residing in national and international infrastructures, training programmes, and disciplines. It will be important that Future Earth works in partnership with the providers of these capabilities for mutual benefit.

The proposed research themes for Future Earth critically depend on access to these capabilities. The capabilities include: observing and data systems, Earth system modelling and theory development. All these are dependent on high performance computing facilities, and data management systems and research infrastructures and appropriate arrangements need to be made to enable access. Future Earth science is likely to place new demands on existing systems and should contribute insights and ideas about how existing platforms could be enhanced or all together new systems be established.

Other important cross cutting capabilities include scoping and synthesis (section 3.3.5.), communication and engagement (section 4), capacity development and education (section 5), and science-policy interface activities including intergovernmental assessments (Section 6). These are also central to achieving Future Earth goals, ensuring that Future Earth benefits society and that scientists across the world are engaged. They are described in more detail in dedicated sections of this report.

All cross-cutting capabilities are expected to provide fruitful opportunities for workshops and collaborative research plans and for bringing and training new groups of researchers into international global change research.

Observing Systems

Future Earth research requires access to a sustained capability to observe changes across the Earth system, to discover unknown relationships, and to drive Earth system models. This recognizes that many key scientific and societal questions concerning global sustainability relate to natural variability and environmental change and to changes in socioeconomic conditions and resource use. The demands for observations are growing in volume and diversity, so new observing and data management technologies are needed to provide the necessary time and space coverage, and manage the resulting datasets to maximize their use. Future Earth will critically depend on major international systems such as the Global Earth Observation System of Systems (GEOSS), the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS) which aim to respond to these observing needs, as well as the systematic observations of international and national agencies such as FAO on food, forests and agriculture and WHO on health. It must support also the emergence of international networks in areas where observing systems are at an earlier stage of development, for example, in biodiversity, governance or social attitudes.

Data Systems

Future Earth will need access to data and will bring large volumes of diverse environmental, biological and social data together. As observing, surveying and modelling systems become more complex, the challenge of accessing and bringing large volumes of diverse data together increases. Future Earth will depend on international initiatives, such as the ICSU World Data System (WDS) which aims to ensure that data holdings are easily discoverable and accessible, seamlessly across the range of disciplines and data types and global data repositories such as the Global Biodiversity Information Facility (GBIF). ICSU-CODATA can make an important contribution on the policy side of scientific data management, especially promoting open environments for data. Future Earth will encourage the implementation of the Organisation for Economic Co-operation and Development (OECD) Principles and Guidelines for Access to Research Data from Public Funding insofar as possible in order to promote wider access.

It will be essential that data be accompanied by: openly accessible meta-data that characterize the data, including information on data quality; and, tools to access, manipulate and visualise the data; and policies that enable the fluid, worldwide movement of data and information. There is a need to prioritise the development of assimilation schemes to synthesize different data types and to confront observational data with output from numerical models. As Future Earth will need access and will bring large volumes of diverse environmental or social data together, data sharing policies will be critical.

CODATA can inform such policies, supporting the scientific research of Future Earth. Annex 3 further develops recommendations for a successful Future Earth data management strategy.

Earth System Modelling

Future Earth will depend on access to state of the art Earth system and integrated assessment models and will contribute to a next generation of models that better capture the dynamics of human-environment interactions, feedbacks and thresholds in the Earth system and that allow for predictions of risks and change on longer time and more detailed regional scales, and take advantage of computing power and skills from a broader range of countries. Understanding of the Earth system is maturing to the extent that the development of useful Earth system models is feasible (e.g. AIMES, CLIVAR, GEWEX, SPARC, the International Global Atmospheric Chemistry project - IGAC). However, challenges remain in: filling knowledge gaps of environmental, biological and social processes even in well understood sectors (e.g. atmospheric convection or international trade); representing the biosphere or decision-making, where process descriptions remain at an early stage of understanding; representing coupled systems and interfaces where physical and biological processes often occur most rapidly; and finding the most computationally efficient and flexible way to couple models of the components of the Earth system. There is an important role for mathematicians and systems analysts in helping develop, refine and improve these models.

Theory Development

Future Earth will need to engage with theoretical debates, drawing from a wide range of disciplines, on how natural systems function and on the fundamental explanations of social, economic and political behaviour and institutions. These debates influence approaches to research, provide insights and solutions and encourage or prevent collaboration across disciplines. Our understanding of earth and societal systems is underpinned by basic theories of how natural and social systems function and often differing views on the fundamental explanations of social, economic and political behaviour and institutions. These theories draw on a wide range of disciplines, from physics, chemistry and biology to anthropology, economics or philosophy and new ideas from these fields often have significant impact on explanations of global environmental change. For example, explanations of human response to environmental change can vary with different theoretical perspectives from the social sciences that assume that people make free rational choices on economic grounds or are more influenced by discourse, culture or control by powerful interests. In ecology, differing theories about basic ecosystem functions can produce different models of how biodiversity may be affected by global environmental change. While theoretical developments from natural and social sciences as well as the humanities will enter into many of the research themes, crosscutting workshops on topics such as social or ecological theory may be helpful to the themes and to entraining a broader group of researchers to work on global environmental change.

3. Organisational design

This chapter presents the governance structure for Future Earth, and suggestions for how Future Earth research should be organised. The programme is led by a multi-stakeholder governing council, advised by a science committee and engagement committee, supported by a dedicated secretariat with regional components. Future Earth research projects are developed and organised by the research community to contribute to the three research themes. It is recognised that the approaches suggested should be monitored and adjusted, as experience is gained with the implementation of Future Earth, notably in relation to co-design and regional engagement. In some cases, initial structures are proposed which can be used, whilst that learning is underway.

3.1. Governance structure

The proposed governance structure of Future Earth is presented in Figure 4. Each part of the diagram and sections below are described more in detail in Table 3 and Appendix 2.

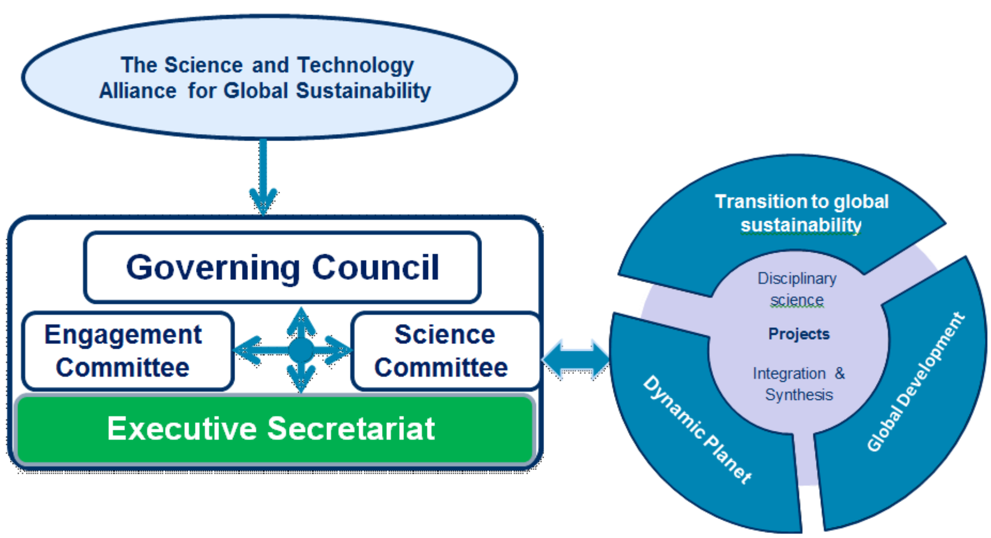


Figure 4: Schematic of the organisational structure of Future Earth. The left hand side of the figure shows the main Future Earth governance bodies. The right hand side shows the thematic structure. Research projects – new and existing, international and regional, and through partnerships with other endeavours will contribute integrated new knowledge to advance one or more themes. Such advances are dependent on basic disciplinary science. Emphasis will also be given to integration and synthesis of research, to meet stakeholder needs.

The **Science and Technology Alliance for Global Sustainability** is establishing Future Earth and will promote and support its development. The Alliance members sponsor Future Earth. The Alliance may grow to include other organisations seen as essential to the successful implementation of this programme.

The **Governing Council** is the main decision making body of Future Earth on all aspects of the Programme, including its strategic direction. The members of this multi-stakeholder body will consist of scientists, policymakers, development actors, representatives of business and industry, civil society and other stakeholders (c.f. Annex 2.1). The members will be selected and appointed by the Alliance.

The Governing Council will be assisted in its deliberations by two dedicated advisory committees: a Science Committee and an Engagement Committee. The Governing Council, the Science Committee and the Engagement Committee will have a balanced composition with respect to gender, geography and discipline. The chairs or co-chairs of these key committees will be international leaders in the research and management of global environmental change and sustainable development.

Based on the Science and Engagement Committees' advice, the Governing Council will initiate and establish themes, projects and/or Future Earth endorsed activities. Similarly, the Council will also assess and monitor the progress of these activities (c.f. Section 3.5), assisted by independent evaluation panels, the Engagement and Science Committees, and taking account of evaluations undertaken by other organisations.

The **Science Committee** will provide guidance to the Governing Council on all science-related aspects of the programme. It will ensure that the science of Future Earth is of the highest quality. Key functions will include the review of existing projects and the selection of new scientific issues for consideration by the Governing Council as either new projects (including prolongation or closure of existing projects) or other scientific activities (e.g. scoping workshops, open science meetings, stakeholder fora and synthesis projects), or new research priorities (c.f. Annex 2.2).

The Members of the Science Committee will be appointed by the Governing Council, based on a slate of nominees selected and proposed by the academic partners of the Alliance, i.e. ICSU and ISSC. ICSU and ISSC will put in place an open nomination and selection process to appoint the Science Committee.

The **Engagement Committee** will provide – in dialogue with the Science Committee - strategic guidance on involving stakeholders throughout the entire research chain from co-design to dissemination, and ensure that Future Earth produces the knowledge that society needs. It will ensure that the components of Future Earth have credible co-design processes, and will have oversight on their implementation. The Engagement Committee will provide a mechanism to bring in voices from business, civil society, and government to ensure that the science is relevant. The Committee will also provide advice on outreach, including publicity, public engagement, and relevant regional activities and capacity building.

The Members of the Engagement Committee will be appointed by the Governing Council, following an open call for membership.

An **Executive Secretariat** will organise the implementation of the research strategies and activities approved by the Governing Council and will carry out the day-to-day management of Future Earth. Among other tasks, the Secretariat will encourage integration across themes, projects and regions, and coordinate cross-cutting issues. There should be designated scientific officer for each Research theme.

The Governing Council and partners of the Alliance should seek adequate funding for the Secretariat and encourage nations or organisations to host and support it. It is expected that the Secretariat will have a global headquarters, with regional nodes. With the aim of stimulating new research activities, a significant part of the human and financial resources of Future Earth should be invested in initiating innovative activities and projects (e.g. new approaches for co-design, synthesis across Themes and stakeholder fora). It is proposed that a significant proportion of the Executive Secretariat's budget should be allocated to these activities.

Research themes are the main strategic organising units for Future Earth research. Themes will be managed initially by a dedicated member of the Executive Secretariat, with oversight from *ad hoc* sub-groups of the Future Earth Science and Engagement committees. External experts may be co-opted onto these sub-groups as necessary. As the programme evolves other governance structures, for example, steering committees may be necessary at the thematic or inter-thematic level. Great care must be taken in the thematic approach to ensure that sufficient attention is paid to theme integration, and that projects that span more than one theme are fully supported.

Research Projects contribute to the research needs of one, or more Future Earth research themes. They are overseen by project Steering Committees and may be administered by project offices, where necessary. Future Earth must encourage new projects, and support existing GEC projects to continue to deliver excellent research, contributing to the Future Earth Research themes, as they transition into the new programme (c.f. Section 3.4.). Research projects will be encouraged to cluster around common interests relating to the Future Earth research themes; some existing projects with a strong degree of scientific overlap may consider merging. The Governing Council and Alliance partners will help to secure the necessary funding for project offices, where these are necessary.

Beyond the key functions highlighted in this proposal for its structural design, the successful implementation of Future Earth will also depend on the open, inclusive and committed leadership of its various committees, and a diverse representation of academic and cultural backgrounds. It is recommended that membership for these committees be selected from a wide pool of experts, drawing from the networks of the Alliance, of the GEC programmes and other relevant organisations at global and regional level. Wherever possible, it is recommended to have co-chairs to allow for an enduring and balanced leadership.

Appointments of co-Chairs and membership of the Governing Council will be the responsibility of the Alliance. The Science and Engagement Committees will be appointed by the Governing Council (noting that in the interim, the Alliance is taking this role). For sub-ordinate groups, a general principle of delegation of appointments will be adopted, to ensure timely decision making and the involvement of the relevant experts. For example, the oversight of the themes can be agreed by the Science and Engagement Committees; project science committee membership could either be agreed by these oversight groups, or self-organisation according to a set of principles could be encouraged. In all cases, a transparent process should be agreed and communicated.

Task	Governing Council	Science Committee	Engagement committee
Overarching	Articulate overall strategy for Future Earth and provide guidance on objectives, priorities and success metrics	Advise the Governing Council on scientific matters	Advise the Science Committee and the Governing Council on research priorities that are relevant for society, and the key principles that underpin engagement of stakeholders across the programme
Research Agenda	Approve research agenda for Future Earth	Propose the research agenda for Future Earth in consultation with the engagement committee and through appropriate consultation with the scientific community and other stakeholder groups Oversee the portfolio of Research themes and advise the associated steering groups Provide advice to projects as required to develop their scientific agenda, ensuring overall consistency with Future Earth framework	Provide feedback on research agenda Provide advice to the leadership of the Research themes to develop co-design and dissemination
Engagement	Decide on a strategy on outreach, fund-raising (including for Secretariat and Research themes), communications, education and regional activities Engage key stakeholders and secure high level support for Future Earth	Reach out to the scientific community and mobilise bottom up ideas around Future Earth research interests Provide feedback on strategy on outreach, fund-raising, communications, education and regional activities	Provide strategic guidance on outreach, fund-raising, and communications; Ensure a demand-driven knowledge sharing model based on stakeholders' needs; propose mechanisms for stakeholder consultation and outreach to ensure bottom up inputs
Proposals for projects, activities, themes	Endorse proposals for new projects and other activities, as well as new Research themes, if required Approves calls for research proposals	Propose new research projects and other activities, as well as new Research themes if required; Organises calls for proposals and evaluates proposals for new projects	Propose projects related to engagement and dissemination of knowledge; Initiate and propose for endorsement open calls for Future Earth activities from stakeholders.
Monitoring and evaluation – criteria	Provide guidance on criteria to perform monitoring and evaluation within Future Earth	Support (with the Engagement Committee) the Governing Council to determine the review process and criteria of Research themes and projects	Jointly with the Science Committee, support the Governing Council to determine the process and criteria for review of Research themes and projects with a particular emphasis

			on the implementation of co-design and overall outcomes.
Monitoring and evaluation - implementation	Arrange periodical external assessment of Future Earth and ensure issues are addressed at strategic and management levels; Review reports on Research themes and projects submitted by the Science and Engagement Committees; Decide end of projects if needed	Jointly with the Engagement Committee, monitor and evaluate progress of the Research themes; Monitor and evaluate the contribution of existing projects and propose end of projects if needed	Jointly with the Science Committee, monitor and evaluate impact and relevance of Research themes and projects, with a particular emphasis on the implementation of co-design and overall outcomes.
Relation with Secretariat	Oversee and evaluate Secretariat	Provide guidance to Secretariat	Provide guidance to Secretariat
Membership	Appoint Science and Engagement Committee members; Ensure appropriate leadership at theme level	Jointly with the engagement committee, form ad-hoc groups to provide leadership for each Research theme (and support the establishment of research theme committees as necessary)	Jointly with the science committee, form ad-hoc groups to provide s leadership for each Research theme
Budget	Approve and oversee implementation of Secretariat and Research themes budgets		
Other		Advise on data policies for Future Earth research; Advise on integration and synthesis across themes and projects of Future Earth; Define and recommend ways to implement cross-cutting capabilities.	

Table 2: Tasks and responsibilities of the different governing bodies within Future Earth

3.2. Future Earth research themes and projects

Future Earth research will occur within the three research themes (Section 2.1.1. and Figure 4). The structure for managing the research is designed to enable the participation of stakeholders in the definition of new activities and in the conduct and review of the research carried out in Future Earth.

3.2.1. Leadership and scientific coordination of individual research themes

It is suggested that each research theme be initially overseen by *ad hoc* sub-groups of the Science and Engagement Committees, to provide strategic leadership and guidance at theme level. These sub-groups may include co-opted external experts and will be supported by scientific staff dedicated to specific themes. In the long term, the Governing Council will decide whether it is appropriate to establish other structures, such as scientific committees, for each research theme.

At the level of each research theme, the strategic leadership and scientific coordination functions include:

- Monitoring the theme's portfolio and defining the needs for new research, new partnerships, integration, capacity building and outreach activities;
- Ensuring the quality and consistency of the research undertaken within the research theme;
- Monitoring the regional coverage and multi-stakeholder involvement of the research theme activities;
- Reporting to the Science Committee and the Engagement Committee on the research theme, its projects and other activities.

3.2.2 Interface with stakeholders

Co-design and co-production with different stakeholder groups is a key innovative aspect of Future Earth. The role of providing Strategic guidelines for stakeholder involvement and co-design lies with the Engagement and Science Committees, advising the multi-stakeholder Governing Council.

At the research theme level, mechanisms to engage with stakeholders might include, for example, convening stakeholder groups to jointly develop the important questions that science will help answer. Stakeholders groups should also be given the opportunity to propose new projects and thus participate in defining and revising the Future Earth research agenda.

The composition of stakeholder groups can change depending on the issues to be discussed or on the availability of qualified people. Different stakeholder bodies may suggest particular individuals or organisations to be involved in these advisory groups. For effective collaboration within constrained timeframes, we also advise that a "pool" of qualified individuals be registered as potential participants in these advisory groups.

As developed in Section 1.4, it is critical for a successful and fruitful collaboration between various stakeholder groups that their representatives within Future Earth speak for a community and not individual/specific interests. In order to act as representatives, there are also requirements regarding competency on the global environmental change issues to be discussed, and legitimacy within their communities.

3.3. Linking global and regional scales

3.3.1. Roles of national committees

The current GEC programmes have independent national committees (which may be an overall global change national committee and/or individual national committees for each programme) in many countries that play an important role in linking the GEC programmes with national research communities and their strategic planning. These committees can also help to secure funding for researchers within their country and translate international research into products for national audiences, particularly national policy. There is a great diversity in the amount of funding, type of members (scientists, policy makers, and funders), convening power and level of activity of these various national committees. Many countries, in particular the least economically developed, do not currently have national committees.

Future Earth will invite existing GEC programme national committees to become Future Earth national committees and encourage development of new national committees where none exist. These committees will support the implementation of Future Earth at the national level, and will be encouraged to integrate their work with other national committees in their region and into regional nodes or networks (e.g. the European Alliance of Global Change Research which is built on existing national committees). This may require some re-designing of national committees to ensure that together they constitute an efficient and manageable network that can help achieve the vision of Future Earth in terms of integration and transformation. A consultation process should be organised for this transition.

Considerable efforts will need to be made by the Executive Secretariat to involve the national committees, in order to catalyse the necessary dialogues so that necessary changes are implemented at the national level, and new structures established (or alternative sub-regional or regional committees) where none currently exist. This should also be encouraged by the Alliance.

It is recommended that within Future Earth, the national committees have five major objectives:

1. Encourage national researchers, research funders and users to become involved in Future Earth and participate in setting Future Earth priorities;
2. Ensure a smooth transition from the existing national structures for GEC programmes or projects towards integrated Future Earth committees that capitalise and extend existing national capacities and disciplinary representation;
3. Initiate and engage in regional activities and networks;
4. Help align national research strategies (including those of funding agencies) with Future Earth activities (e.g. syntheses, projects and outreach); and
5. Communicate Future Earth research and other outputs to key audiences at a national level including the national research community, policymakers, NGOs, and other stakeholders.

National committees will be invited to report annually to the Future Earth Secretariat and appropriate Regional nodes on their activities. Engaging national committees in Future Earth will require substantial human resources within the Future Earth secretariat. Tools, particularly web tools, should be developed to encourage networking.

3.3.2. Supporting national engagement

As national landscapes are often heterogeneous, a critical action will be to map and convene the various key research funders to meet with national scientists to co-design a common strategy for the transition towards Future Earth. It is envisaged to stimulate IGFA/Belmont Forum members to organise national kick-off meetings of potential key funders of Future Earth, with the direct help of existing GEC programmes, GEC projects and key national scientists. It will be important to identify new players to invite, in particular for other stakeholder groups. Such kick-off meetings should address not only how to stimulate national developments of Future Earth activities, but also national contributions to regional networking and/or international Future Earth projects and secretariats. Similar meetings should be organised at a regional level to bring together those countries that do not have the resources to support national committees.

3.3.3 Regional nodes

Although regions share similar challenges in a changing world, their intensity will vary across the globe and the responses available will depend on institutional capacity and social contexts at regional and national levels. Regional approaches to global change challenges are receiving increasing attention as evidenced by the new Intergovernmental Platform on Biodiversity and Ecosystem Services, which proposes to build from a regional focus to global integration and have already demonstrated some successes in research.

These regional challenges and response options have historically led to the development of regional bodies for action programmes and capacity building. For example there is the Inter-American Institute for Global Change Research (Box 1); the Asia-Pacific Network for Global Change Research; ICSU regional offices in Africa, Asia-Pacific and Latin America and the Caribbean which develop and implement ICSU priorities in a regional context; and the START network, which focuses on capacity building in the developing world with a focus on Africa and Asia. The nature of these efforts can be quite different, some, like APN or IAI being intergovernmental, while others, like START, being independent non-governmental organisations.

Future Earth will need to produce, as part of its overall scientific strategy, a regional engagement strategy to define activities at the regional level. This is an early responsibility of the Governing Council. A regionally distributed executive secretariat will be an important component of this strategy; this will need to work in close co-ordination with all regional activities. This strategy will involve making an inventory of existing regional networks, and a dialogue with existing networks to seek new partnerships and new development models in every region.

A regionally distributed secretariat can identify key regional stakeholders and develop products and a plan to best target these audiences. Key stakeholders should be given the opportunity to help regional networks identify research gaps that Future Earth can address. These stakeholders should also be involved in developing Future Earth communication products that are regionally relevant. Regional alliances should actively help Future Earth distribute products to key audiences.

3.3.4. Scoping, Synthesis, and science for policy

One of the important outputs of the GEC programmes that should be continued and strengthened under Future Earth is scoping studies and syntheses of the status of scientific knowledge in specific areas.

Box 1: Example of a Regional Network: The Inter-American Institute for Global Change Research (IAI)

The Inter-American Institute for Global Change Research (IAI) is an intergovernmental treaty organisation with a supporting Conference of the Parties. It provides funding for projects that support a targeted and integrated approach to global change issues. An example of the nature of the research approach is embodied in the recent call for bottom up proposals which stated that “proposals will require excellent disciplinary science, interdisciplinary integration including natural and social sciences, international collaboration, a clear communication strategy, and capacity building to develop the next generation of GC scientists. The IAI considers that capacity development, outreach and science applications are an integral part of excellence in GC science. Each proposal must involve at least four IAI member countries. The IAI's mandate is to promote science that cannot be conducted by any one country alone”. (www.iai.int)

These activities are distinct from, but often linked to, the formal intergovernmental science assessments, such as IPCC (see below). They are more flexible and rapid than these latter processes and are particularly important in identifying emerging scientific issues and gaps in current knowledge. There is considerable potential for Future Earth to evolve the GEC programme scoping and synthesis processes, which have been mainly ‘internal’ to the scientific community, and to more fully incorporate the concerns and perspectives of other stakeholders. Co-designed and co-produced Future Earth scoping studies and syntheses should be important products of the various themes and the programme as a whole.

Future Earth should have a role in helping to improve the science-policy interface. This goes beyond participating in intergovernmental and governmental processes to working with policymakers to analyse and improve how science connects with policy. A strong engagement and communication strategy will be necessary to engage policymakers at all levels. Policymakers receive information on science from a variety of sources – media, NGOs and industry. Therefore Future Earth’s science for policy strategy must be part of the wider engagement strategy targeting these sectors and society as a whole (see chapter 4).

A particular concern is how science preserves its objectivity and independence in the face of political and other interests. In science-policy research, different dialogue approaches have evolved (e.g. van den Hove 2007), with different interpretations and solutions to resolving the tension between advocacy and providing scientific advice. Effective approaches vary depending on the topic, interface mechanism, cultural context and relationship between the scientists and policymakers in question. In many cases the role of science can be clearly limited to providing new knowledge and to assessing and advising on the consequences of different choices. In this situation, scientists can comfortably be considered as knowledge brokers but not issue advocates (Pielke 2007). In other cases scientists may be expected by both policymakers and the public to advocate more strongly for a course of action. There can be no one-size-fits-all solution to this issue, and it will always require careful consideration. However, as a general principal, Future Earth should aim to be policy relevant rather than policy prescriptive and use tools such as evidence-based scenario setting to support informed policy development.

Inter-governmental Assessments

As part of its role in feeding into formal science policy processes, Future Earth will focus particularly on the supra-national and international level assessments, such as IPCC and IPBES, and thematic assessments, such as those as on oceans or land. Future Earth's Engagement and Science Committees will be tasked with monitoring and overseeing how Future Earth feeds into these processes, and where new opportunities are arising. It is recommended that Future Earth has designated staff within the Secretariat to engage with these processes. In addition to bringing together the expertise and generating the interdisciplinary knowledge that is needed for these integrated assessments, the assessments themselves will provide important strategic directions for Future Earth.

3.4. Mechanisms to develop the research framework

3.4.1. Guidelines for defining research themes, Priorities and Projects

Although the current three research themes are designed to be comprehensive, new research themes could eventually be necessary. Priority areas or actions within existing themes will also need to be identified. These could be initiated in different ways. A way forward is suggested in the text below, which will need to be revisited and refined by the Governing Council.

Proposals for new actions could originate from a variety of sources, including:

- the Science and Engagement Committees of Future Earth;
- stakeholder consultations;
- individual scientists or scientific communities,;
- regional bodies (e.g. IAI or APN); and

Requests and suggestions for new research themes or priorities should be directed to Future Earth's Governing Council via the Executive Secretariat, which will seek advice and guidance from the Science and Engagement Committees. At the annual meetings of the Governing Council, the on-going research themes will be reviewed, possible gaps[8] identified and discussed, the need for new themes and priority actions assessed, and proposals, after a review by the Science Committee, will be discussed, and, if found appropriate, endorsed (Table 3). Before new proposals are implemented, funding possibilities should be investigated in close collaboration with the Alliance and especially the Belmont Forum.

Additionally, the Governing Council, advised by the Science and Engagement Committees, will evaluate on-going themes, projects, cross-cutting activities and other initiatives. Timely reporting and independent reviews (c.f. Section 3.5) will clearly indicate the development phase of individual projects (e.g. starting, developing, consolidating, synthesising). Over time it is hoped that existing GEC projects will align with Future Earth objectives and themes, for example in linking to stakeholders, integrating natural and social sciences, or ensuring involvement of young or developing country scientists. If the research and organisation is not developing in line with the Future Earth aims and criteria, then projects should be closed, or Future Earth's support for them discontinued.

The main selection and implementation criteria for any project, priority action (or new research theme) relate to (1) the best-possible, innovative and timely science, which is accepted and supported by the respected peer communities and academic constituencies, (2) engagement of the appropriate stakeholder communities in identifying the broader research needs and articulating the more specific research questions, (3) implementing an appropriate co-design between the scientists and the users to ensure that proposed and established solutions are acceptable in actual societal contexts, and (4) a clear perimeter and added value compared to other research themes or projects.

In addition to the above, there should also be possibilities to develop within Future Earth, projects and activities that are not suited for specific or individual research themes. These could involve specific activities that supersede or cut across one or more research themes, such as synthesis activities, short-term activities emerging from the research community (like the IGBP's fast-track initiatives), development of transdisciplinary research guidelines, (regional) capacity building, open science conferences, communication with stakeholders and international conventions, and further integration. Future Earth will be engaging with stakeholder communities that are traditionally not involved in research activities. Although some experience exists in doing such research, Future Earth has to take stock and learn from the on-going experiences. Specific activities to harvest and document processes that work or fail, are important. These lessons learned on transdisciplinary science will be an essential Future Earth contribution to research for global sustainability. Harvesting these lessons requires substantial human, institutional and financial resources, and these should be facilitated by the Executive

[8] Such a gap-analysis can be supported by reviews of individual Alliance members, such as UNEP's 21 Issues for the 21st Century (UNEP 2012).

Secretariat. The Governing Council should establish procedures to recognise, solicit, and endorse these types of activities but also define clear sun-set clauses for each of them.

3.5. Mechanisms to monitor and evaluate progress

Monitoring and evaluation of Future Earth and its component parts are complex, vital topics but arrangements for carrying out these functions should not be specified in too much detail at this initial framing of the programme. However, some general points can be made as follows:

- Funders of global change research will continue to evaluate/monitor the work they support. Where possible, evaluations carried out by Future Earth should be done in coordination with such national/regional evaluations;
- The Governing Council should early on set the criteria for measuring success to be used in both the internal reviews of Future Earth's activities and the external review of the programme as a whole;
- In its initial ten year life it will be appropriate to review the whole Future Earth programme twice, i.e. after the first five years and at the end of the first decade. These reviews should be done by external experts, reporting to the Governing Council;
- Future Earth will want to carry out periodic internal evaluation of its research themes and new and existing projects under the direction of the Science/Engagement Committees reporting to the Governing Council. All Future Earth activities should have sun-set clauses at their inception and closure/renewal at the end of that period (or exceptionally earlier) will be determined by the Governing Council informed by the Science/Engagement Committees' evaluation; and
- It will be necessary for the Governing Council to set-up periodic reviews of the operation and effectiveness of the Future Earth Executive Secretariat. This is key since the success of Future Earth as a programme will be very dependent on the leadership and accountability of the Executive Secretariat and the quality and relevance of its products.

4. Towards a Communication and Engagement Strategy

This section provides initial thinking to guide the development of a Communications and Stakeholder Engagement Strategy for Future Earth during the next phase.

4.1. Vision

Future Earth aims to position itself as an international platform to provide knowledge required for societies to face the challenges of global environmental change and to help inform the transition to global sustainability. Delivery of this objective can only be fully realised if strategic stakeholder engagement alongside other communications activities are at the heart of the programme. Dialogue with stakeholders and their participation in the co-design and production of Future Earth research will help the delivery of better attuned, relevant and useful insights to those who will use Future Earth research. How Future Earth knowledge is developed and shared with the wider world will fundamentally affect not only how the research is situated in its wider social and environmental context, but also how policy makers, decision takers and the wider population not only think about global sustainability but also respond to its challenges through, for example, taking research informed decisions to change behaviours, social practices and policy.

4.2. The rationale for stakeholder engagement

Definitions of research stakeholders are multifarious. Building on the Intergovernmental Panel on Climate Change (IPCC) definition of a stakeholder as ‘a person or an organisation that has a legitimate interest in a project or entity, or would be affected by a particular action or policy’ (IPCC, 2007) Future Earth recognises its legitimate stakeholders as bodies or people that have a declared or conceivable interest in its work (see also section 1.4.2 for a listing of stakeholder groups).

Recognition that stakeholder engagement with research practice is valuable and strengthens research is not new. There is significant evidence that demonstrates it maximises not only the quality of the research, but also mutual learning and knowledge exchange between researchers and their stakeholder community, helping deliver meaningful impacts. The success of strategic stakeholder engagement has been particularly noticeable in complex, interdisciplinary research that is associated with high levels of uncertainties and complexities, such as environmental change (Blackmore, 2007). There are multiple reasons why Future Earth will benefit from such engagement including that it can:

- add legitimacy to the research reducing stakeholder scepticism about the science, when they are forming policy, assessing or acting on research evidence (Norgaard & Baer, 2005);
- help open up routes to blending basic fundamental and normative research without undermining either, whilst also helping Future Earth orientate its science towards the delivery of its own strategic goals;

- lead to a wider input from and dialogue with those playing critical roles in many of the uncertainty debates prevalent in environmental change research; and,
- facilitate mutual learning across research and stakeholder communities helping both secure wider support for research whilst also identifying weakness in beliefs, perceptions, and responses and planning for environmental change (Davis and Burgess 2004).

4.3. Three principles of Future Earth stakeholder engagement

There is a comprehensive science policy and science technology studies literature about, and many models of, stakeholder engagement that Future Earth might choose to draw from. These approaches all have some common elements, particularly: the critical need to engage stakeholders from the very beginning of the research process to and beyond its conclusion; the fundamentality of seeking to open up not close down dialogue between parties throughout the process; and, the importance of using appropriate for context communications methods. Methods that might variously be interactive, web-centric or focused on knowledge sharing and reflexive learning.

In the light of this Future Earth will adopt three key principles that will underpin its stakeholder engagement and communication strategy:

- a mutual commitment to excellent science, societal and economic impact and independence;
- an understanding that co-design commences at the outset and stakeholders are partners in knowledge production throughout; and
- a parallel commitment by Future Earth's partners to recognise, value and resource partnership.

In addition to stakeholder engagement as part of the research process itself, Future Earth will also support wider communication activities using the full range of media available. This work will concentrate on communicating Future Earth science and other work to multiple audiences in a clear fashion, using media that will allow both generic and bespoke information and two way exchanges.

4.4. Developing the strategy

There are multiple models of stakeholder engagement that may be appropriate for Future Earth and each has relative strengths and weaknesses, with differing objectives and outcomes. These will need to be reviewed as the programme advances. At the centre of the strategy is the Engagement Committee, working alongside the Science Committee with strategic oversight for helping Future Earth research achieve its goals and deliver a step-change in designing and making research more attuned, useful and accessible to stakeholders.

The current communications practices for the global environmental change community have tended to focus on internal communications, from scientists to the scientific community and scientific media. It has been often characterised by a one-way model of information flow from the producer to the consumer followed by a long, uncertain time lag before any impact. While a number of programmes have been developing user engagement in their activities, this will need to be amplified and transformed towards a more interactive and responsive approach to stakeholder engagement in Future Earth. An approach is needed that is embedded across all activities of Future Earth and builds on a commitment to ensuring the highest possible quality research that will be supported is informed by stakeholders perspectives and framed and communicated in ways that are most likely to inform their decision making. This though must not be at the expense of important, traditional routes for science communication which must also continue to be delivered. The success of Future Earth will be judged, not only on the quality of its science, but also on the demonstrable impacts it has had in delivering its stated objectives. This will require careful deliberation and reflective analysis of progress over time.

Whilst no single stakeholder engagement model is singled out at this stage, as the strategy develops, it is essential that the relationship between the researchers and other stakeholders is dynamic, and characterised by multiple flows of information back and forth which enable researchers to learn about stakeholders and vice versa, in an environment of dialogue and reflexivity.

In preparation for the development of the strategy a first round of stakeholder interviews was conducted in 2012 to inform early thinking on engagement. The remit was to help inform Future Earth's understanding of how to engage new stakeholders, and who these stakeholders might be. Stakeholders from outside the current Future Earth community – including funders, business, civil society and science – were asked to give their views on the Future Earth concept and on the likelihood and nature of their involvement.

The analysis of this pilot concluded that Future Earth's vision was strong and identified its assets, or unique selling points, as:

- an international platform;
- provision of independent, reliable, impartial information that commands a high level of trust; and,
- access to world-class expertise.

The study also found that Future Earth faces a significant challenge in building a broader community of stakeholders: showing that stakeholders outside an 'inner circle' of the Global Environmental Change community have no concept of how they might engage with or be engaged by Future Earth, or use or contribute to Future Earth's research.

In the next phase Future Earth will develop a model of communications and engagement that is: suitable to its character, a complex, global interdisciplinary programme; and, that allows it to be not only truly responsive to the needs of its partners and stakeholders, but also to bring them into the processes of the programme itself. It will do this in the context of a commitment to making all Future Earth communications and engagement activities fully open, encouraging free access to scientific knowledge, data and information. And, where this is challenging, Future Earth will seek to work with partners to help find ways forward.

There are huge opportunities to use web-based media, reporting in real time and harnessing the potential of social networks to gather and distribute information and engage directly with users. However, whilst Future Earth will use such resources strategically, it is also cognoscente of curent trends for media fragmentation, and that the rise of ideologically driven sources of information and news are enabling audiences to self-select information according to their social values and individual preferences. Future Earth will therefore also pay attention to finding ways to reach out to stakeholders who are self-selecting coverage with a particular perspective or orientation that is completely sidestepping environmental change agenda. The communications and engagement strategy will therefore not only realize the opportunities of multi and digital media, but will also seek to address some of the challenges they give rise to.

Getting communications and stakeholder engagement right is first and foremost about people. It is about resourcing and coordinating communications strategically for impact. It is about hiring the best people and talking with the most appropriate people at the right time. It must provide a nimble and flexible structure that can be adjusted rapidly. At its best, this can help position a research organisation as the trusted ‘go to’ source for new, reliable knowledge on sustainability for civil society, business, governments and the media.

4.5. Action points for Future Earth Communications and Engagement

A new model of communications and engagement for Future Earth should build on the existing core strengths of the Global Environmental Change programmes. It should enhance existing mechanisms which already work well, such as the research-monitoring-assessment-policy chain of WCRP-GCOS-IPCC-UNFCCC or DIVERSITAS-GEO BON-IPBES-CBD. In addition it will also seek to learn from other areas of science which have been grappling with these same important challenges (such as those researching nanotechnology, genetically modified organisms (GMOs), nuclear power, stem cells, genomics and synthetic biology).

The real difficulty in developing and implementing a new approach does not lie in learning how to use new tools or tactics, but rather how to bring about a shift in mind-set to embrace a new culture of communications and engagement. In this respect, a Future Earth leadership which embodies a new networked mind-set can help foster such cultural change. This means operating with an awareness of the networks the organisation is embedded in, and listening to and cultivating these networks to achieve impact. It means sharing by default and communicating through a network model.

Recommendations to develop a communications and engagement strategy for Future Earth include:

1. Nominate an expert Engagement Committee early on in the transition process to spearhead thinking on an engagement and communications strategy.

2. Future Earth Interim Director to appoint an Interim Communications and Engagement Director to lead development of the engagement and communications strategy.

3. Commission a review of existing knowledge of what works and doesn't and, using this, consider how to best operationalise the research and engagement and communications strategy.

4. Building new incentives to support a culture of communications and engagement

5. Organize a working group on internal communications to develop a new, centralised coordination function for the Future Earth secretariat that will over time develop new value for the Projects in their interactions with each other and with the Secretariat.

The thinking on a communications and engagement strategy should be informed from the outset by a clear understanding of what Future Earth aims to have delivered at the end of the 10-year timeframe. The metrics for success of Future Earth should include impact for communications and engagement. Part of the process for defining these metrics could include a facilitated workshop which defines aspirations, goals and success.

5. Towards an education and capacity building strategy for Future Earth

This chapter provides initial reflections for the development of an education and capacity building strategy for Future Earth. Education and capacity building are core capabilities that Future Earth needs to nurture, through partnerships. Particular priorities are:

- effective and sustained collaboration across and between the regions;
- to support a culture of transdisciplinary research, and of holistic thinking among other stakeholder groups regarding GEC and sustainability issues; and
- to support the uptake of scientific findings in policies and practices to advance transition towards global sustainability at all levels.

A review of existing initiatives on education and capacity building for sustainable development will be needed to develop and focus the Future Earth strategy, particularly with respect to partnership building.

5.1. Education

Education for sustainable development requires a comprehensive approach incorporating a large range of issues, as well as pedagogical approaches to develop the appropriate skills in support of sustainable development. Thus science education should be seen in the broader context of education for sustainable development.

Science education today occurs in many different venues. Conventionally, students learn in formal educational systems in primary and secondary schools, colleges, and universities, with the guidance of educators. Non-formal learning venues such as museums, science centres, aquaria, parks, and planetariums provide additional opportunities for learners of all ages to engage with exhibits in an experience designed to leverage the curiosity-driven nature of these venues, though perhaps with a greater emphasis on natural rather than social sciences. In addition to these “place-based” venues, learners of all ages today are also increasingly learning online through a vast array of online educational programmes and resources (of uneven quality). Some of these resources are connected to formal place-based programmes with which learners are involved, some are associated with “virtual” schools, and some are designed to supplement formal programmes or for non-formal audiences. Non-formal education represents an important complement to science education in the context of formal educational venues, especially at the primary and secondary school level.

Science education also takes place informally, through “citizen science” programmes, in which people (sometimes in family or community groups) engage in observations (monitoring) and mapping in campaigns outside of a formal context, and in special events co-designed with the scientific and environmental community (such as the International Polar Year, World Water Day, the International Day of Biological Diversity, Earth Day, etc.).

Finally media outlets in multiple formats – print, broadcast, cable, and film provide an excellent channel for education, albeit that the quality of the education content can be very uneven. While some media outlets provide excellent science education programming, others provide far lower quality programming that appears to be "educational", but in fact frequently misinforms. In less wealthy countries, access to media-based science education resources is uneven, as is access to online learning in general, as it requires access to internet and electric power.

Future Earth must focus on using its unique capability efficiently. It will not attempt to design large education programmes on its own, but seek partnerships with established programmes and networks, and draw on the achievements of the current GEC programmes. In this model, partner organizations are the prime movers on most educational efforts, but they should also participate in the continuous co-design process of Future Earth. The role of Future Earth scientists is to engage in education activities as experts, advisers and resource/data providers. Scientist engagement at the undergraduate and graduate/capacity building level is likely to be more direct, given their closer connection with students and young professionals at this level.

Priority audiences and main envisaged activities

The following high-leverage avenues are particularly promising based on audience need and the availability of strong partners for Future Earth researchers to work with:

- primary and secondary education
- undergraduate education
- online education users and providers
- engagement with youth, notably through social media
- engagement with the media in interviews, documentaries, and print media, and recurring public engagement efforts, such as yearly days (e.g. "Earth Day") and annual citizen science campaigns (but not focused on individual science "Years")
- science and technology centres (e.g. through Anthropocene exhibitions), with a particular emphasis on integrated socio-ecological perspectives

Education staff at the Future Earth secretariat

The scope of educational effort will require adequate staffing resources at the secretariat across several areas of education expertise – primary, secondary, tertiary and non-formal education.

As anticipated above, the secretariat will work with relevant partners in mobilizing their expertise as well as in the effort to mainstream the work and findings of Future Earth in their science education programmes.

5.2. Capacity Development

Providing high quality science education, as described above, is a first crucial step in the longer-term process of developing capacity for the production and use of scientific knowledge that can inform and motivate societal action addressing the risks and opportunities of global environmental change and sustainability. Future Earth in particular will help support the development of the next generation of researchers on GEC and sustainability and the enhancement of institutional capacity to help scientists participate in international collaborations.

As a global initiative concerned also with issues of local and regional risks, vulnerabilities and resilience, Future Earth must involve scientists and communities around the world. Yet the capacity and conditions for involvement varies across the world. Working with relevant partner organisations to tackle these divides will be a key function of Future Earth. It will require rigorous attention to ensuring that researchers from around the world have access to and are fully engaged in setting and implementing Future Earth research agendas. And it will require capacity development: capacity for the production and utilisation of knowledge, but also capacity for international collaboration on the basis of mutual respect for different socio-geographic perspectives and methodological and conceptual approaches. A particular emphasis relates to less developed regions, where research systems are poorly resourced. Brain-drain should be counteracted by efforts to “do the research where the problems are”, giving high priority to the establishment and development of attractive research environments.

Understanding what research capacity development entails is central to the development of an effective strategy for improving the delivery to society of relevant knowledge within Future Earth. Following the approach of organisations like the UNDP and OECD, the 2010 World Social Science Report (WSSR) analyses global research capacity at three levels: individual, organisational and systemic (ISSC-UNESCO 2010).

- **The individual level**

  At this level, capacity development focuses on whether or not individual scientists have the necessary education and professional skills to conduct research, develop research questions, put together proposals, lead research teams, communicate their results, inform public debates and advise on policy. From the Future Earth perspective, training in inter- and trans-disciplinary research approaches – including the co-design, co-production and co-delivery of relevant knowledge – will be of particular significance. Examples of initiatives that could be implemented include setting up training classes and summer schools for scientists and other stakeholder groups, and developing international post-doctoral programmes and mentoring programmes to promote interactions between senior and young scientists from different regions.

- **The institutional level**

No matter how well trained individual researchers are, the work they do will depend in important ways on whether there is demand for their skills and a reasonably well resourced and enriching environment within which to apply them. Are there strong national scientific institutions – especially research universities and science academies – with high standards and international connections? Are there sufficient research positions within such institutions to build critical mass or a community of research practice able to support and advance their professional growth? Are infrastructural provisions adequate, and is there sufficient support for fieldwork, the recruitment of assistants, attendance of conferences, spending time abroad, publishing? Through its focus on cooperation with and fostering of regional networks, Future Earth can support the development of attractive working condition for young scientists. In the case of Future Earth, it would also be important to strengthen capacity for the management of large, international research consortia and multiple donor support. Initiatives could include the development and dissemination of international, but regionally adapted Earth system curriculum, supporting leadership of scientists or institutions from lesser developed countries in international research collaborations, establishing or supporting existing networks for knowledge and priority sharing, etc.

- **The research system level**

  Of concern at this level of analysis is the broader policy framework and socio-political context within which researchers operate. Do national strategies reflect unambiguous commitments to the development of science and technology? Is there a business sector willing to invest in research and innovation and willing to work together with the research community to apply the knowledge acquired? Is there broader public support for science, a scientifically literate society that appreciates the values and contributions of science to its well-being? The systemic level also includes issues such as the salaries and working conditions of researchers, which are typically linked to the civil service systems. Do these provide sufficient incentives for researchers to continue doing research rather than join the private sector, take on short-term consultancies, or look for opportunities abroad? Future Earth should support national/regional research policies that promote the integrated research that Future Earth will pursue. Actions that should be explored include the development and communication of job opportunities for students trained in transdisciplinary research, especially at national and regional level, and the definition of innovative mechanisms to review and reward research. The latter are particularly needed to better and more consistently valuate transdisciplinary research in the socio-ecological domain.

  Particular attention will have to be given to research and education systems in less well resourced countries. Networks between research actor are often poorly developed and, and in many cases, if existent rely on strong "nodes" in donor countries. When developing international cooperation, Future Earth should put an emphasis on poorer regions ("south-south" cooperation). While the development of such regionally anchored structures is a longer term endeavour, shorter term measures, such as regional mentoring networks between universities, as mentioned above (explored e.g. by START), should be pursued.

Some aspects of capacity development are clearly easier to address than others: it is easier to train individual researchers than it is to retain them; it is easier to build an institution than it is to build a research community; and it is easier to facilitate discussion of supportive policies and priorities amongst national research funders (where they exist) than it is to guarantee broader government and public support for science and technology. Yet effective, sustainable capacity development requires action at all levels with probably different time scales.

Future Earth will therefore have to operate with a multi-tiered approach to research capacity building for global sustainability. This will entail, in the first place, a commitment to recognizing – and operationalising – capacity development as a horizontal priority in all Future Earth activities. In other words, consideration of how to maximize the positive impacts on individual researchers, their institutions and the research systems within which they are embedded should be central to all Future Earth operations: from the development of new global research consortia to the provision of international opportunities for scientific exchange and publication, from the formation of special working groups and networks, to the facilitation of better access to data, research, and communication technologies.

Secondly, Future Earth will have to facilitate and support activities that are explicitly designed to enhance capacity development, particularly at the individual and institutional levels. At the individual level this may, for example, involve training events or advanced institutes, multi-stakeholder fora, research fellowship schemes, mentoring, and the provision of opportunities to participate in and help develop strong international networks of scientists committed to international inter- and trans-disciplinary research. At the institutional level, the development of functional regional nodes will be of central importance. Such nodes will provide platforms for researchers in developing and developed regions to engage in active collaboration, and help to promote new centres of international scientific leadership.

Finally, Future Earth will seek to impact on the systemic level through a commitment to the idea of co-designing research and education strategies in collaboration with stakeholders from government, the private sector and civil society. At this level of capacity development effective communication and outreach activities, as well as the promotion of productive science-policy-practice interfaces will be equally important.

As emphasised above, to achieve these capacity development objectives, Future Earth will need to work closely with partners to mobilise resources and deliver capacity development activities in different parts of the world. Partner organisations should include, but not be limited to, the Global Change SysTem for Analysis Research and Training (START), the Inter-American Institute for Global Change Research (IAI), and the Asia-Pacific Network for Global Change Research (APN). Future Earth will also benefit from – and should work to help promote – the capacity development efforts of members of the Science & Technology Alliance for Global Sustainability. The function of the Future Earth Secretariat in relation to this area of work will be to engage the partner organisations mentioned above in the development and delivery of a sustained and coordinated global capacity development strategy for Future Earth. In view of the importance of the development of regional networks in less wealthy countries, the regional nodes of the secretariat will play a vital role.

6. Towards a funding strategy for Future Earth

This chapter provides some initial steps towards developing a funding strategy for Future Earth, considering both the interim operating phase (2013-2014), and preparing the funding foundations for the programme as a whole. Future Earth is going to need to secure support from many different funding sources, including organisations not currently funding global environmental change research, if it is to deliver on its ambitions. With this in mind, Future Earth has from the start engaged the funding community; in particular, the Belmont Forum. The Belmont Forum is a group of environmental research funders, a founding member of the Science and Technology Alliance for Global Sustainability and a co-sponsor of Future Earth. The Forum has contributed to the design of Future Earth, is playing a crucial role in co-ordinating the development of a funding strategy for Future Earth, and will help ensure a smooth transition to a fully operational programme.

6.1. Global landscape for funding global change research

The unprecedented scale of Future Earth will require current levels of GEC funding to be scaled-up significantly to deliver on international, scientifically integrated collaborative research. This challenge comes at a time when many nations are facing economic challenges, but equally a sizable portion of global research is shifting to emerging countries. It is important to note that many of the existing funding institutions and sources operate with different funding goals, objectives, assumptions and processes – which can hamper the challenge to find more integrated, multi-lateral approaches.

Over the past decades, an *ad-hoc* International Group of Funding Agencies (IGFA[9]), formed in 1990, has played an important role in the launch and support of the four GEC programmes. Two funding mechanisms were particularly successful: i) the significant support for the GEC Secretariats and ii) the partial co-alignment of priorities and requirements within national programmes, through exchanges of best practices and strategic priorities between GEC researchers and funders.

In addition, new research directions were propagated throughout the global research community and stimulated many successful GEC submissions to national blue-sky programmes. Finally, bilateral calls between agencies have assisted international research teams, but truly multilateral calls were rare, except at a regional level.

Support for GEC research worldwide has increased over the past decades, reaching billions of $/€. However, in this process, the fragmentation of resources increased across disciplines, countries,

---

[9] http://www.igfagcr.org/

agencies and organisations. In some instances, there was considerable integrated action covering large portions of the GEC challenges, such as the USGCRP[10] that focused on Climate Change research to support disciplinary research, emergent international research as well as research coordination (1.2 $ Bn for the financial year 2013, without NASA contributions). These kinds of collaborative efforts were the exception rather than the rule. Furthermore climate, engineering, biodiversity and social science initiatives were rarely integrated despite the presence of many societal challenge-oriented research programmes. Europe has followed the US example mentioned above, but here global change research funding is still split between the European Commission on the one hand and national allocations by the 27 EU members on the other. This is despite some forthcoming joint programming initiatives such as the Joint Programming Climate Initiative[11]. It is also important to note that the contributions from emerging countries are rapidly increasing, following their national priority setting processes and their related funding commitments.

The complexity of the current global environmental change research "funding ecosystem" has been emphasised by all concerned actors to date, as an area requiring attention. An intensive review was initiated as a fast track action to be completed early in 2013 in order to map out current funding flows and sources associated to GEC programmes and projects.

As Future Earth will build on the successes of DIVERSITAS, IGBP, IHDP, WCRP and ESSP, a clear transition from the present GEC activities to Future Earth in 2014 is urged, to secure, revise and extend the funding landscape.

6.2. Future Earth Research – elements of a funding strategy

A set of different funding instruments are needed to stimulate and coordinate GEC research worldwide. A schematic representation of the global funding pyramid that stretches from basic research using "blue sky" funding opportunities (Level D) to strategic research that could be promoted by more focused or applied programmes (Level C) at a national level, to trans-national support for international research (Level B) and coordination of global research (Level A) is presented in Figure 6. A rough order of magnitude of funding associated with each level is also included.

---

[10] http://www.globalchange.gov/

[11] http://www.jpi-climate.eu/

Figure 5: Schematic of various levels of public funding associated with GEC research

The Future Earth Funding Strategy should jointly target the four funding levels to increase the funds available (notably for levels A and B) but also to deepen the vertical alignment:

- Global cooperation (A): Build a coherent global network of regional & international offices, synchronized by a secretariat, that facilitates collaboration between research communities, funders and stakeholders;
- Trans-national research (B): Sustain research teams across countries and across disciplines on complex research subjects that cannot be solved by an individual agency or at a national level;
- National strategic programmes (C): Develop proactive and co-aligned programmes on emergent fields, including inter- and trans-disciplinary research question framing and commensurate research actions;
- Basic Research (D): Create highly visible flagships to engage scientists and research activities and build a new generation of researchers, by stimulating Future Earth related proposals to national blue sky funding mechanisms.

The Future Earth Governing Council will take the lead on advocacy for funding, supported by all members of the Alliance, and the Future Earth secretariat. Supporting the four funding levels will require a mix of familiar and more novel approaches, but in each instance scaled-up to meet the needs of Future Earth. For example:

- An international call will be made to support a globally distributed Future Earth secretariat. It is expected to have a headquarters and regional nodes, and help garner the intellectual and financial resources needed to manage Future Earth.
- International collaborative research will continue to be driven by researchers working together on exciting international research agendas which then influence the priorities of national and regional funders, but this approach will be enhanced by involving a variety of funders of research earlier on in the strategic discussions.
- New international and regional funding tools will be developed such as the Belmont Forum International Opportunities Fund (see below).
- Future Earth will reach out to new funders – in government – beyond science and environment ministries (e.g. development, health, foreign affairs), development agencies, the private sector, foundations and philanthropic organisations. For example, already ICSU, ISSC, the Swedish International Development Agency (Sida) and Swedish Secretariat for Environmental Earth System Sciences (SSEESS) are working to develop new partnerships between development and environmental research funders.
- Newer funding and research modes will be encouraged, such as the successful model adopted for the International Polar Year and sourced broadly for research funding.

6.3. The Belmont Forum – an example of a new integrated approach to funding international research on GEC

To face these complex funding challenges and trigger the evolution of a more appropriate funding system, the IGFA Council of Principals, the Belmont Forum[12] was created in 2009. This body gathered key agencies from post-industrialized and emergent countries together with ICSU and ISSC, to develop and publish the Belmont Challenge in 2011: "To deliver knowledge needed for action to mitigate and adapt to detrimental environmental change and extreme hazardous events[13]". Furthermore, in 2012 the Belmont Forum launched a new open and flexible process (the International Opportunity Fund, IOF) to support international Collaborative Research Actions through annual multilateral calls[14]. The IOF of the Belmont Forum will contribute to support the implementation of Future Earth.

Notwithstanding the creation of the Belmont Forum, there is still considerable fragmentation of GEC funding sources, as described above. Nationally, Belmont Forum and IGFA members represent only 5 to 20% of GEC research funding from each of their countries and thus a co-ordinated approach which

[12] http://igfagcr.org/index.php/belmont-forum

[13] http://igfagcr.org/images/documents/belmont_challenge_white_paper.pdf

[14] http://www.igfagcr.org/index.php/iof-home-page

brings the range of existing national funders together is needed. As a member of the Alliance, the Belmont Forum will help organise and drive this process.

6.4. Next steps

In the immediate future, the Belmont Forum and IGFA members propose to harness the complex "funding ecosystem" to ensure a smoothly funded transition for the 2013-2014 interim operating phase, both for GEC programmes and projects, as well as for the Future Earth secretariat. As national funding sources are still locked up in yearly national level budget allocations, it is proposed to convene within each key country a "National Funders Meeting" during 2013. The objectives would be to organize a smooth transition to Future Earth following a few guidelines:

- be facilitated by local IGFA or Belmont Forum funders;
- co-organized with key GEC programmes and/or projects, as well as National Committees and leading researchers;
- build a constituency by targeting relevant ministries, other research agencies and organizations, foundations, development agencies and funders, to gather past/present GEC or potential new funders to support the GEC transition to Future Earth and its challenges;
- provide a rational and motivated adjustment in national "funding ecosystem" from 2014 and beyond, to ensure the transition and appropriate extensions to meet the Future Earth challenges.

Beyond the suite of "National Funders Meetings", it is proposed to arrange for complementary "Regional Funders Meetings" to provide a platform for and involve countries within broader regions.

7. Towards the implementation of Future Earth

The Future Earth Transition Team has developed the initial design of Future Earth, as described in the previous chapters of this report. This chapter provides a brief introduction to the implementation of Future Earth.

7.1. Initial roadmap and main priorities

Following the completion of its initial design, Future Earth will enter an interim operating phase that is expected to last about 18 months. This will be marked by the Alliance taking on the role as the interim multi-stakeholder governing council, the appointment of the permanent Future Earth science committee to take on the scientific leadership of the programme, the establishment of an initial engagement committee and the establishment of an interim secretariat. The aim is that Future Earth will be fully operational from mid-2014, with the appointment of a permanent secretariat and the other envisaged governance bodies.

Whilst the initial design is now complete, it is recognised that Future Earth describes a very large undertaking which aims to engage new communities to respond to the major challenges of environment and sustainability. Full implementation will take time, and whilst it is aimed to get the programme structure in place relatively quickly (including the transition from current programme structures) – the full ambition of Future Earth will take longer.

The need to broaden the engagement of the scientific community and other stakeholders in the continued development of Future Earth is also recognised. A set of regional consultations in Africa, Asia-Pacific and Latin America and the Caribbean were held in 2012, and further consultations in Europe, North America and the Middle-East and North Africa are planned for the first half of 2013. Future Earth continues to sponsor sessions at major community conferences (e.g. AGU, EGU, AAAS), national meetings are being arranged by many interested communities, and a conference of representatives of all GEC projects was held at the end of 2012 (with a further meeting being planned for 2013). A strong appetite has been expressed for scientific conferences which reflect the scientific breadth of Future Earth, building on the success of *Planet Under Pressure*, a major conference co-sponsored by the GEC programmes in 2012.

Whilst the full implementation of Future Earth will take some time, it is very important that early opportunities to engage become clear. Beyond the conferences described above, new initiatives are already being delivered (for example, ICSU/ISSC Young scientists networking conferences on integrated science and Belmont Forum Collaborative Research Actions). The Future Earth Science Committee and secretariat will need to ensure that this trend continues and increases, for example, by giving consideration to the research model championed by the International Polar Year as a way of ramping up Future Earth research and engagement. The programme will also need to identify a mechanism for partnership with the large number of initiatives asking to 'join' Future Earth.

Effective mechanisms that engage an even larger group of scientists than can be directly involved in structured themes and projects, or even workshops and conferences, are needed in Future Earth in order to draw on the vast and diverse expertise in the global community. These mechanisms need to be flexible, likely taking advantage of new and emerging internet based technologies. The activities in such processes will be relatively short-term (months up to two years) and primarily bottom-up driven. They will likely address specific issues, encourage out-of the box thinking, develop new networks of people that have not worked together previously, and hopefully in many cases will involve a very wide range of backgrounds and expertise. They will potentially lead to published papers, or perhaps to new projects or eventually new themes. A key element of these mechanisms is that they are open to essentially anyone who can contribute constructively, and because they are virtual networks/groups little to no travel would be involved. Some of the best, brightest and most innovative ideas are likely to emerge from such processes. Organising and enabling them, will take Secretariat resources to help develop, facilitate, monitor, report, working in partnership with the research and stakeholder communities. There should be some small research grants within a research theme or administered by the Executive Secretariat, so that these ideas can actually be pursued.

In summary, over the interim operating phase, the main implementation milestones include:

- Immediate
  - initial design complete & accepted by Alliance
- Short term (6 months)
  - scientific leadership in place (Science Committee)
  - interim director and secretariat in place
  - process for establishing governing council, engagement committee and permanent secretariat agreed and being implemented
- Medium term (18 months)
  - permanent governance and secretariat in place
  - merging of IGBP, IHDP and Diversitas and transition of projects near completion
  - strategies and partnerships for delivering cross-cutting capabilities in place

7.2. The implementation process

There are many practical questions and concerns regarding the transition from current programme and project structures to the full implementation of Future Earth. With this in mind, the Alliance established an implementation management project in late 2012, to develop and oversee the transition arrangements.

The implementation management project is overseen by a project board, and reports to the Alliance. The board is co-chaired by Steven Wilson (ICSU) and Jakob Rhyner (UNU), and its membership includes a small number of representatives of the Alliance, GEC programmes and projects. Four core workpackages for the project have been identified together with a draft set of tasks for each (see Annex 5).

An interim director will be recruited to provide executive leadership to the programme during the interim operating phase, supported by an interim secretariat (composed of a dedicated team and contributions from Alliance members and the existing GEC programme secretariats).

Some of the key tasks during the interim operating phase include:

- Establishing the permanent Future Earth secretariat.
- Engaging the global environmental change research, user and funding communities in the further development of Future Earth.
- Supporting existing global environmental change programmes and projects to merge into Future Earth.
- Creating early funding opportunities to support Future Earth research and developing the mid- to long-term funding base, including engaging new potential funders, for example development donors, foundations and venture philanthropists.
- Defining metrics to monitor progress and evaluate success

7.2.1. Transition of existing core projects into Future Earth

There are currently about thirty Core Projects in the global environmental change research programmes. Much of the research in global environmental change is carried out by them so it is vital that this work is retained and enhanced in Future Earth. Core Projects will provide the fundamental knowledge needed for many activities in Future Earth. As Future Earth develops there may well be a need to initiate new Core Projects; these may be specific to a particular research theme or may feed into several of them, there may even be a need for new free-standing Core Projects. However, the intention is that Core projects in Future Earth will be as closely integrated into research themes as possible. An initial analysis of the current GEC Core and Joint projects indicates that all of today's projects contribute to at least one Future Earth theme. It is recognized that many projects contribute to more than one theme, and this re-emphasises the need for excellent co-ordination across the themes. It is also recognized that there is an opportunity for projects to work together by clustering around common interests, set within the overall context of Future Earth priorities.

All core and joint projects of the current GEC programmes have been invited to be part of Future Earth. A review process with criteria for initiating and ending projects will be set up by the Future Earth Science Committee. This will be done in close consultation with the current Scientific Committees of the GEC programmes and leadership of their projects. Thus, there must be an excellent interaction with and feedback from the individual GEC core and joint projects. Decisions to maintain or change course of the core projects will be taken by the Governing Council, based on recommendations by the Science Committee and in part on the review of the Research themes' research committees. This will ensure that Core Projects meet the needs of the Future Earth community. In the initial stages of Future Earth it would be hugely beneficial if some members of the Science Committee were recruited from the existing GEC Scientific or Project Committees to ensure that existing GEC projects are effectively incorporated into Future Earth and to minimise any transitional problems.

7.2.2. Developing new projects

There is a need for a clear process to invite/solicit or identify proposals for new projects and activities. Developing and establishing this process will be an important high priority task for the Future Earth Science Committee, supported by the secretariat. Although we will not elaborate in detail, a possible process could involve a web-based system in order to facilitate a more equitable generation of relevant ideas with either a global relevance or a more regional focus. The system should also capture all the different ideas and link them to existing knowledge and on-going activities. This helps to further allow for an innovative bottom-up exploration, generation and evaluation of ideas coming from a much broader constituency than the usual research communities, as well as from the relevant stakeholder communities.

Glossary

Boundary organisation

Co-design: the research community and other stakeholders jointly identifying and defining research agendas and priority research questions.

Co-production: the research community and other stakeholders working together to jointly frame, design, execute research and its applications

Core projects

Earth system: The unified set of physical, chemical, biological and social components, processes and interactions that together determine the state and dynamics of the Earth, including its biota and its human occupants.

Engagement

Global sustainability: Global sustainability is a broadening of the term "sustainable development" to apply at the global scale of the world or Earth system. Sustainable development was defined by the Bruntland commission (1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" and is normally conceived in terms of the three integrated pillars of social, economic and environmental sustainability. Similarly, global sustainability integrates both human and environmental dimensions of sustainable development, while placing an emphasis on the importance of sustainability also at the global and planetary scale in order to safeguard opportunities for development at all other scales. The emphasis on global sustainability arises from the growing scientific evidence of the rising human pressures on the Earth system, and the growing connectivity and inter-dependence across scales between social sectors, geopolitical regions, institutions, and earth system processes (from interactions between local ecosystems, to biophysical systems on Earth). Global sustainability places an emphasis on improving the quality of human life while living within the carrying capacity of the life-support systems on Earth, recognising that this includes both local ecosystems as well as the stability and functioning of environmental processes at the regional scale, such as the monsoon systems, and the global scale, such as the climate system.

Hackathons

Interdisciplinary research: research that involves several unrelated academic disciplines in a way that encourages them to cross subject boundaries to create new knowledge and theory, and solve a common research goal.

Joint projects

Node

Stakeholder: a person or an organisation that has a legitimate interest in a project or entity, or would be affected by a particular action or policy' (IPCC, 2007). In the context of Future Earth, the main stakeholder groups are: Academic research; Science-policy interface organisations; Research funders; Governments (national, regional and international); Development bodies; Business and industry; Civil society; and Media.

Transdisciplinary research: research that both integrates academic researchers from different unrelated disciplines and non-academic participants, such as policy-makers, civil society groups and business representatives to research a common goal and create new knowledge and theory

References

The references provided below are illustrative and do not constitute a comprehensive review of the literature relevant for Future Earth.

Alcamo, J., G. J. J. Kreileman, and R. Leemans. 1996. “Global models meet global policy - how can global and regional modellers connect with environmental policy makers? what has hindered them? what has helped?” Global Environmental Change 6:255-259.

AoA Assessment of Assessments: http://www.unga-regular-process.org/index.php?option=com_content&task=view&id=11&Itemid=11

Arneth A, Harrison SP, Zaehle S, Tsigaridis K, Menon S, Bartlein PJ, Feichter J, Korhola A, Kulmala M, O’Donnell D, Schurgers G, Sorvari S, and Vesala T 2010. “Terrestrial biogeochemical feedbacks in the climate system”. Nature Geoscience 3, 525 - 532, doi:10.1038/ngeo905

Asrar, G. R., V. Ryabinin, et al. (2012). "Climate science and services: Providing climate information for adaptation, sustainable development and risk management." Current Opinion in Environmental Sustainability 4(1): 88-100.

Banse, M., H. van Meijl, et al. (2011). "Impact of EU biofuel policies on world agricultural production and land use." Biomass and Bioenergy 35(6): 2385-2390.

Belmont Forum (2011) “The Belmont Challenge: A Global, Environmental Research Mission for Sustainability” http://igfagcr.org/images/documents/belmont_challenge_white_paper.pdf

Berkhout, F., P. Marcotullio, et al. (2012). "Understanding energy transitions." Sustainability Science: 1-3.

Biermann, F., M. M. Betsill, et al. (2010). "Earth system governance: A research framework." International Environmental Agreements: Politics, Law and Economics 10(4): 277-298.

Blackmore, C. (2007) “What kinds of knowledge, knowing and learning are required for addressing resource dilemmas: a theoretical overview” Environmental Science and Policy 10: 512-525

Bogardi, J. J., D. Dudgeon, et al. (2011). "Water security for a planet under pressure: interconnected challenges of a changing world call for sustainable solutions." Current Opinion in Environmental Sustainability 4(1): 35-43.

Bradley, B. A., D. M. Blumenthal, et al. (2011). "Global change, global trade, and the next wave of plant invasions." Frontiers in Ecology and the Environment 10(1): 20-28.

Brown, B. J., Hanson, M. E., Liverman, D. M., & Merideth Jr, R. W. (1987). Global sustainability: toward definition. *Environmental management*, *11*(6), 713-719.

Brown, V. A., J. A. Harris, and J. Y. Russell, editors. 2010. Tackling wicked problems through the transdisciplinary imagination. Earthscan, London.

Brundtland, Gro Harlem. (1987) Report of the World Commission on environment and development:" our common future". United Nations.

Canadell, J. G., P. Ciais, et al. (2010). "Interactions of the carbon cycle, human activity, and the climate system: a research portfolio." Current Opinion in Environmental Sustainability 2(4): 301-311.

Canfield, D. E., A. N. Glazer, et al. (2010). "The evolution and future of Earth's nitrogen cycle." Science 330(6001): 192-196.

Cardinale, B. J., J. E. Duffy, et al. (2012). "Biodiversity loss and its impact on humanity." Nature 486(7401): 59-67.

Carney et al (2009) "A Dynamic Typology of Stakeholder Engagement within Climate Change Research" Carney, S. Whitmarsh, L. Nicholson-Cole, S. and Shackley, S. Tyndall Working Paper 128, January 2009

Chambers, R. 2002. Participatory workshops: A sourcebook of 21 sets of ideas & activities. Earthscan, London.

Clark, W. C. 2007. Sustainability Science: A room of its own. Proceedings of the National Academy of Sciences 104:1737-1738.

Cordell, D., J. O. Drangert, et al. (2009). "The story of phosphorus: Global food security and food for thought." Global Environmental Change 19(2): 292-305.

Costanza, R., S. van der Leeuw, et al. (2012). "Developing an Integrated History and future of People on Earth (IHOPE)." Current Opinion in Environmental Sustainability 4(1): 106-114.

Crutzen, P.J. (2002). "Geology of mankind: the Anthropocene". Nature 415: 23.

Davies, G., and Burgess, J. (2004) "Challenging the 'view from nowhere': citizens' reflections on specialist expertise in a deliberative process" Health and Place 10: 349–361

DeFries, R. S., E. C. Ellis, F. S. Chapin, P. A. Matson, B. L. Turner, A. Agrawal, P. J. Crutzen, C. Field, P. Gleick, P. M. Kareiva, E. Lambin, D. Liverman, E. Ostrom, P. A. Sanchez, and J. Syvitski (2012). "Planetary Opportunities: A Social Contract for Global Change Science to Contribute to a Sustainable Future". Bioscience 62:603-606.

De la Vega-Leinert, A., D. Schröter, R. Leemans, U. Fritsch, and J. Pluimers. 2008. “A stakeholder dialogue on European vulnerability”. Regional Environmental Change 8:109-124.

Elzen, B., F. W. Geels, et al. (2004). System innovation and the transition to sustainability: theory, evidence and policy, Edward Elgar Publishing.

Foley, J. A., N. Ramankutty, et al. (2011). "Solutions for a cultivated planet." Nature 478(7369): 337-342.

Foufoula-Georgiou, E., J. Syvitski, et al. (2011). "International year of deltas 2013: A proposal." Eos, Transactions American Geophysical Union 92(40): 340.

Funtowicz, S. O. and J. R. Ravetz. 1990. Uncertainty and quality in science for policy. Kluwer Academic Publishers, Dordrecht.

Galaz, V., F. Biermann, B. Crona, D. Loorbach, C. Folke, P. Olsson, M. Nilsson, J. Allouche, Å. Persson and G. Reischl. 2012. “'Planetary boundaries’ — exploring the challenges for global environmental governance”. Current Opinion in Environmental Sustainability, 4 (1): 80-87

Gardner, T. A., J. Barlow, et al. (2010). "A multi-region assessment of tropical forest biodiversity in a human-modified world." Biological Conservation 143(10): 2293-2300.

GEA, 2012: Global Energy Assessment - Toward a Sustainable Future, Cambridge University Press

GSP, UN. (2012) "Resilient people, resilient planet: A future worth choosing."

Gurung, A. B., S. W. von Dach, et al. (2012). "Global Change and the World's Mountains-Research Needs and Emerging Themes for Sustainable Development." Mountain Research and Development 32(S1): 47-54.

Hackmann H and St. Clair AL (2011). Transformative Cornerstones of Social Science Research on Global Change. Draft.

Halpern, B. S., S. Walbridge, et al. (2008). "A global map of human impact on marine ecosystems." Science 319(5865): 948-952.

Hare, W. L., W. Cramer, et al. (2011). "Climate hotspots: key vulnerable regions, climate change and limits to warming." Regional Environmental Change 11: 1-13.

Hendry, A. P., L. G. Lohmann, J. Cracraft, S. Tillier, C. Haeuser, D. P. Faith, S. Magallon, E. Conti, R. Zardoya, K. Kogure, A. Prieur-Richard, K. A. Crandall, C. A. Joly, C. Moritz, T. Yahara, and M. J. Donoghue. 2010. “Evolutionary biology in biodiversity science, conservation, and policy: A call to action”. Evolution 64:1517-1528

ICSU (2011) “Summary of the 3rd Earth System Visioning meeting”, http://www.icsu.org/news-centre/news/pdf/Visioning_ThirdMeeting_Summary.pdf

ICSU/ISSC (2010). Earth System Science for Global Sustainability: The Grand Challenges. International Council for Science, Paris.

ICSU (2010b). Regional environmental change: Human action and adaptation. What does it takes to meet the Belmont Challenge. ICSU Report, International Council for Science, Paris.

IGBP "A vision for integrative global-change research for a sustainable future", http://www.igbp.net/download/18.2709bddb12c08a79de780002812/IGBPDraftvision27September.pdf

IHDP Strategic Plan 2007-2015, IHDP Update. March 2008, http://www.ihdp.unu.edu/file/get/7706

Ingram, J., P. Ericksen, et al. (2010). Food security and global environmental change, Earthscan/James & James.

IPBES: Intergovernmental Platform on Biodiversity and Ecosystem Services http://www.ipbes.net/

IPCC (2007). Climate Change 2007: Synthesis Report. Cambridge University Press, Cambridge.

IPCC (2007) Intergovernmental Panel on Climate Change. Climate Change 2007: Working Group II. Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Parry, M, Canziani, O, Palutikof J, Cambridge: Cambridge University Press.

Kanie, N., Betsill, M.M., Zondervan,R., Biermann, F. and Young, O.R., 2012. "A Charter Moment: Restructuring Governance for Sustainability". Public Administration and Development, 32 (3): 292–304.

Kates, R. W. 2011. "What kind of a science is sustainability science?" Proceedings of the National Academy of Sciences 108:19449-19450.

Klein, J. T. 2004a. "Interdisciplinarity and complexity: An evolving relationship". Emergence: Complexity & Organization 6:2-10.

Klein, T. J. 2004b. "Prospects for transdisciplinarity." Futures 36:515-526.

Kovats, R. and C. Butler (2012). "Global health and environmental change: linking research and policy." Current Opinion in Environmental Sustainability. 4(1):44-50.

Lang, D., A. Wiek, M. Bergmann, M. Stauffacher, P. Martens, P. Moll, M. Swilling, and C. Thomas. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustainability Science 7:25-43.

Lemos, M. C., & Morehouse, B. (2005). The Co-Production of Science and Policy in Integrated Climate Assessments. *Global Environmental Change*, 15(1), 57-68.

Lenton, T., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S., Schellnhuber, H.-J. , 2008. "Tipping element's in the earth's climate system." Proceedings of the National Academy of Sciences USA, 105: 1786-1793.

Larigauderie, A., A. H. Prieur-Richard, et al. (2012). "Biodiversity and ecosystem services science for a sustainable planet: the DIVERSITAS vision for 2012–20." Current Opinion in Environmental Sustainability.

Leemans, R. (2012). "Global-change research to understand, handle and solve problems of a Planet under Pressure." Current Opinion in Environmental Sustainability 4(1): 1-2.

Leemans, R., G. Asrar, et al. (2009). "Developing a common strategy for integrative global environmental change research and outreach: the Earth System Science Partnership (ESSP)." Current Opinion in Environmental Sustainability 1(1): 4-13.

Lubchenco J (1998) "Entering the Century of the Environment: A New Social Contract for Science", *Science* 279

Malhi, Y. and O. L. Phillips (2004). "Tropical forests and global atmospheric change: a synthesis." Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences 359(1443): 549-555.

Matthew, R.A. et al. (2009). Global environmental change and human security, MIT Press.

Mauser W, Klepper G, Rice M, Schmalzbauer BS, Hackmann H, Leemans R, Mooreg H: "Transdisciplinary global change research: the co-creation of knowledge for sustainability" Current Opinion on Environmental Sustainability 2013, (Submitted)

McBean, G. A. (2012). "Integrating disaster risk reduction towards sustainable development." Current Opinion in Environmental Sustainability 4(1): 122-127.

McDonald, D., G. Bammer, and P. Deane. 2009. Research integration using dialogue methods. ANU E Press, Canberra.

McIntyre, B. D., H. R. Herren, J. Wakhungu, and R. T. Watson. (2009). International assessment of agricultural knowledge, science and technology for development (IAASTD) : a synthesis of the global and sub-global IAASTD reports. Island Press, Washington DC.

Messerli, B. (2012). "Global Change and the World's Mountains." Mountain Research and Development 32(S1): 55-63.

Meyfroidt, P. and E. F. Lambin (2011). "Global forest transition: Prospects for an end to deforestation." Annual Review of Environment and Resources 36: 343-371.

Millennium Ecosystem Assessment. (2005). Millennium Ecosystem Assessment Synthesis report. Island Press, Washington DC.

Monks, P., C. Granier, et al. (2009). "Atmospheric composition change - global and regional air quality." Atmospheric Environment 43(33): 5268-5350.

Newman, L., T. Kiefer, et al. (2010). "The science and strategy of the Past Global Changes (PAGES) project." Current Opinion in Environmental Sustainability 2(3): 193-201.

Norgaard, R., and Baer P., (2005) "Collectively Seeing the Complex Systems: the Nature of the Problem" BioScience 55(11): 953-960

O'Brien, K. (2012). "Global environmental change II From adaptation to deliberate transformation." Progress in Human Geography 36(5): 667-676.

Pereira et al. 2010. Scenarios for Global Biodiversity in the 21st Century. Science. 330(6010):1496-1501

Perrings, C., A. Duraiappah, et al. (2011). "The biodiversity and ecosystem services science-policy interface." Science 331(6021): 1139.

Perry, R. I., A. Bundy, et al. (2012). "Special issue on aquatic and marine systems". Current Opinion in Environmental Sustainability 4(3)

Pielke, R. A. 2007. The honest brooker. Making sense of science in policy and politics. Cambridge University Press, Cambridge.

Planet Under Pressure (2012). State of the Planet Declaration. http://www.planetunderpressure2012.net/pdf/state_of_planet_declaration.pdf

Pohl, C. 2008. "From science to policy through transdisciplinary research". Environmental Science & Policy 11:46-53.

PROVIA Programme of Research on Climate Change Vulnerability, Impacts and Adaptation http://www.provia-climatechange.org/

Ramanathan, V. and Y. Feng (2009). "Air pollution, greenhouse gases and climate change: Global and regional perspectives." Atmospheric Environment 43(1): 37-50.

Raupach, M. R. and J. G. Canadell (2010). "Carbon and the Anthropocene." Current Opinion in Environmental Sustainability 2(4): 210-218.

Reid, W. V., C. Bréchignac, et al. (2009). "Earth system research priorities." Science 325(5938): 245-245.

Reid, W. V., D. Chen, L. Goldfarb, H. Hackmann, Y. T. Lee, K. Mokhele, E. Ostrom, K. Raivio, J. Rockström, H. J. Schellnhuber, and A. Whyte. 2010. "Earth System Science for Global Sustainability: Grand Challenges." Science 330:916-917.

Richardson, K., W. Steffen, D. Liverman, T. Barker, F. Jotzo, D. M. Kammen, R. Leemans, T. M. Lenton, M. Munasinghe, B. Osman-Elasha, H. J. Schellnhuber, N. Stern, C. Vogel, and O. Wæver. 2011. Climate Change: Global Risks, Challenges and Decisions. Cambridge University Press, Cambridge.

Richardson, K., W. Steffen, et al. (2009). Synthesis report. Climate Change: Global Risks, Challenges & Decisions, Copenhagen.

Robinson K.S. (2012) *2312: A novel*. Orbit.

Rockström, J. Steffen, W. Noone, K. et al. 2009. "A Safe Operating Space for Humanity". Nature, 461: 472 - 475

Schellnhuber, H.J., 2009. Tipping Elements in the Earth System. Proceedings of the National Academy of Sciences USA, 106 (49) : 20561 - 20563

Schipper, E. L. F. (2009). "Meeting at the crossroads?: Exploring the linkages between climate change adaptation and disaster risk reduction." Climate and Development 1(1): 16-30.

Scholz, R. W. 2011. Environmental literacy in science and society. Cambridge University Press, Cambridge.

Scholz, R. W., D. J. Lang, A. Wiek, A. I. Walter, and M. Stauffacher. 2006. "Transdisciplinary case studies as a means of sustainability learning: Historical framework and theory". International Journal of Sustainability in Higher Education 7:226-251.

Seitzinger, S.P., U. Svedin, et al. (2012). "Planetary stewardship in an urbanising world: beyond city limits." Ambio 41 (8): 787-794

Seto, K. C., R. Sanchez-Rodriguez, et al. (2010). "The new geography of contemporary urbanization and the environment." Annual Review of Environment and Resources 35: 167-194.

Seto, K. C. and D. Satterthwaite (2010). "Interactions between urbanization and global environmental change." Current Opinion in Environmental Sustainability 2(3): 127-128.

Spini, L., Z. Adeel, et al. (2011). "The nexus of water and human health in the context of global changes." Current Opinion in Environmental Sustainability 3(6): 447.

Steffen, W., Sanderson, A., Tyson, P.D., Jäger, J., Matson, P., Moore III, B., Oldfield, F., Richardson, K., Schellnhuber, H.J., Turner, B.L., and Wasson, R.J (2004) "Global Change and the Earth System: A Planet Under Pressure". The IGBP Global Change Series. Berlin Heidelberg New York: Springer-Verlag.

Steffen, W., Persson, Å., Deutsch, L., Zalasiewicz, J., Williams, M., Richardson, K., Crumley, C., Crutzen, P., Folke, C., Gordon, L., Molina, M., Ramanathan, V., Rockström, J., Scheffer, M., Schellnhuber, J., Svedin. U., 2011. The Anthropocene: From global change to planetary stewardship. Ambio, 40 (2011), pp. 739–761

Thomson, M. C., S. J. Connor, et al. (2011). "Africa needs climate data to fight disease." Nature 471(7339): 440-442.

UNCSD (2012). United Nations Conference on Sustainable Development, The Future We Want. http://www.uncsd2012.org/thefuturewewant.html

UNEP (2012a). Global Environment Outlook 5: Environment for the future we want. United Nations Environment Programme (UNEP), Nairobi.

UNEP (2012b). 21 Issues for the 21st Century: Result of the UNEP Foresight Process on Emerging Environmental Issues. United Nations Environment Programme (UNEP), Nairobi, Kenya.

UNESCO (2012) Managing Water under Uncertainty and Risk. UN World Water Development Report.

United Nations. 2012. The future we want. Conference Outcome A/CONF.216/L.1, United Nations, New York.

UNMDG (2012) United Nations Millennium Development Goals Report. http://www.un.org/millenniumgoals/reports.shtml

Van den Hove, S. 2007. “A rationale for science-policy interfaces”. Futures 39:807-826.

Vermeulen, S., B. M. Campbell, et al. (2012). "Climate Change and Food Systems." Annual Review of Environment and Resources 37(1).

WBGU, 2011. “World in Transition: A social contract for Sustainability. German Advisory Council for Global Change”, Berlin, Germany.WCRP Strategic Framework for the years 2005-2015 Coordinated Observation and Prediction of the Earth System (COPES) - http://www.wcrp-climate.org/documents/WCRP_strategImple_LowRes.pdf.

Wiek, A., F. Farioli, K. Fukushi, and M. Yarime. 2012. “Sustainability science: bridging the gap between science and society”. Sustainability Science 7:1-4

Wynne, B (2001). “Creating public alienations: expert cultures of risk and ethics on GMOs Science as Culture”, Volume 10, Number 4, 2001.

Young, O. R., L. A. King, et al. (2008). Institutions and environmental change: Principal findings, applications, and research frontiers, MIT Press Cambridge, MA.

Zalasiewicz, J., Williams, M., Steffen, W., Crutzen, P., 2010. The New World of the Anthropocene. Environmental Science and Technology, 44 : 2228–2231

Annexes

Annex 1. Initial design phase overview

A1.1: Composition and mandate of the Transition Team

The Transition Team was formed as a group of high level scientists and experts from the scientific, funding, user and operational service provider communities to advise on the initial design of Future Earth.

The tasks of the Transition Team during its 18-month lifetime were as follows:

1. **Develop a research strategy for the initiative.** This will draw on the outputs of the ICSU visioning process, the Belmont forum White Paper and the strategies of the other main partners in the Alliance to set out the critical research challenges, the required thematic priorities and capabilities, desired outcomes, impacts and success measures, and how progress will be evaluated.

2. **Identify gaps in the partnership, and then reach out to potential partners** to encourage them to join the initiative and secure the necessary high-level commitment from governments, business and civil society.

3. **Find ways to build on existing capability and investments.**

   Develop a plan for greater and more effective integration of GEC programmes. The TT will probably progressively replace the current Scientific Committee of the ESSP. Supported by the outcomes of a SWOT analysis, the TT will carry out discussion with GEC programmes and projects regarding the integration of programmes into the new structure, in a transition that would ensure continuity of existing commitments.

4. **Identify mechanisms for funding and models for delivery focussing on open, flexible approaches,** considering:

   - Processes and mechanisms that would allow the scientific community to move forward faster and deliver more effective research need to be identified. Options for funding could include bilateral, multilateral, or coordinated actions.

   - Implementation of preferred network design and development of a procedure to identify possible regional ‘nodes’ for the network, through dialogue with relevant players and taking into account strengths and weaknesses of existing regional activities.

- Options for knowledge management systems, that would enable cost-effective interaction and information exchange across the network and beyond to broad research user and provider stakeholder groups.

5. **Facilitate the design of a research and implementation plan for the first three years of the Initiative, setting out the early phase priority areas**. Based on the strategy for the initiative, develop a specific action plan. As a first step in this effort, a small number of priority areas/directions must be established. The implementation plan should also include a communication strategy.

6. **Make recommendations for the governance for the initiative**. The TT has a life time of 18 months, after which it will be replaced with a more permanent governance structure.

The members of the Transition Team were appointed by ICSU, ISSC and the Belmont Forum on behalf of the whole Science and Technology Alliance for global sustainability. The Transition Team met for the first time in June 2011.

Members	
Tanya Abrahamse	CEO, South African Biodiversity Research Institute, South Africa
Bertha Becker	Emeritus Professor, Federal University of Rio de Janeiro, Brazil
Rohan D'Souza	Professor, Centre for Studies in Science Policy, School of Social Sciences, Jawaharlal Nehru University, India
Karl Jones	Executive Director, Catastrophe Management Services, Asia Pacific and Australia, Willis Re Australia, Willis Group, Australia
Rik Leemans	Professor, Wageningen University, Netherlands
Peter Liss	Professor, University of East Anglia, United Kingdom
Diana Liverman	Co-Director Institute of the Environment University of Arizona, US
Harold Mooney	Professor, Stanford University, US
Isabelle Niang	Professor, Université de Dakar, Senegal
Karen O'Brien	Professor, University of Oslo, Norway
Hermann Requardt *Represented by Sacha Daeuber*	CEO, Siemens Health Care Sector, Germany

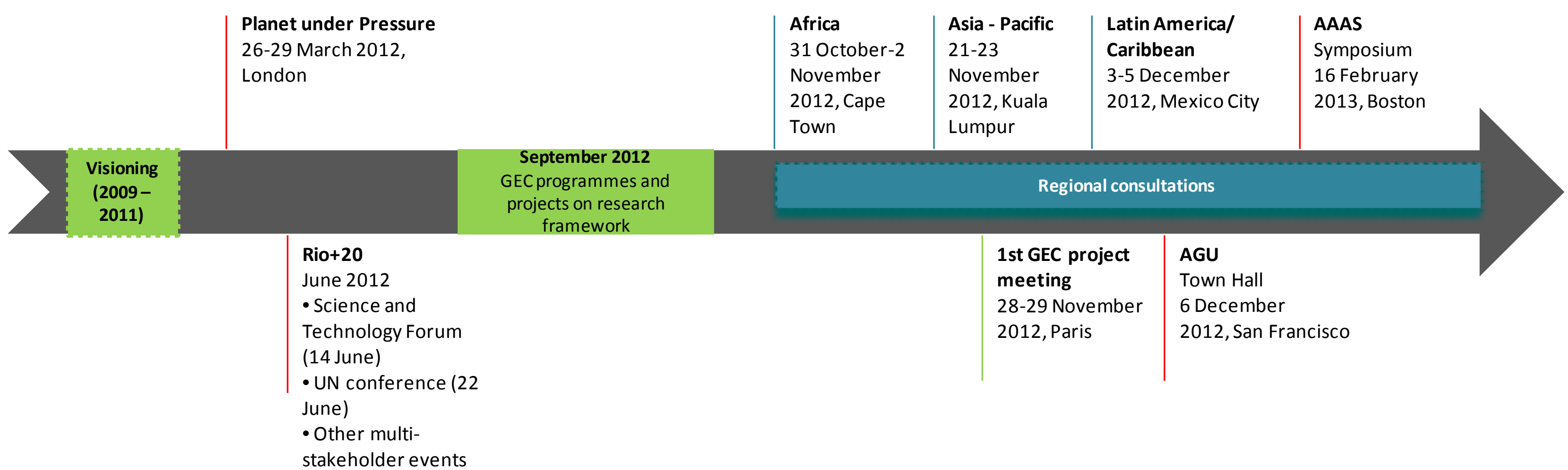
Johan Rockström	Executive Director, Stockholm Resilience Centre, Sweden
Roberto Sanchez	Professor, Department of Urban and Environmental Studies, El Colegio de la Frontera Norte Mexico, Mexico
Martin Visbeck	Professor, Chairman of Physical Oceanography Helmholtz-Centre for Ocean Research Kiel, Germany
Robert Watson	Director, Strategic Development, Tyndall Centre University of East Anglia, United Kingdom, and former Defra Chief Scientific Advisor
Tandong Yao	Director, Institute of Tibetan Plateau Research Chinese Academy of Sciences, China
Stephen Zebiak	Director, Climate Services Initiativeat the Earth Institute, Columbia University, US
Ex-officio members	
Joseph Alcamo	Chief Scientist, United Nations Environment Programme (UNEP)
Heide Hackmann	Executive Director, International Social Science Council (ISSC)
Gretchen Kalonji *Represented by Salvatore Arico*	Assistant Director General for Natural Sciences, United Nations Educational, Scientific, and Cultural Organization (UNESCO) *Senior Programme Specialist, Biodiversity Assessments and Inter-agency Coordination Leader, UNESCO*
Albert van Jaarsveld	Co-chair, Belmont Forum
Patrick Monfray	Co-chair, Belmont Forum
Jakob Rhyner	Vice-Rector in Europe, United Nations University (UNU); Director, UNU-EHS, Institute for Environment and Human Security
Paul Rouse	Economic and Social Research Council (ESRC), United Kingdom
Steven Wilson	Executive Director, International Council for Science (ICSU)
Observers	
Ghassem Asrar	Director, World Climate Research Programme (WCRP)
Anantha Duraiappah	Executive Director, International Human Dimensions Programme (IHDP)
Anne Larigauderie	Executive Director, DIVERSITAS, an international programme of biodiversity

	science
Jeremiah Lengoasa	Deputy Secretary, General of World Meteorological Organization (WMO)
Sybil Seitzinger	Executive Director, International Geosphere-Biosphere Programme (IGBP)

A1.2: Initial design as a consultative process

Throughout the initial design process, public presentations and targeted consultations were organised to discuss Future Earth, collect feedback and ideas on the research framework and governance structure as they were being developed, engage the established GEC programme and project research community, reach out to scientists and other stakeholders beyond these familiar networks to start building a broad community around Future Earth, stimulate interest and initiate partnership building at global and regional levels. These consultations built on the Visioning process (2009-2011) which consisted of a large consultation with the scientific community to explore options and propose steps to implement a holistic strategy for Earth system research. The Visioning process together with other related Alliance initiatives led to the creation of Future Earth.

The outputs of these different consultations have been considered by the Transition Team in putting together this report. The timeline below summarises the main events where Future Earth was presented and discussed during the initial design phase.



As the programme moves into the interim operating phase, other consultations are planned. These include:

- Future Earth Town Hall at the European Geosciences Union (EGU) General Assembly, Vienna, Austria, 9 April, 2013
- Future Earth workshop for Europe: 13-14 May 2013, Paris
- Future Earth workshop for North Africa and the Middle East: 6-8 June 2013, Cyprus
- North America: two webinars followed by in-person meeting: 26-27 June 2013, Washington DC
- 2nd meeting of the GEC projects: by mid-July 2013

Annex 2: Future Earth and the follow up to Rio+20 UN Conference on Sustainable Development

The creation of a set of sustainable development goals (SDGs) was one of the most significant outcomes from the Rio+20 United Nations Conference on Sustainable Development in June 2012. The goals should address and incorporate the economic, social and environmental dimensions of sustainable development and their interlinkages in a balanced way. The SDGs should be global in nature and applicable to all countries, developed and developing alike, while taking into account different national realities and capacities. This makes them different from the Millennium Development Goals (MDGs), which are targeted at eradicating extreme poverty and related social ills in developing nations by 2015. The goals should also have fixed indicators and monitoring programmes incorporated into them, to measure and assess progress. An intergovernmental UN Open Working Group (OWG) was set up on 22 January 2013 by the UN General Assembly. It is tasked with developing a set of proposed SDGs during 2013 and 2014, to be submitted to the UN General Assembly for approval in 2015.

However, in terms of the implementation and monitoring of the goals, Future Earth should play a key role. The interdisciplinary nature of the SDGs, including environmental, social and economic aspects, means that they will require interdisciplinary knowledge and monitoring during their implementation. Furthermore the global, but regionally and nationally differentiated, nature of the goals would be complemented well by Future Earth's global coverage with regional and national level interfaces. Work is already being done by the Alliance to position Future Earth as a future partner to efforts on the SDGs.

Another decision made at Rio+20 was to create a 'high level political forum' (HLPF) that would replace the Commission on Sustainable Development (CSD) as the deliberating body for sustainable development in the UN. Paragraph 85 of the Rio+20 outcome document delineates potential elements of the work areas of the new body, including one which calls on the HLPF to "strengthen the science-policy interface through review of documentation, bringing together dispersed information and assessments, including in the form of a global sustainable development report, building on existing assessments". At present the United Nations General Assembly is still developing the formal title, functions and mechanisms of the HLPF, so it is unclear how science advice will be provided to this new body. Once again, efforts will be made as the HLPF develops to encourage the body to make use of the knowledge and expertise that will be available through Future Earth, and to set up mechanisms by which this relationship can be formalised.

Improving the science-policy interface within UNEP was also a key decision at Rio+20, and this is another key UN process in which Future Earth could be involved. While these improvements still need to be defined, Future Earth could play a key role in providing the interdisciplinary scientific advice that the organisation requires. It will be important to follow these developments in the coming years to ensure that Future Earth is engaged and integrated into efforts to improve UNEP's science-policy interface.

Annex 3. Roles of the different governing bodies

A3.1. Role of the Future Earth Governing Council

The Governing Council is the decision-making body and develops the strategic vision for the overall Future Earth programme. It is a multi-stakeholder body, comprising between 15 and 25 members, with a strong representation of the scientific community. The Alliance partners appoint the Governing Council. The independent[15] chairs of the Science and Engagement committees are members of the Governing Council. The chairs of the Steering Committees of the Research themes will be ex officio members (assuming that the Alliance partners may be represented in the Council in *ex-officio* capacity). Other groups that could be represented include funders (other than the Belmont Forum, such as development agencies), business and industry, representatives of civil society and government.

The Governing Council will meet once a year and may have a smaller Executive Committee, including the chair, which meets (often virtually) more frequently. The Executive Committee has in principle the same responsibilities as the larger committee but essentially 'paves the way' for the annual meeting and communicates on a more regular basis with the Executive Secretariat.

The functions of the Governing Council include (c.f. Table 2):

- Articulate overall strategy for Future Earth and provide guidance on objectives and priorities;
- Consider, evaluate and approve recommendations from the Science, Engagement and Scientific Steering Committees (see relevant sections and summary in Table 1);
- Provide leadership on a fundraising strategy for Future Earth, including for the Secretariat and the research themes.
- Approve and oversee implementation of the Executive Secretariat's and research themes' budgets;
- Oversee the Secretariat, including appointing its Director, and to evaluate the Secretariat.
- Appoint Science Committee and Engagement Committee members
- Appoint members of Science Committee, Engagement Committee, and Steering Committees of the Research themes (c.f. Table 1);
- Approve the research agenda for Future Earth;
- Provide guidance on criteria for monitoring and evaluation within Future Earth (see Section 6);

[15] That is: not formally associated with any of Future Earth's research elements.

- Arrange periodical external assessment of Future Earth;
- Endorse new projects or activities and decide to end existing projects or activities; and
- Approve new research themes if and when required.

A3.2. Role of the Future Earth Science Committee

A Science Committee will provide scientific guidance to Future Earth and report to the Governing Council. It will ensure that the science of Future Earth is of the highest quality, building on the excellence that the global environmental change programmes have developed over the years, and take on emerging issues. The Science Committee will bring to the attention of the Governing Council scientific issues for consideration as projects, other scientific activities (e.g. scoping workshops, open science meetings, stakeholder fora and synthesis), or new research themes if and when required. Members of the committee should be appointed by the Governing Council, based on nominations from the academic partners of the Alliance (i.e. ICSU and ISSC).

The remit of the Science Committee will cover the full spectrum of global environmental change science from natural, social, engineering and human sciences, as well as science from other sectors, such as government and industry. It will comprise around eighteen appointed members. Especially in the early stages, the Science Committee will be responsible for integrating projects and activities of the current global environmental change programmes into Future Earth. The Science Committee will meet twice a year, ideally at the same time as the Engagement Committee. Independent experts can be invited to advise the Science Committee, as appropriate.

ICSU and ISSC – on behalf of the Alliance - will submit nominations for members of the Science Committee to the Governing Council for their approval. Science Committee members are selected based on their scientific excellence and standing in the community, with due attention paid to gender, age and geographical balance, in addition to disciplinary balance and inter- and transdisciplinary expertise. The Science Committee, like the Engagement Committee, is in principle a subsidiary body to provide advice and recommendations to the Governing Council to which it reports. Its advice and activities are, however, independent of the Governing Council, because its main remit is to guarantee scientific quality and integrity. This can only be achieved when the Science Committee is truly independent.

To ensure the highest levels of scientific quality, independence and credibility for all products delivered by Future Earth, the Science Committee will perform the following activities:

- Advise the Governing Council on scientific matters;
- Propose the research agenda for Future Earth (taking into account bottom up contributions from steering committees, projects, the broader scientific community, and users, including through the Engagement Committee; and where necessary proposals to fill gaps in the research agenda);
- Oversee the portfolio of research themes and advise the associated leadership;

- Propose new projects and other activities, as well as new research themes if and when required
- Jointly with the Engagement Committee, support the Governing Council in determining the process and criteria for review of the research themes;
- Jointly with the Engagement Committee, monitor and evaluate progress of research themes based on the information provided by the research committees;
- Monitor and evaluate the contribution of existing projects and propose continuation, merging or closure of projects;
- Evaluate proposals for new projects;
- Provide feedback on strategy on outreach, fund-raising, communications, education and regional activities
- Define and recommend ways to the cross-cutting capabilities needed to implement the research framework;
- Advise on data policies for Future Earth research in cooperation with relevant bodies such as CODATA;
- Jointly with the Engagement Committee, propose a capacity building strategy for Future Earth;
- Propose nominees for the Science Committees of research themes and projects for consideration by the Governing Council; and
- Advise on integration and synthesis across themes and projects of Future Earth.

A3.3. Role of the Future Earth Engagement Committee

The **Future Earth Engagement Committee** is a strategic advisory group whose primary purpose is to ensure that Future Earth is a genuine platform for international science engagement which will deliver the knowledge that society needs. It will focus activities and strategy at the international level. It will provide formal links to international assessments processes and agencies. It will provide advice and recommendations on how to develop new links with stakeholder groups not traditionally engaged with the global change community, thereby building a new constituency for Future Earth knowledge.

Over time, effective stakeholder engagement should ensure that Future Earth provides more relevant and informed guidance and solutions for a more sustainable society in which research is co-designed with end-users.

Such a committee is rather novel in the global change community, so the committee should be viewed as a work in progress whose functioning and structure may evolve over time. Its main functions are:

1. to advise and provide recommendations to the Science Committee and the Governing Council on research priorities that are relevant for society, notably by assessing where knowledge gaps exist for decision-makers and stakeholder groups.
2. to agree and oversee the Future Earth engagement and communication strategy. Notably by providing strategic guidance on stakeholder engagement, communications and outreach. To find

new ways of fostering and nurturing a culture of engagement and partnership. This will include providing strategic links into international assessments and processes (e.g. IPCC, IPBES, SDGs).

3. to provide advice on fund-raising activities and fund-raising strategy
4. to ensure relevance and input to major intergovernmental processes such as the SDGs.
5. to work closely with the Science Committee to make sure that the principles of co-design are embodied in projects and programmes.
6. to initiate, propose and endorse open calls for Future Earth activities from stakeholders. The activities would be officially branded as part of Future Earth and could become a model for engagement with a broad group of stakeholders. Such activities could include reports, hackathons, fast-track research and co-branded research with private sector entities.
7. to provide technical guidance to the private sector on global sustainability. To facilitate the co-design of sustainability solutions with the private sector ensuring its engagement also in the production and scaling up of these solutions.
8. to develop task teams and working groups on constituencies, processes, assessments or themes.
9. To provide strategic guidance to Future Earth national committees on engagement at a national level with funders, policy, research and other stakeholders.

The Engagement Committee will have the same status and priority as the Science Committee, and the two will work closely together to provide advice and recommendations to the Governing Council. It will help the Science Committee to advance its objectives by ensuring linkages with different stakeholders via an ongoing, two-way exchange of information.

The Engagement Committee (like the Science Committee) will report directly to the Governing Council, and is accountable to the Governing Council.

The Engagement Committee can challenge recommendations of the Science Committee, but cannot reject any scientific proposal, as such decisions ultimately rest with the Governing Council.

The committee will typically meet twice a year, at the same time as the Science Committee to ensure coordination and dialogue.

A3.4. Role of the Future Earth Executive Secretariat

The Future Earth Executive Secretariat ensures that the strategies and activities approved by the Governing Council are realised. It carries out the day-to-day functions of Future Earth and acts as a hub to synthesise input from all components of Future Earth. The functions of the Secretariat mirror those of the Governing Council at an operational level, and are defined as follows.

Administrative:

- Support the work of the Governing Council, the Science Committee and the Engagement Committee by carrying out the necessary administration tasks (planning and operations, including nomination and appointment processes, council and committee meetings etc.);
- Implement the fundraising strategy adopted by the Governing Council, with help from the Alliance and other relevant experts; including coordination of seed funding for development of new ideas (see Section 6);
- Prepare the Executive Secretariat's budget for submission to the Governing Council, manage the funds and prepare financial reports;
- Support the monitoring and evaluation process for Future Earth (c.f. Section 7);
- Provide coherence and coordination in the scientific work of Future Earth by liaising with the leadership of all research themes and projects;
- Plan activities and oversee management of synthesis and integration across (multiple) Future Earth activities and themes;
- Provide coherence and coordination by liaising with regional nodes;
- Provide coherence and coordination by liaising with National Committees;
- Design and manage innovative mechanisms for idea generation (e.g. fast-track research, a web-based platform etc.);
- Organise the submission of ideas for proposals for new projects for discussion by the Science and Engagement Committees and approval by the Governing Council (horizon scanning);
- Support the design of a Future Earth data policy and facilitate its implementation by research themes, projects and activities of Future Earth data producers, in particular by liaising with World Data System, CODATA, GEO/GEOSS and the observing systems, research funders, and others, as appropriate; and
- Develop and facilitate implementation of a sustainability strategy for all operations of Future Earth (including Secretariat, projects offices, procurement, travel, operations of Science Committee, Governing Council and Alliance etc.).

Communication, engagement and science-policy assessments:

- Jointly with the Science and Engagement Committees, develop strategies for communication, capacity building, education and engagement with key stakeholder groups;
- Coordinate with relevant partners on communication, capacity building, education and stakeholder engagement to implement strategies, as above;

- Ensure that Future Earth has a prominent role within the international science-policy interface (e.g. process to develop SDGs etc.);
- Organise and manage outreach activities (e.g. conferences, workshops, stakeholder fora, panels in partnership with key stakeholders etc.);
- Develop a network and engage stakeholders from all regions, with a particular effort to engage young scientists and scientists from developing countries; and
- Coordinate scientific input from Future Earth into assessment processes (such as IPBES, IPCC).

The Director of the Secretariat will appoint other members of the Secretariat. The Secretariat should be fully operational shortly after the end of the transition period in order to support the setup of the rest of the governance structure. It is envisaged that the existing GEC secretariats will serve as the interim Future Earth Secretariat.

Annex 4. Future Earth Data and information

The following input is based on advice from Roberta Balstad (Editor-in-Chief, Weather, Climate, and Society, American Meteorological Society, Center for Research on Environmental Decisions, Columbia University) to the Transition Team.

Although general recognition of the importance of data to international science appears to be increasing, there remain significant barriers to developing and implementing sound data management programmes and infrastructure in a timely manner to meet desired objectives such as open access, long-term stewardship, and support for both research and application needs. Many lessons can be learned from the data challenges experienced by the International Polar Year Initiative.

Similar challenges exist with regard to the Future Earth programme to work proactively to identify key data needs, coordinate data development and infrastructure activities, develop data management and funding strategies, and support community outreach and participation in data-related activities. In addition, Future Earth will present substantial data challenges associated with the need for integrated analysis of natural and social science data.

In planning for the transition to Future Earth, then, it will be essential to establish data policies and systems at the outset of the programme, before the actual research and observations begin. Data-related organisations and programmes (e.g., CODATA and ICSU-WDS) must be involved appropriately in the early stage of Future Earth considering policies, standards, and methods that affect scientific data management across a wide range of sciences. Proactive interactions and effective collaboration with these key data programmes and activities can ensure Future Earth data are properly managed and preserved as its legacy.

A4.1 Data and information as a strategic component of the Earth system science

Data and information constitute a challenging but an essential component within Future Earth. Although Future Earth is a scientific research programme designed to facilitate research among diverse multilateral and multi-disciplinary scientists (including present and future physical and natural scientists, social scientists, engineers, etc.), it also bridges the scientific research community with the public and private sectors. These latter groups include managers, consumers, and policy- and decision-makers. Because of the broad diversity of these audiences, it is essential that provisions for data and information preservation, documentation and quality, and access and dissemination which meet the needs of both scientists and stakeholders be established for the programme and that this be accomplished before its onset.

An emphasis on data has been a strategic component in Future Earth since the earliest discussions about the activity. One of the five Grand Challenges identified by the Earth System Visioning process was “Observing”, which specifically includes the need for a data and information system in Future Earth. The first ICSU report, leading to the formation of the current Transition Team, emphasised that, "A robust data and information system is needed that can combine data and knowledge gathered over centuries with new observations and modelling results to provide a range of integrated, interdisciplinary dataset, indicators, visualizations, scenarios, and other information products. Ensuring wide access to both past and future data, especially with regard to societal dimensions, is a key challenge that cannot be taken for granted" (p. 12, *Earth System Science for Global Sustainability; The Grand Challenges*, ICSU, 2010).

A second Grand Challenge was "Forecasting", an activity that is a heavy consumer of data. In Future Earth, there will be an emphasis on integrated forecasting, modelling, and prediction, which will require the use of socioeconomic, ecosystem, and geophysical data over long time periods. If the past experience of the IPCC is any guide, there could be public skepticism and *post hoc* requests from both scientific and public sources for information on Future Earth assumptions, data, and model output, and the Future Earth will be evaluated in part on its ability to meet those requests through its data and information system.

Still other Grand Challenges also have implications for the Future Earth data strategy. Under the challenge of "Confining", for example, one of the priority research questions was "How can we identify, analyse and track our proximity to thresholds and discontinuities in coupled social-environmental systems?". These types of activities will depend upon the capacity to integrate quantitative indicators, models, visualizations, and other data and information products through some kind of Future Earth-sponsored data service.

In sum, data are both the drivers of scientific research, the means of accomplishing research, and part of the basic infrastructure in Future Earth. In this chapter, major issues related to the role of data and information in Future Earth and policies for data are discussed. There is a summary of data policy recommendations in the final section.

A4.2: Why are data critical in Future Earth?

The arguments for including planning for data and information within the broader scientific Future Earth initiative are both scientific and pragmatic. Given that the goals of Future Earth are (1) to create an integrated scientific research vision for sustainability in the context of global change, (2) to provide a vision of how we can respond to these changes and achieve global sustainability, and (3) to mobilise the research community and decision makers to address these issues, then a coordinated focus on data and information beginning within the planning process is critical. To the extent that the initiative will be establishing a capacity for tracking future changes related to sustainability, baseline data sets will need to be identified and created. To the extent that research associated with Future Earth will be examining change over time, data at multiple temporal and spatial intervals (both new and extant data) will be needed both now and in the future to measure and monitor such change. As a recent OECD report stated, "Databases are rapidly becoming an essential part of the infrastructure of the global science system." This is as true for Future Earth as it is for other scientific activities.

Because Future Earth will be engaged in the difficult work of integrating research and data across disparate disciplines and fields and across physical and temporal scales (such as global and national or provincial scales), the credibility of the research may rest on the perceived validity of the data integration. Consequently, Future Earth projects, if they are to accomplish their goals, may require research on data collection and integration prior to or in parallel with substantive research on sustainability.

Still another reason that data and information will be critical to Future Earth is that they will be needed by future public and scientific users. If Future Earth will be communicating the results of research to the broader society and its policy- and decision makers, it must be able to provide these users with the data they need to understand the extent and pace of change. They will also need appropriate data, routinely provided, in order to track and respond to changes taking place in their jurisdictions. Being able to provide these users with open access to the data after the conclusion of Future Earth research will be important in establishing the legitimacy of both the initiative and the scientific work done under its banner.

Finally, data from Future Earth research must be preserved and made continually accessible so that they will be available not only for today's scientists, but also for future generations of scientists and their students to use. In many international scientific programmes, scientific data constitute one of the most important and enduring legacies of the programme.

A4.3: What kinds of data will be used and produced in Future Earth?

One of the scientific challenges in managing data in Future Earth is related to the nature of the data produced and analysed in the programme. Because of the programme's focus on sustainability, impacts, and future development, there will be a continuing need for socioeconomic and cultural data that can be used both by themselves and in conjunction with physical and natural science data. Scientists in both the natural/physical sciences and the social/behavioural sciences have considerable experience in obtaining, analysing, preserving and managing, and disseminating scientific data in their disciplines. However, they often have only limited experience in integrating data across these two broad fields of science. In order to understand the challenges posed by the breadth of the data needed in Future Earth, it is useful to describe some of the varieties of socioeconomic data, albeit briefly, and to discuss the problems that can be encountered in integrating socioeconomic and physical/natural science data in research and modelling.

Socioeconomic data differ in significant ways from other types of scientific data. They include, for example, demographic data, that is, strictly speaking, data on individual births, deaths, morbidity, and migration. Increasingly, however, demographic data encompass a much broader range of data on individuals. Because these data are collected by governments, they are usually available by political or administration jurisdictions, such as the country, sub-national units such as province, state, or prefecture, and local governmental units.

A second form of data collected by governments are official statistics, including census data on household composition; data on labor force participation (employment and unemployment); consumption data; economic data on individuals, firms, and political jurisdictions; health and disease data; agricultural production data; and others. These data are uneven in their availability, with the developed countries having more extensive data resources than the developing countries, but some of these data can be estimated for developing countries from clustered surveys.

A third set of data are classified as behavioral and transactional data. These data are created from the records of individual transactions or activities and include the much-vaunted Google Flu dataset, which consists of records of Internet searches to determine the frequency, in this case, of flu symptoms in the general population. This category of data is far broader than Internet searches, however. It includes information on purchases, travel and commuting patterns, water and energy usage, and a broad range of other activities, and increasingly social scientists are able to ascertain behavioral patterns, regional and economic differences in behaviour, and even individual health characteristics from these data.

A fourth source of socioeconomic data is survey data, that is, data obtained through formal probability surveys of a population. These data can provide information on attitudes, perceptions, intentions, and self-reported behaviours. It is the source of a great deal of data on political attitudes and voting behaviour, including attitudes and behaviour related to sustainability.

Other new and emerging sources of data include continuous time process data, computerisation of self reports, and crowd sourcing.

These various types of socioeconomic data can be analysed administratively, spatially, temporally, or culturally. The unit of analysis can be the individual or the family; a linguistic, economic, or religious group; a political or administrative area; or an individual, policy, or collective action. The data can also be systematically combined to form indices, such as the well-known Human Development Index of the United Nations, which combines measures of life expectancy, educational attainment, and income into an index that provides a means of comparing nations on human development. Another index is the Environmental Performance Index, which tracks a set of nations on their performance related to environmental issues.

As this very brief foray into socioeconomic data suggests, these data pose new types of analytical and data integration problems for scientists conducting multidisciplinary research. For example, it is difficult to combine data for a set of cities with meteorological or hydrological data. Should one use individuals or families as the basic analytical unit? The individual is an indivisible unit, but the family may be the basic unit for consumption decisions. In this, as so many areas, it depends upon the nature of the research problem. There are other problems that are related to data access, such as the size of data collection efforts, legal restrictions on the use of individual microdata, and even fabrication or distortion of data by governments seeking to influence political, social, and economic agendas or outcomes. Because individual and collective behaviour (e.g., the behaviour of the family, ethnic, political or religious group) often differs considerably for country to country and from region to region, it is difficult to draw global scale conclusions for Future Earth from data collected in one country. As a result, socioeconomic data collection has to be extensive and broadly inclusive, and it can be both expensive and time-consuming to obtain adequate global- or regional-scale data bases. It also requires working with different sets of collaborators in many countries.

In addition, data collected on individuals is often subject to legal and regulatory controls due to the need to protect individuals' privacy and confidentiality. These regulations can complicate analysis of the data by forcing researchers to take an extra step to disguise individual responses or characteristics in the microdata. However, if privacy and confidentiality controls are not in place, or citizens have no faith in the implementation of the privacy and confidentiality controls that are in place, they often disguise their responses and their behaviours to protect themselves. This, obviously, distorts the data and undercuts scientific research. Still another problem is that state-sponsored data collection and dissemination can be subject to political interference by governments that want to control the information available to and received by both citizens and external groups about their population.

The purpose of this section is not to focus exclusively on socioeconomic data because it is the only type of data that is important for Future Earth. However, the programme is focused on scientific research on global sustainability and socioeconomic data will be essential to that research. The characteristics of these data are generally less well known in the climate, environment, and global change research communities than are the characteristics of physical and natural science data. For that reason, identifying some of the ways that socioeconomic data differ from other types of scientific data is useful to clarify issues related to the difficult task of integrating socioeconomic and physical/natural science data in Future Earth research, analysis, and modelling. It also serves to emphasise that data integration itself will need to be a research task in the programme.

A4.4: Data policies—the ICSU experience with international programmes

ICSU has many decades of experience in developing and implementing policies for data and information during and after conducting multinational research programmes. In the course of organising the International Geophysical Year, IGBP, IPY, and other programmes, and also through its Committee on Data for Science and Technology (CODATA), ICSU has learned a great deal about what are effective and ineffective data policies and procedures in scientific programmes. Participating scientists and affiliated groups have also learned from their own experiences of the importance of having agreement on common data policies and strategies during and after the research programme. Increasingly, scientists recognise that data collection and analysis are improved when there are widely accepted provisions for data documentation and quality, dissemination, and preservation. ICSU has learned that it is extremely difficult to impose data management policies upon scientists after research programmes are underway or, worse, after they are finished.

In planning for the transition to Future Earth, then, it will be essential to establish data policies and systems at the outset of the programme, before the actual research and observations begin. ICSU has learned that it is at the beginning of international research programme that expectations are set.

Without common expectations for data, it will be very difficult to persuade either scientists or funding agencies to support data activities later in the research process. It should be recognised that effective data policies for global scientific activities will also require advancing data access and management capacity in developing countries; training potential new users of scientific data, especially non-scientists; and identifying adequate financial support for data activities. It will also be critical to identify institutional partners and collaborators who can become advocates for the programme's data policies.

The four major areas of data policy that should be addressed include documentation and quality, preservation, access and dissemination, and costs.

Documentation and Quality. Data management involves documenting the data so that others can use it, and data documentation requires some assessment of quality if the data are to be scientifically valuable. Data documentation is a professional activity, but one that is often assigned to apprentice scientists on a research team. To be done right, it must be closely supervised by both professional data managers and by the research scientists who were responsible for collecting and analysing the data. It is particularly important that data that could be used by future generations of scientists be well documented. The data documentation process can be costly, and it will be necessary for the funders to provide funding for data documentation in their research grants.

Preservation. Data preservation refers to both short-term and long-term data retention. It also involves the protection of scientific data from degradation over time and adaptation of the data to changing technologies and data protocols. Well-defined data preservation policies are particularly important for the use of data in scientific research that seeks to measure change over time. To be done well, data preservation requires institutional support, trained staff, clear and widely circulated data documentation and interoperability standards to be followed by scientists submitting data for preservation, and access to advanced technical systems for documentation, preservation, and storage of the data. The access system for these data should be capable of being used easily by current and future scientists, data providers, and public data users.

Access and Dissemination. Access to and dissemination of Future Earth data by both the scientific community and the public is critically important to meeting the goals of the programme. Because access and dissemination are now electronic activities, they are often easier in the developed, high tech nations than in the developing world. They are also easier for individuals within the scientific community than those in the public and private sector policy communities. For this reason, it could be useful to establish a single system of data management that provides separate paths of access for scientists and the public. It will also be useful to provide training in data access in developing countries.

One ICSU policy that is important for the programme is that data access should be equitable for all potential users (scientific and public) and the data should be available at minimum cost, if any. It is recommended that Future Earth adopt this policy. It is also recommended that Future Earth adopt the OECD Principles and Guidelines for Access to Research Data from Public Funding (Paris, OECD, 2007). In order to avoid intellectual property issues from limiting access to the data, data collected or modified for use in research under the auspices of Future Earth should be co-owned by Future Earth and the investigator.

Costs. Data documentation, preservation, and access and dissemination are costly activities. Changes in the cost structure of these activities should be expected over time, and financial support and institutional commitments to preserve and disseminate scientific data may actually be declining. The current system for data documentation, preservation, and dissemination, gradually built up during several decades of relative prosperity and widespread financial support for science and its institutional infrastructure, may be unsustainable. For this reason, Future Earth needs to join with other organisations in innovative partnerships to ensure that data and information obtained in the programme will be available for scientists, educators, and decision makers now and in the future.

As a result of the costs of various steps in data management, it is too easy for scientists to ignore data documentation and preservation when they have finished their research. To avoid the loss of this critical scientific resource, Future Earth must seek to change the incentives. The national funding agencies, multilateral organisations, and foundations supporting Future Earth research should commit themselves to provide adequate funds to cover the transfer of research data from the scientific investigator to a data centre or archive. Again, this commitment to providing financial support for research data management should be an integral part of Future Earth and be in place at the outset of the programme.

A4.5: Links with international Observing Systems, GEOSS, and government observing and statistical programmes

Because establishing an independent data documentation, preservation, and access system for Future Earth will be costly and complex, and because there are excellent organisations and institutions that are already committed to these activities, the programme should seek to work with existing data organisations and structures insofar as possible. In this section and the next, ideas for building upon the existing scientific data infrastructure—rather than recreating it—are explored.

The study of international scientific research programmes shows that identifying large scale data set needs and obtaining necessary data are intricately tied into the selection of research themes for the programme. Individual investigators will obviously seek their own data for specific research problems. However one of the benefits of major international programmes is that the resources available to scientists—financial, scientific, and, yes, data—are greater than they would be for a scientist acting alone. It is not yet possible to identify the data needed for Future Earth because the research themes are still being discussed and research planning has not yet begun. When the transition is completed and the formal programme is launched, however, it will be valuable to identify needed baseline and other data for research.

In the past, widespread collaboration in identifying data needs has been a significant stimulus toward actually obtaining the data. Future Earth should plan to work with the observing systems and GEO/GEOSS to identify and possibly even calibrate needed data sets for research on global sustainability. This will entail both ICSU and Future Earth building an active partnership with both the observing systems and GEO/GEOSS. Through GEO/GEOSS, Future Earth will be working in partnership with national data and observing systems where many of the decisions about data collection are actually made.

It will also be important to identify needed socioeconomic data. The socioeconomic “observing systems” are run by a different set of institutions than the physical and ecological observing systems. Much of the currently available socioeconomic data are now collected by or under the auspices of government statistical agencies and some of this is brought together by UN agencies, national development agencies, or the World Bank. There is less consensus on what transactional data sets are important for research on sustainability, and identifying such data sets is an important research task. Again, active partnership with existing multilateral organisations will help in identifying needed data and stimulating the collection of data.

A4.6: Roles for data centres and the World Data System

The cost of providing financial support for the data centres that manage, preserve, and disseminate Future Earth data is beyond the scope of the programme. Moreover, the programme should not have to pay these costs if it collaborates with extant scientific, university, and national data centres. Extant scientific data centres, such as those that are members of ICSU’s World Data System (WDS), have significant experience, secure funding, and an institutional existence that will continue beyond the active life of Future Earth. Because many of the WDS data centres are heavily focused on data in the Earth sciences, Future Earth should encourage the World Data System to expand, encouraging the formation of new data centres focused on such topics as sustainability and integrated socioeconomic and natural science research.

There are also data centres for socioeconomic data in many countries and these should be included in Future Earth data planning as well. Some of these centres antedate the World Data Centres established at the time of the International Geophysical Year and have a long history of excellence in social science data documentation, preservation, and dissemination. They also have little experience in working with ICSU science projects. For this reason, it may be necessary for Future Earth leadership to contact these archives to discuss the project and potential collaboration.

One of the advantages of working with existing data centres is that the data professionals in these centres will have the scientific and technical expertise to deal with the complex technical issues regarding data documentation, preservation, and dissemination over time. Should the data be stored in a cloud repository? Probably, but that is a decision for the data centres to make, not the scientists who are collecting and analysing the data. It will be valuable for Future Earth to have its own metadata catalogue, but this should be constructed in addition to, not instead of, the metadata catalogues at each of the data centres that hold Future Earth data.

A4.7: Data issues for Future Earth

There are data issues that should be discussed as part of the transition process. For research, it could identify needed data at multiple time periods and locations, methods for collecting and integrating those data across disciplines, and use of those data in scientific research and modelling. New sources of data could include both "organic" data (created for other purposes but available for use in research) and scientifically designed and specially collected data. They could also include the digitisation of administrative and transactional data from both contemporary and historical sources. Working Group I [16] should consider whether the creation of critical baseline data sets should be a part of the Future Earth. If so, identification of Future Earth baseline data sets will take time and required widespread discussion and collaboration; they will also require funding. Thus, discussions about needed baseline data sets for Future Earth should take place early in the planning process and should include discussions with the observing systems and GEO/GEOSS to identify partners in this process.

In considering analytical issues related to integrated Future Earth sustainability research, WG I should consider data availability and necessary data development. Methodologically, the programme may need to identify needed improvements in record matching and data mining. Other critical issues for WGI are methods for the integration of site-specific socioeconomic and ecosystem data with global scale physical and meteorological data and the blending of digital and non-digital sources of data in situations where there is great unevenness in our capacity to observe and collect data across regions, countries, and fields of science.

Non-research issues related to the integration of disparate types of research data include consideration of nationally based privacy and confidentiality restrictions, current and historic politicisation of data collection and reporting, and data aggregation and integration methods, as discussed above. Finally, there is a need to balance goals for meeting current needs for research data with the preservation of the longer term data legacy of Future Earth, including the scientific, educational, and policy infrastructure for data. The overarching non-research issue remains the financing of the Future Earth data system now and in the future.

Working Group II will be focused on institutional design issues. Past experience has shown that if scientific data are to be useful and accessible to researchers and students, data documentation and quality, dissemination, and long term preservation must be institutionalised. At the same time, however, experience in data collection and the capacity to manage, disseminate, and preserve data are very unevenly distributed across countries, regions, and disciplines. This suggests that if nothing is done, the

[16] References to 'Working Groups' relate to the Transition Team working groups on the Research Framework (I), Institutional design (II) and Stakeholder engagement, education and communication (III). The relevant recommendations should continue to be highlighted during implementation.

default mode for data management will be that it becomes the responsibility of scientists in industrialised countries.

This raises obvious problems of equity and scientific sustainability. Data for Future Earth research (physical, ecosystem, and socioeconomic data) are needed from many countries and regions, and scientists in the developing world should be deeply engaged in this research and data collection. Data quality will be improved with the participation of scientists in all nations because of their access to relevant national institutions and individuals. Scientists in the developing world are often reluctant to make real-time and historical data sets freely available to scientists elsewhere, however, because they believe that this contributes to the advancement of science in the developed world rather than in their own countries. They might be more apt to collaborate if they see some benefit from data exchange in terms of institutional and scientific capacity building in their own countries. For this reason, it is recommended that where possible, existing data centres be used in Future Earth, but that the programme commit itself to fostering the creation of at least one new data centre in each region where there is an ICSU Regional Centre.

Although Working Group III is less directly involved in data issues, it is responsible for education, communication, and interactions with stakeholders. This working group has a strong interest in ensuring the on-going availability of Future Earth data because data are critical for scientific training and education and essential for public education, monitoring, and policy. This working group should also look into fostering the growth of local and national information systems focused on global sustainability. These would be available for use by Future Earth stakeholders to obtain access to monitoring and observation data. WGIII's focus on education and training should encompass the training necessary to produce data collection and management specialists, both in developed and developing countries.

A4.8: Summary of Data Recommendations for Future Earth

- Policies for the management, preservation, and dissemination of scientific data collected under the auspices of Future Earth should be developed in collaboration with CODATA and WDS. These policies must be in place at the onset of the programme. All data policies should be accessible to all participants on the Future Earth web page.
- Future Earth data policies should include a mandatory requirement for archiving data from Future Earth research projects in a funded data archive and for listing the metadata in a metadata catalogue linked to the Future Earth web page.
- Insofar as possible, existing data centres and archives should be used for Future Earth data. New data centres should be established in connection with the ICSU Regional Centres. Training should be made available for those who work in the centre.
- If a scientist has no archive immediately available for research data, the ICSU World Data system should be responsible for finding an "archive of opportunity" for the scientist to use in depositing data.

- Funding for data documentation and transfer to data centres should be in place at the beginning of the Future Earth research programme and should be supported as a routine part of research project funding.
- Data should be documented and archived within one year of the completion of the research project.
- All data collected or modified for research under Future Earth auspices should be declared to be co-owned by the investigator and by Future Earth. These data should be made available to all who request them on an equitable basis and at no more than the cost of reproduction.
- Provision should be made for a web site providing separate data access by public and private sector users. This web site should provide non-scientific users with guidance to the databases and links to Future Earth research.
- Data integration should be a recognised research task eligible for funding in the Future Earth research programme.
- Data needs for each major area of Future Earth research should be discussed early in the planning process, in collaboration with CODATA and WDS. Where deemed useful, needed baseline data sets should be identified.
- It is also essential to recognise that effective global science will require the development of data access and management capacity in developing countries, the training of potential users, especially non-scientists, about the data, and the identification of adequate financial support for data activities. CODATA and WDS can assist in identification of institutional partners and collaborators in this arena.

Annex 5: Four work packages for the implementation of Future Earth during the transition period

WP 1: Future Earth initial design: developing research framework, institutional design option and outreach strategy (this is the work of the Transition Team, reported in this document)

1. Developing an overall vision and a research framework (WG1)
2. Developing an institutional design including option(s) for developing regional nodes (WG2)
3. Developing a framework for stakeholder engagement, education, communication (WG3)
4. Delivering recommendations in a report marking the end of the initial design phase (TT)

WP2: Transition approach: ensuring that the fundamentals are in place

1. Ensuring high level vision and expected outcomes for Future Earth are in place
2. Clarifying the role of the Alliance with respect to Future Earth, during the transition phase and beyond
3. Defining a way of working, within the Alliance, with the Transition Team, and relevant external players (e.g. GEC programmes)
4. Agreeing on individual partner roles, responsibilities and resources that partners can dedicate to the design and early implementation of Future Earth
5. Engaging all existing GEC co-sponsors and major funders of projects to support the evolution to Future Earth

WP3: Funding: securing the funding necessary for the transition phase and the initial operations phase; planning funding for full operations

1. Clarifying current funding landscape for GEC activities (secretariats, IPOs, research)
2. Defining and securing funding needs for the transition phase of Future Earth (now-end 2012)
3. Defining and securing funding needs for initial operations of Future Earth (Jan 2013-end April 2014)
4. Including early research funding opportunities
5. Defining funding needs, fundraising strategy and financial management mechanism for the full operating phase
6. Securing commitments from existing funders (to be continued within Future Earth)

7. Conducting scoping of funding opportunities and potential sources (external expertise available to support this task)
8. Engaging potential new funders

WP4. Governance: managing the transition to Future Earth governance

1. Establishing the long term governance
2. Defining the terms of reference of the governance bodies and test that the structure is appropriate
3. Establishing the Future Earth Scientific Committee (nomination, call, selection)
4. Establishing the Future Earth multi-stakeholder Governing Council (nomination, call, selection)
5. Establishing the Future Earth Executive Secretariat (conducting dialogue with funders, call, negotiation, hiring)
6. Establishing any other required governance bodies
7. Planning the implementation of regional nodes
8. Establishing the interim governance
9. Identify the required governance bodies, define their terms of reference and test that the structure is appropriate
10. Plan the transition to an interim Secretariat (agreeing roles and tasks, defining operating process)
11. Establishing the interim governing council
12. Establish any other required interim governance bodies

WP5: Building a Future Earth community: identifying, engaging and building partnership with key stakeholders

1. Identifying key stakeholders
2. Define and implement a communications and stakeholder engagement strategy for the interim period
3. Planning activities to engage stakeholders globally and regionally
4. Building partnerships with key stakeholders that can provide support to Future Earth
5. Defining and implementing an outreach plan during the transition (PUP, Rio+20, other)

Complementing the work packages identified above, it is recognised that there will be an essential change management task to support the transition from the current GEC programme structure to Future Earth. This is needed to both support the motivation of those involved through effective communication and engagement, and also to recognise that the changes may affect people's roles and this needs to be managed sensitively. The transition project needs to think carefully about change management, and draw in expert advice as needed.

Annex 6: Acronyms

AAAS: American Association for the Advancement of Science

AGMIP: Agricultural Model Intercomparison and Improvement Project

AGU: American Geophysical Union

AOA: Assessment of Assessments

APN: Asia-Pacific Network for Global Change Research

CBD: Convention on Biological Diversity

CCAFS: Climate Change, Agriculture and Food Security

CGIAR: Consultative Group on International Agricultural Research

CIFOR: Centre for International Forestry Research

Clic: Climate and Cryosphere

CLIVAR: Climate Variability and Predictability

CMIP: Coupled Model Intercomparison Project

CODATA: Committee on Data for Science and Technology (ICSU)

CRA: Collaborative Research Action (Belmont Forum)

CSD: Commission on Sustainable Development (UN)

DIVERSITAS: an international programme of biodiversity

EGU: European Geosciences Union

ENSO: El Niño Southern Oscillation

EPSRC: Engineering and Physical Sciences Research Council

ESG: Earth System Governance

ESSP: Earth System Science Partnership

EU: European Union

FACCE: Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE – JPI)

FAO: Food and Agriculture Organisation (UN)

GBIF: Global Biodiversity Information Facility

GCOS: Global Climate Observing System

GCP: Global Carbon Project

GEC: Global Environmental Change

GECHS: Global Environmental Change and Human Security project

GEO: Group on Earth Observations

GEO-BON: Group on Earth Observations Biodiversity Observation Network

GEOSS: Global Earth Observation System of Systems

GEWEX: Global Energy and Water Exchanges Project

GLP: Global Land Project

GOOS: Global Ocean Observing System

HLPF: High Level Political Forum (UN)

IAI: Inter-American Institute for Global Change Research

ICSU: International Council for Science

IGAC: International Global Atmospheric Chemistry project

IGBP: International Geosphere-Biosphere Programme

IGFA: International Group of Funding Agencies for Global Change Research

IHDP: International Human Dimensions Programme on Global Environmental Change

IHOPE: Integrated History of People on Earth

IOF: International Opportunity Fund

IPBES: Intergovernmental Platform on Biodiversity and Ecosystem Services

IPCC: Intergovernmental Panel on Climate Change

IPO: International Project Office

IPY: International Polar Year

IRDR: Integrated Research on Disaster Risk

ISSC: International Social Science Council

IT: Industrial Transformation (IHDP)

LOICZ: Land-Ocean Interactions in the Coastal Zone

LUCC: Land Use and Climate Change

MDG: Millennium Development Goal

MEA: Millennium Ecosystem Assessment

NASA: National Aeronautics and Space Administration

OECD: Organisation for Economic Co-operation and Development

PECS: Programme on Ecosystem Change and Society

PUP: Planet Under Pressure

SDG: Sustainable Development Goal

SSEESS: Swedish Secretariat for Environmental Earth System Sciences

Sida: Swedish International Development cooperation Agency

SOLAS: Surface Ocean - Lower Atmosphere Study

START: the Global Change SysTem for Analysis Research and Training

TT: Transition Team

UNDP: United Nations Development Programme

UN OWG: United Nations Open Working Group (on sustainable development goals)

USGCRP: United States Global Change Research Program

WBCSD: World Business Council for Sustainable Development

WBGU: German Advisory Council on Global Change

WCRP: World Climate Research Programme

WDS: World Data System

WHO: World Health Organisation

WMO: World Meteorological Organisation

WTO: World Trade Organisation

UNEP: United Nations Environment Programme

UNFCCC: United Nations Framework Convention on Climate Change

Annex 7: Global Environmental Change programmes, partnerships and projects

This annex identified the activities commonly referred to as 'GEC programmes' and 'GEC projects' in this report.

Global Environmental Change Programmes and their partnership

Acronym	Full name	Sponsors
DIVERSITAS	International programme on biodiversity	International Council for Science (ICSU) International Union of Biological sciences (IUBS) Scientific Committee on Problems of the Environment (SCOPE) United Nations Educational, Scientific and Cultural Organisation (UNESCO)
IGBP	International Geosphere-Biosphere Programme	International Council for Science (ICSU)
IHDP	International Human Dimensions Programme on Global Environmental Change	International Council for Science (ICSU) International Social Science Council (ISSC) United Nations University (UNU)
WCRP	World Climate Research Programme	International Council for Science (ICSU) Intergovernmental Oceanographic Commission (IOC – UNESCO) World Meteorological Organisation (WMO)
ESSP	Earth System Science Partnership	Transitioned into Future Earth 31/12/12.

Global Environmental Change Projects[17]

Full name	Acronym	Sponsors
agroBIODIVERSITY		DIVERSITAS
Analysis, Integration and Modelling of the Earth System	AIMES	IGBP
bioDISCOVERY		DIVERSITAS
bioGENESIS		DIVERSITAS
bioSUSTAINABILITY		DIVERSITAS
Climate and Cryosphere	CliC	WCRP
Climate Change, Agriculture and Food Security	CCAFS	ESSP (then ICSU) CGIAR
Climate Variability and Predictability	CLIVAR	WCRP
Earth System Governance	ESG	IHDP
ecoHEALTH		DIVERSITAS
ecoSERVICES		DIVERSITAS
freshwaterBIODIVERSITY		DIVERSITAS
Global Carbon Project	GCP	ESSP
Global Environmental Change and Human Health	GECHH	ESSP
Global Environmental Change and Human Security	GECHS	IHDP
Global Energy and Water Experiment	GEWEX	WCRP
Global Land Project	GLP	IHDP; IGBP
Global Mountain Biodiversity Assessment	GMBA	DIVERSITAS
Global Water System Project	GWSP	ESSP
Industrial Transformation	IT	IHDP
Integrated History and Future of People on Earth	IHOPE	IHDP; IGBP/AIMES/PAGES
Integrated Land Ecosystem-Atmosphere Processes Study	iLEAPS	IGBP
Integrated Marine Biogeochemistry and Ecosystem Research	IMBER	IGBP; SCOR

[17] This is a list of core projects. Additional projects and working groups implemented by the GEC programmes have not been included.

Integrated Risk Governance	IRG	IHDP
International Global Atmospheric Chemistry	IGAC	IGBP; iCACGP
Land-Ocean Interactions in the Coastal Zone	LOICZ	IHDP; IGBP
Monsoon Asia Integrated Regional Study	MAIRS	ESSP
Past Global Changes	PAGES	IGBP
Programme on Ecosystem Change and Society	PECS	ICSU, UNESCO
Surface Ocean - Lower Atmosphere Study	SOLAS	IGBP; WCRP, SCOR, iCACGP
Stratosphere-troposphere Processes And their Role in Climate	SPARC	WCRP
System for Analysis, Research and Training	START	ESSP
Urbanization and Global Environmental Change	UGEC	IHDP