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21 Transformative research for a sustainable future Earth

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Abstract. The scientific consensus is that we have entered the Anthropocene, a new geologic epoch defined by our own massive impact on the planet. This paper addresses the broad scope of interconnected issues, such as biogeochemical flows and biodiversity integrity, land-system and climate change, which are all interconnected. There is need to identify and quantify the planetary boundaries that provide a "safe" operating space for humanity. In the present international context, the issues are being dealt with as disaster risk reduction (Sendai Framework), climate change (Paris Agreement) and Sustainable Development Goals. How can science best provide the inputs to these policy processes and more importantly to help governments and people address the issues? These questions require outputs leading to outcomes that address complex socio-economic, natural, health, engineering, philosophical and cultural issues and most challenging their intersections.

The Program Future Earth: Research for Global Sustainability has, as its goal: "To provide the knowledge required for societies in the world to face risks posed by global environmental change and to seize opportunities in a transition to global sustainability". The program has adopted a unique approach of both a Science Committee and an Engagement Committee to co-design and co-produce the scientific research program. The Science Committee: represents the full spectrum of scientific fields, as well as scientists from other sectors and the Engagement Committee includes representatives from business, civil society and government. The research theme of transformations to

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sustainability will be a special challenge in dealing with issues such as transformation processes and global and regional governance, including incentives and international law. The challenge for Future Earth will be to bring together interdisciplinary, transdisciplinary teams of scientists to undertake transformative research providing outputs leading to outcomes that make a difference for global sustainability.

Keywords: sustainable development, climate change, disaster risk reduction, transformative research, international research collaboration, science for policy, science and society.

1 Introduction

The scientific consensus is that our planet has entered the Anthropocene, the age of humans, a new geologic epoch defined by our own massive impact on the planet (Steffen, Crutzen, & McNeill, 2007). This paper addresses the broad scope of interconnected issues, such as biogeochemical flows and biodiversity integrity, land-systems, ozone layer depletion and climate change, which are all interconnected. There is need to identify and quantify the planetary boundaries that provide a "safe" operating space for humanity (Syvitski, 2012). How far have we gone? Where are the global "tipping" points that may exceed the planet capacity of adaptation? What actions can turn us back? These are critically important policy issues for societies and governments that are challenging global realities. A global perspective of the relative risks of climate change, extreme weather and natural disasters was given in The Global Risks Report 2016 (World Economic Forum, 2016). The failure of actions on climate change mitigation and adaptation is now ranked as the global risk with the highest impact and one of the most likely ones. The Top 5 Global Risks in Terms of Likelihood are ranked to be: 1. Large-scale involuntary migration; 2. Extreme weather events; 3. Failure of climate change mitigation and adaptation; 4. Interstate conflict with regional consequences; and, 5. Major natural catastrophes. We are living in a world of converging crises and facing the imperative of profound social transformation. As we go forward, there will be more and more interdependencies, of which we understand less and less. The bringing together the typical ingredients for an upcoming crash means that it is essential to have coordinated efforts of public authorities, civil society, industry, and academia to avoid possible collapse of society as we know it (Lechner, Jacometti, McBean, & Mitchison, 2016).

An example of the issues and their interconnectedness is what we may call the "Disaster Risk-Poverty Nexus" (International Strategy for Disaster Reduction, 2009). There are global drivers of risk, such as uneven economic and urban development, climate change and weak governance and limited endogenous capacities. When these are imposed on the underlying risk drivers, such poor urban and local governance, vulnerable rural livelihoods, ecosystem decline and lack of access to risk transfer and social protection and the mix of everyday, extensive or intensive risk resulting in disaster impacts, the results are poverty outcomes which in turn accentuate the poverty and

related factors, making the community's risks even higher. The result is a "feedback" loop in that communities that are already poor are more impacted by hazards, leading to further enhancement of their poverty and, hence risk, with even greater negative impacts when the next hazard strikes. Hence, weak governance, limited endogenous capacities and superimposed climate change, lead to uneven economic and urban development, further enhanced when a hazard strikes, demonstrating the linkages of the issues of poverty, health, environment, development and governance.

These interconnected issues are challenging, and changing, science, and all its aspects. Doing integrated science that makes a difference and pursuing excellence through engagement in open knowledge-action arenas is important and necessary to address these issues. There is need for science-based information as inputs to the issues of global security, intersections of cultures and societies and these are challenges for science policy and practice. Now is the time to create the 'conditions of possibility', to support science for a sustainable and just world. The characterization of today's global realities includes (United Nations Educational, Scientific and Cultural Organisation & International Social Science Council, 2009):

- the inseparability of social, political, cultural and environmental problems;
- the centrality of people;
- the inadequate social responses to date; and
- the urgent need for social transformation.

There is need for transformations recognizing the complex processes of profound social change, the altering of our social and economic systems and the values and lifestyles in ways that could put society on a fundamentally different development path. The global scientific community needs to, and is, responding to these changes.

2 The International Council for Science

The International Council for Science (ICSU)[1] is a leading non-governmental science organization that was created in 1931. The Council now has 122 National Members and 31 Unions or Associations of scientists by discipline. The scope of these disciplines include math, physics, chemistry, geology, biology, anthropology, sociology and the history and philosophy of science. The Mission of the International Council for Science (ICSU) is *"to strengthen international science for the benefit of society"*, for all societies. The vision of the Council is for a world where excellence in science (all sciences) is effectively translated into policy making and socio-economic development, with universal and equitable access to scientific data and information, where

[1] http://www.icsu.org

all countries have scientific capacity, enabling the generation of new knowledge and nations can establish their own development pathways in a sustainable manner. The Council's key priorities and associated activities are: Science for Policy (and policy for science); Universality of Science with the freedom to do science while recognizing the responsibilities of science and scientists; and International Research Collaboration.

The International Council for Science works closely with the International Social Science Council (ISSC)[2]. ICSU and ISSC are co-sponsors of the Integrated Research on Disaster Risk Program and the Future Earth Program. They also collaborate in other ways, such as through Science International[3]. In 2015 the International Council for Science (ICSU) initiated 'Science International' as a new series of action-oriented meetings bringing together major international science bodies: International Council for Science (ICSU); the International Social Science Council (ISSC); The World Academy of Sciences for the advancement of science in developing countries (TWAS)[4]; and the InterAcademy Partnership (IAP)[5]. The 2015 edition of Science International has developed an international accord on the values of open data in the emerging scientific culture of big data. The Accord recognises the need for an international framework of principles on "*Open Data in a Big Data World*" and proposes a comprehensive set of principles. The Accord has now close to 100 endorsements from academies and other international organisations. Negotiations are now underway towards a merger of the two councils to create a scientific organization for "all" sciences".[6]

Another example of the ICSU and ISSC working together was the proclamation of the 2016 International Year of Global Understanding[7] by the International Council for Science (ICSU, International Social Science Council (ISSC) and the Conseil International de la Philosophie et des Sciences Humaines (CIPSH)[8], based on an initiative of the International Geographical Union (IGU). The IYGU stems from the recognition that global understanding is an important and essential human condition. In the face of global change, it is important we think globally recognizing that local actions alter global processes and that global understanding clarifies the connections between the local and the global. The International Year of Global Understanding was established to address the ways in which we inhabit an increasingly globalized world and examine the questions: "How do we transform nature?" and "How do we build new social and

[2]http://www.worldsocialscience.org/

[3]http://www.icsu.org/science-international/science-international

[4]TWAS. http://twas.org/

[5]IAP. http://www.interacademies.org/ The InterAcademy Partnership is an umbrella organization that brings together IAP - the global network of science academies, the InterAcademy Medical Panel (IAMP), and the InterAcademy Council (IAC).

[6]http://www.icsu.org/general-assembly/extraordinary-general-assembly-oslo-2016/background

[7]http://www.global-understanding.info/

[8]http://www.cipsh.net/htm

political relationships for the emerging global reality?" It is recognized that societies and cultures determine the ways that we live with and shape nature. They influence how we perceive the global consequences of our everyday actions. Hence, we need to understand what our daily actions mean for the world as a whole in order to overcome global challenges. The IYGU is an important example of transformative approaches for a sustainable future Earth.

3 International environmental policy agenda and the international agreements of 2015

The year 2015 was a crucial year for the international policy agenda with the Third UN World Conference on Disaster Risk Reduction (WCDRR)[9] and the ensuing Sendai Framework on Disaster Risk Reduction 2015–2030[10], United Nations Sustainable Development Summit and ensuing Agenda 2030 and Sustainable Development Goals (SDGs)[11] (2015), the 21st Conference of the Parties (COP-21) of the UN Framework Convention on Climate Change and its Paris Climate Agreement[12] (2105) and the International Conference on Financing for Development (2015)[13]. For these international negotiations, the International Council for Science was the principal in the Science and Technology Major Group [14] [15] and, hence, had a major participatory role. To address these issues, there is need for integrated information on these topics and related issues. As we look ahead for the next decades, there is need for recognizing the responsibilities of global science to contribute to post-2015 frameworks, including the Sendai Framework, Agenda 2030, Paris Climate Agreement and the urban agenda at Habitat III Conference[16].

[9] www.wcdrr.org/

[10] UNISDR; www.unisdr.org/we/inform/publications/43291

[11] Sustainable Development Goals; https://sustainabledevelopment.un.org/?menu=1300. SDG/Agenda 2030 "Transforming our world: the 2030 Agenda for Sustainable Development" http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

[12] Paris Agreement, UNFCCC; https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

[13] Third International Conference on Financing for Development, http://www.un.org/ga/search/view_doc.asp?symbol=A/CONF.227/20

[14] https://sustainabledevelopment.un.org/majorgroups/scitechcommunity

[15] www.icsu.org ›Science for Policy ›Sustainable Development Goals

[16] https://www.uclg.org/en/issues/habitat-iii

3.1 Sendai Framework for Disaster Risk Reduction 2015–2030

In 2005, nations agreed to the Hyogo Framework for Action on disaster risk reduction[17]. In 2015, at the meeting in Sendai, nearby to the location of the Fukushima disaster, negotiations were undertaken to provide a post-Hyogo Framework. As Representative of Science and Technology Community Major Group, I was invited to make presentations both on panels and as part of the negotiation process. The new Sendai Framework for Disaster Risk Reduction 2015–2030 takes into account the experience gained through the implementation of the Hyogo Framework for Action. The Framework states: *"In pursuance of the expected outcome and goal, there is a need for focused action within and across sectors by States at local, national, regional and global levels in the following four priority areas:*

1. *Understanding disaster risk;*
2. *Strengthening disaster risk governance to manage disaster risk;*
3. *Investing in disaster risk reduction for resilience; and*
4. *Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction."*

These intergovernmental negotiations on the post-2015 development agenda, financing for development, climate change and disaster risk reduction provide the international community with a unique opportunity to enhance coherence across policies, institutions, goals, indicators and measurement systems or implementation, while respecting the respective mandates. It is important to ensure credible links, as appropriate, between these processes that will contribute to building resilience and achieving the global goal of eradicating poverty. The Council is collaborating with UN and other partners to make this a reality, including at the now completed International Conference, held in January. 2016 in Geneva, and specifically through the Integrated Research on Disaster Risk Program (IRDR)[18] and its projects on data and monitoring systems and methodologies for forensic investigations of disasters. The IRDR Program has a major role in addressing the Sendai Framework.

3.2 Sustainable development goals

Sustainable Development (World Commission on Environment and Development, 1987) (World Commission on Environment and Development, 1987) is defined as: *"Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs"*. A principal key part of the sustainable development is the linking of

[17] https://www.unisdr.org/we/coordinate/hfa

[18] http://www.irdrinternational.org/

social, economic, technology, science and environmental issues and connecting the future with the present. It essentially leads to science-informed decision making. The concept of "seeing the future" (McBean, 2008) is an essential part of sustainable development, and disaster risk reduction. Another important aspect is understanding the interconnectivity between actions and responses across and around the planet with its major societal, logical and philosophical issues.

There are 17 Sustainable Development Goals[19] with 169 targets agreed to for the Post-2015 Development Agenda. They collectively address issues of: poverty; hunger and food security; healthy lives; inclusive and equitable quality education; gender equality; water and sanitation; sustainable and modern energy; sustainable economic growth; inequality; and sustainable consumption and production patterns. Specifically linked to the other pillars of the 2015 international agenda include: Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; and Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable; - linked to Sendai and Goal 13: Take urgent action to combat climate change and its impacts – obviously links to the Paris Agreement. Goal 14 is: Conserve and sustainably use the oceans, seas and marine resources for sustainable development; and Goal 15 is: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Goal 16 is about peaceful, inclusive societies and justice. It also includes, importantly, accountable and inclusive institutions at all level. Goal 17 is: Strengthen the means of implementation and revitalize the global partnership for sustainable development. The latter specifically addresses the challenges for transformative research for a sustainable future Earth.

Associated with the 17 Goals are 169 Targets and the International Council for Science and International Social Science Council convened a group of experts to review the targets from the philosophical perspective and issues of measurement, measurability, logic and methodology (International Council for Science & International Social Science Council, 2015). The Group concluded that the SDG framework was a major improvement on the Millennium Development Goals (MDGs) but also concluded that the SDG framework would benefit from an overall narrative articulating how the goals will lead to broader outcomes for people and the planet and that it does not identify the wide range of social groups that will need to be mobilized. Of the 169 targets, 49 (29%) were considered well developed, 91 targets (54%) could be strengthened by being more specific, and 29 (17%) require significant work.

Following from this, a draft framework for understanding SDG interactions (International Council for Science, 2016) was developed as part of a project led by the Council to explore an integrated and strategic approach to implementation of the SDGs. The

[19] Sustainable Development Goals; https://sustainabledevelopment.un.org/?menu=1300. *SDG/Agenda 2030" Transforming our world: the 2030 Agenda for Sustainable Development* "http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

framework is a starting point for building an evidence base to characterize the goal interactions in specific local, national or regional contexts. The Council is currently convening research teams to develop thematic case studies, starting with the SDGs for health, energy, and food and agriculture. The case studies will be compiled into a report, expected to be published at the end of 2016. Through these initiatives, international science is playing a major role in addressing the international development issues.

3.3 Climate Convention

As part of the preparatory process for the 21st Conference of the Parties (COP-21) of the UN Framework Convention on Climate Change and its Paris Climate Agreement, ICSU convened on 6 July 2015 in Paris an event Science and the Road to Transformation: Opportunities in the post-2015 Global Climate Regime[20] which brought together leading scientists and journalists to examine the scientific issues. UNESCO, Future Earth, and ICSU convened in Paris the *Our Common Future Under Climate Change* 7-10 July 2015. The Outcome Statement[21] noted that: *"Science is a foundation for smart decisions at COP21 and beyond. Solving the challenge of climate change requires ambition, dedication, and leadership from governments, the private sector, and civil society, in addition to the scientific community"* and expressed the commitment of the scientific community *"to understanding all dimensions of the challenge, aligning the research agenda with options for solutions, informing the public, and supporting the policy process."*

A separate event, *Climate Summit of the Americas*[22] was held 7–9 July, 2015 in Toronto, Canada to bring together representatives from the western hemisphere. Included in the Summit was a climate science statement calling for governments, industry and community leaders to make risk- and science-based decisions to limit global warming. The result was the first-ever Pan-American action statement on climate change signed by 23 states and regions in the Americas. These scientific events contributed to the successful Climate Convention CoP21 Paris, 2015[23].

4 International research collaboration

The International Council for Science (ICSU) is very involved in initiating, organizing and leading international research collaboration, often partnering with other gov-

[20] http://www.icsu.org/events/ICSU%20Events/science-and-the-road-to-transformation-opportunities-in-the-post-2015-global-climate-regime

[21] http://www.commonfuture-paris2015.org/The-Conference/Outcome-Statement.htm

[22] https://www.ontario.ca/page/climate-summit-americas-retrospective

[23] https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

ernmental and non-governmental organizations. The International Geophysical Year (IGY)[24] of 1957 is an important early example. Recognizing the increasing societal concerns about the climate system, the International Council for Science (ICSU) and the World Meteorological Organization (WMO) joined in 1980 to create the World Climate Research Programme (WCRP)[25] with the scientific objectives: to determine: *the predictability of climate; and the effect of human activities on climate.* The Intergovernmental Oceanographic Commission of the UN Educational, Scientific and Cultural Organization (UNESCO) became a co-sponsor in 1992, to most effectively connect the global oceanographic community to the WCRP. By the mid-1980's, the level of international concern regarding climate change and broader issues of global environmental change, plus the discussions on sustainable development, led the International Council for Science (ICSU) to initiate the global change program, International Geosphere-Biosphere Programme (IGBP)[26] to: *study earth system science and to help guide society onto a sustainable pathway during rapid global change.* In 1992, the International Council for Science (ICSU), with one of its unions, the International Union of Biological Sciences, and the ICSU Scientific Committee on Problems of the Environment, with UNESCO, recognizing the concerns about the state of biodiversity on the planet, created the program DIVERSITAS[27] , as an integrative biodiversity science, that links biological, ecological and social disciplines to address the complex scientific questions posed by the loss in biodiversity and ecosystem services and to offer science-based solutions to this crisis. The International Human Dimensions Programme on Global Environmental Change (IHDP)[28] was established in 1996 by its two scientific sponsors, the International Council for Science (ICSU) and the International Social Science Council (ISSC). IHDP was an international, non-governmental, interdisciplinary research programme addressing the coupled human-natural system in the context of global environmental change (GEC). It fostered high quality research aimed at describing, analysing and understanding the human dimensions of GEC. Human dimensions are the ways in which individuals and societies contribute to global environmental change, are influenced by global environmental change and mitigate and adapt to global environmental change.

The impacts of natural hazards continue to increase around the world with hundreds of thousands of people killed and millions injured, affected, or displaced each year because of disasters, and the amount of property damage has been doubling about every seven years over the past 40 years. To address the shortfalls in current research on how science is used to shape social and political decision-making in the context of hazards and disasters, the International Council for Science (ICSU) initiated the Integrated

[24] http://www.icsu.org/publications/about-icsu/the-international-council-for-science-and-climate-change-2015/the-international-council-for-science-and-climate-change-2015-1

[25] http://www.wcrp-climate.org/

[26] http://www.igbp.net/

[27] http://www.diversitas-international.org/

[28] http://www.icsu.org/what-we-do/past-interdisciplinary-bodies/hdp

Research on Disaster Risk (IRDR) Programme[29]. The IRDR mission is to develop trans-disciplinary, multi-sectorial alliances for in-depth, practical disaster risk reduction research studies, and the implementation of effective evidence-based disaster risk policies and practices. The IRDR Programme objectives are: 1) Characterization of hazards, vulnerability and risk; 2) Understanding decision-making in complex and changing risk contexts; and 3) Reducing risk and curbing losses through knowledge-based actions. Attainment of these objectives through successful projects will lead to a better understanding of hazards, vulnerability and risk; an enhanced capacity to model and project risk into the future; better understanding of decision-making choices that lead to risk plus how they may be influenced; and how this knowledge can better guide disaster risk reduction. The IRDR Programme is now co-sponsored by the International Council for Science (ICSU), the International Social Science Council (ISSC) and the UN Office for Disaster Risk Reduction (UNISDR, International Strategy on Disaster Reduction)[30].

With the increasing growth of populations in cities and the accompanying health issues, the International Council for Science (ICSU), in partnership with the UNU International Institute for Global Health[31] and the Inter-Academy Medical Panel (IAMP)[32] created the Health and Wellbeing in the Changing Urban Environment: a Systems Analysis Approach Programme[33] to promote systems approaches to understanding health and wellbeing in urban settings by understanding the functioning of the urban system as a whole. The systems approaches involves one or more of the following elements: 1) development of new conceptual models that incorporate dynamic relations; 2) use of systems tools and formal simulation models; and 3) integration of various sources and types of data including spatial, visual, quantitative and qualitative data. The overarching vision for the Urban Health and Wellbeing Programme is the development of aspired levels of wellbeing for people living in healthy cities.

5 Science system realities

The realities of the global scientific system include the persistent funding pressures and the unfortunately continued, and in some place growing, public mistrust of science. These lead to the new sense of urgency, and unrelenting pressure, for science to make a difference to real-world problem-solving. The grand challenge is: to urgently contribute transformative solutions to a converging set of global crises and to work simultaneously to protect planetary resources, safeguard social equity and hu-

[29] http://www.irdrinternational.org/

[30] https://www.unisdr.org/

[31] iigh.unu.edu

[32] www.iamp-online.org/

[33] http://urbanhealth.cn/

man wellbeing. These issues bring forward the needs for integrated science, which can be seen as:

- Works across disciplines and fields – (inter-disciplinarity)
  - Supporting the joint, reciprocal framing, design, execution and application of research
- Works globally – (international collaboration)
  - Including the agendas, perspectives, approaches, methods and models of scientists from all parts of the world
- Works with society – (trans-disciplinarity) (Mittelstrass, 2011)
  - Engaging decision makers, policy shapers, practitioners, as well as actors from civil society and the private sector as partners in the co-design and co-production of solutions-oriented knowledge, policy and practice

6 Future Earth: Research for Global Sustainability

In recognition of these issues, the International Council for Science joined with others for the Science and Technology Alliance for Global Sustainability[34]. Strategic planning sessions were held to develop the concepts (Reid et al., 2010). A transition team was formed in 2011 and the result was Future Earth: Research for Global Sustainability[35], launched in 2015, as major international research platform, with the Goal: *"To provide the knowledge required for societies in the world to face risks posed by global environmental change and to seize opportunities in a transition to global sustainability"*. Future Earth will advance Global Sustainability Science, build capacity in this rapidly expanding area of research and provide an international research agenda to guide natural and social scientists working around the world. It is also a platform for international engagement to ensure that knowledge is generated in partnership with society and users of science, connecting closely with the Sustainable Development Goals and climate and biodiversity agreements (United Nations Framework Convention on Climate Change and the Convention on Biological Diversity[36] and the Intergovernmental Platform on Biodiversity and Ecosystem Services[37]).

Future Earth brings together and, in partnership with existing programmes on global environmental change, coordinated new, interdisciplinary approaches to research on

[34] http://www.icsu.org/future-earth/who

[35] http://www.futureearth.org/

[36] https://www.cbd.int/

[37] http://www.ipbes.net/about-us

three themes: Dynamic Planet; Global Sustainable Development; and Transformations towards Sustainability. DIVERSITAS, the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP) have been merged into Future Earth and the World Climate Research Programme (WCRP) is a partner. Partnerships with START[38] and other programs are also being undertaken.

Future Earth is a platform for international engagement to ensure that knowledge is generated in partnership with society and users of science and will bring together scientists of all disciplines, natural and social, as well as engineering, the humanities and law. The governance structure of Future Earth embraces the concepts of co-design and co-production of science with relevant stakeholders across a wide range of sectors (Mauser et al., 2013).

Future Earth is led by a Governing Council and supported by two advisory bodies: a Science Committee and an Engagement Committee. The Governing Council of Future Earth is composed 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, the United Nations Environment Programme, the United Nations University, World Meteorological Organization, Sustainable Development Solutions Network (SDSN)[39] and the STS Forum[40]. The Future Earth Engagement Committee is a strategic advisory group, comprising thought-leaders from stakeholder groups including business, policy and civil society. Working together with the Future Earth Science Committee and the Secretariat, its primary purpose is to foster in-depth and innovative interactions between science and society. The Engagement Committee provides leadership and creative thinking on how to bridge the gap between knowledge and solutions for sustainable development. Through their joint actions the research program of Future Earth is developed to co-design the themes, priorities and approaches with the stakeholder community so that the co-produced knowledge, technologies and approaches with better address societal needs.

Future Earth, and all ICSU related programs, have a role in outreach, communication, regional activities. The Future Earth program is building Open Knowledge Action arenas in specific socio-ecological settings that focus on concrete challenges and address specific transformation needs or opportunities (Cornell et al., 2013). The arenas are to: traverse boundaries between different disciplines, perspectives, approaches, and types of knowledge; bring knowledge partners—academic and non-academic—together in networks of collaborative learning and problem solving; and to contribute to a global knowledge trust that can support transformations to a sustainable and just world.

[38] http://start.org/programs

[39] http://unsdsn.org/

[40] www.stsforum.org/

The Future Earth science co-design, co-produce and co-deliver model changes the science-policy-practice interface from the linear model, with its impacts and uptakes, in which "science proposes, society disposes"(Guston, 2001)(Guston & Sarewitz, 2002) and dualistic mechanisms of production and use (policy briefs, assessments, some advisory systems) to iterative interaction, with feedback loops and sometimes messy processes on all sides.

7 Science for Policy and policy for science

An important area of action for the International Council for Science (ICSU) is Science for Policy, which includes the international research programs described above, and policy for science. In the global policy arena, there are the intersecting issues of climate change, disaster risk reduction and sustainable development and their applications for cities, energy, resilience, health, populations and security. As shown schematically in Figure 1, there is the need to bring the integrated science together for policy so that the issues of technology and society can be addressed for the benefits of future societies. There is also the need to address fully global science capacity so that science benefits of all societies.

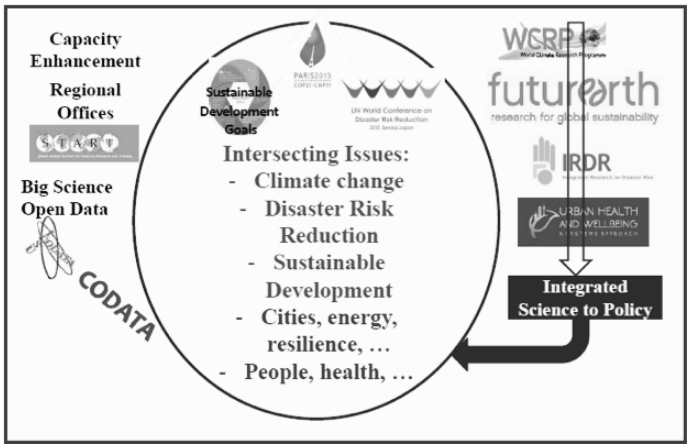

Figure 1. Intersecting issues and the need for integrated science to policy

8 Relevance, autonomy and science-society relationships

It is important that the relevance of science be established and highly considered in its planning and implementation. There is a need to change from "taken-for-granted promise of science" to approaches that:

- do strategic basic or use-inspired fundamental research
- drive innovation, economic growth and competitiveness
- address complex global challenges that require science to step into the transformative 'solutions spaces' of, for example, open Knowledge-Action Networks

The principle of "academic autonomy" has always been important but it is important to move from being unfettered by external constraints: autonomy as a right to autonomy as "collaborative assurance": working with society in securing the public good of science. This will result in changing conceptions of who society is, i.e., who has a say in steering science, shifting from only governments to governments and industry and then to the full range of 'users' and stakeholders, including funders, practitioners, citizens and social movements. The knowledge that counts will shift from only ivory tower expertise to multiple knowledge actors and a diversity of valid knowledge claims as we shift to science with society relationships.

There are challenges which will continue. Disciplines will still dominate in academic training, funding priorities and mechanisms, evaluation, rewards and career advancement. The integration of the natural, social (and human and other) sciences remains a challenge, including incentive mechanisms. The added value of international collaboration is still questioned, and when it is supported, historically institutionalized hegemonic systems and practices persist. The co-design and co-production of knowledge is not well understood, let alone supported in real dollar terms. There is also a need for researchers to have the process and communication skills needed to facilitate and manage the processes involved.

9 Conclusions

Although we are aware of the challenges and complexity of transformative research, the important "BUT" is, it is very important and essential to address issues of climate change, reduce risk, sustainable development for people and the planet. It also is essential towards addressing and solving the issues of intergenerational and international equity and ethics. Through the Future Earth Program and its co-development in integration with the Integrated Research on Disaster Risk, Urban Health and initiatives such as another science-policy issue of "big" science and open data Accord. The Accord is an example of international science, the global voice of science, addressing issues of policy for science.

This paper has discussed the building on transformative research to address global issues and bringing all the sciences together, to enable through collective actions to have the "future we want". It has focussed on the role of the International Council for Science (ICSU) as a key, leading international non-governmental organization that works with many partners to achieve these common goals. We look forward to working together for the benefit of all societies.

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