

IHDP Global Carbon Cycle Research

International Carbon Research Framework



February 2001

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and the IHDP Secretariat



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1 Introduction

For thousands of years, human activities have influenced one of the world's great biogeochemical cycles, the carbon cycle. Changes to vegetation patterns are as old as human society, and even in the pre-modern era such changes have had significant impacts on the stocks and flows of carbon in various reservoirs. Atmospheric CO₂ levels are now the highest they have been for over 2 million years, approaching those of the Eocene period, when the world was essentially ice-free. It is clear that the relative impact of human activities on a naturally variable system has increased dramatically over time. Today, human activity is changing the global carbon system with potentially irreversible effects, in particular because of the impacts on the climate system.

Carbon dioxide, one of the most important greenhouse gases, is exchanged among three major active reservoirs: the ocean, land, and atmosphere. The exchanges between the various reservoirs depend on physical, chemical, and biological mechanisms, including both living and inanimate components. The behaviour and functioning of the terrestrial and atmospheric reservoirs, in particular, are now intimately related to human activities (in particular, as Figure 1 indicates, land use change and, even more, fossil fuel use contribute to changes in the carbon cycle). The significant human activities include energy use, industry, trade, agriculture, forestry, and leisure-time activities; even our scientific preoccupation leaves traces in landscapes and biogeochemical cycles. In fact, human uses of fossil fuels in energy production/consumption and transportation presently dominate the recent changes in carbon flows in the industrialised world. Land use changes, such as deforestation and agricultural developments have played an important role in the past and continue to play an important role in some areas today. The Earth's social, cultural, political and economic systems provide the context and comprise the activities that contribute to changes of the carbon cycle. These have received much attention in recent years, because they provide the context within which climate change is perceived and debated.

The degree to which carbon flows balance each other – human activities leading to carbon emissions into the atmosphere, vegetation and oceans soaking it up – is the subject of vigorous debate. It is not yet possible to define quantitatively the global effects of human activities such as forestry and agriculture, and may never be so. However, studies to determine these effects have emerged as critical for understanding how the earth's climate will evolve in the future.

Global concern about the potential implications of the behaviour of the carbon cycle under anthropogenic stress includes concepts of system instability and large scale change¹. To contribute to understanding this behaviour, and our potential responses to it, requires a thorough investigation of both biophysical and social systems. Until recently, most scientific assessments of such risks focused on the anatomy of conceivable environmental changes themselves, devoting little

1 For example, climate warming in high northern latitudes would lead to melting of the permafrost and thus to release of further carbon into the atmosphere – a positive feedback effect. A dramatic change in the ocean circulation of the Atlantic Ocean, due to changes in temperature gradients is an example of system instability.

attention to either the human driving forces or the ecosystems and societies that might be endangered by the changes. Recently, however, questions about the linkage and interaction of social, ecological, and biogeochemical systems are emerging as a central focus of policy-driven assessments of global environmental risks. The approach used here is to accept humans as an integral part of the carbon cycle, not as an agent perturbing an otherwise natural system – indeed, this approach assumes there is no independence of the different components of the carbon cycle. The human dimensions research community sees this critical and necessary re-conceptualisation as the foundation of a new approach to studying the interaction between human and environmental systems.

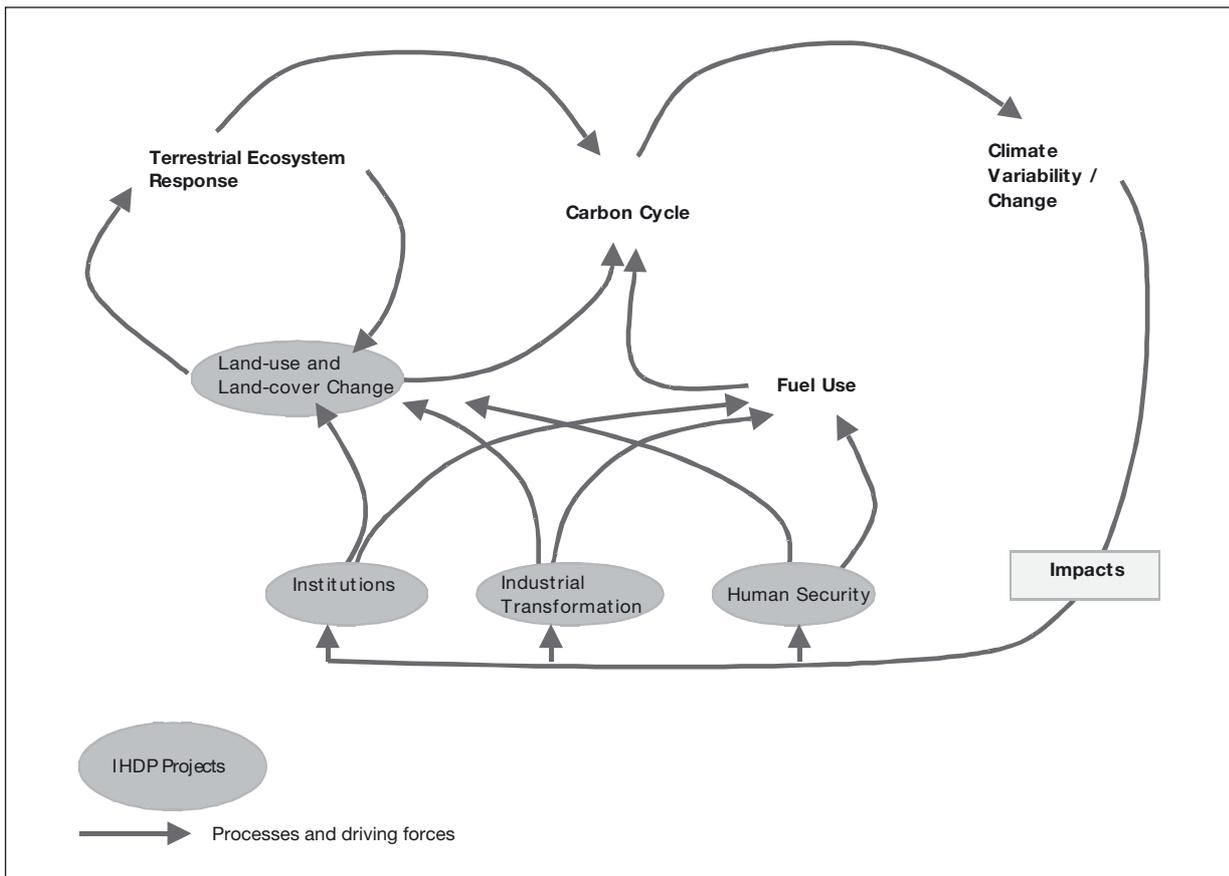


Figure 1: Interactions within the human – environment system with respect to the global carbon cycle

The framework presented in this document outlines the objectives of a human dimensions driven research plan on the global carbon cycle, identifying researchable questions for three broad topics: the patterns of activities affecting the C-cycle, the socio-economic and technological processes, and possible future behaviours. Finally, it outlines ways in which IHDP research structures may contribute to such an initiative. It is important to note, however, that the development of the IHDP position paper on carbon cycle research is seen as a parallel activity to the joint carbon project of IGBP, IHDP and WCRP and not as a competing one. It is set up in order to contribute to the development of the joint carbon project, to learn from its ongoing discussions and furthermore to establish a statement on what the human dimensions community's interests are with respect to this research area.

This endeavor not only involves linking the four IHDP core projects , but rather aims at the development of an agenda that might even go beyond the current IHDP mandate.

2 Objectives

The scientific aim of this framework is to provide an integrated understanding of the global human – environment system we call the carbon cycle. Figure 1 shows the relationship between the carbon cycle and major human dimensions themes. The carbon cycle comprises the environmental components of the system (land, ocean, atmospheric, oceanic and fossil reservoirs of carbon). The two main anthropogenic processes that influence the carbon cycle are fossil fuel use and land-use changes. A complete understanding of this system is presently beyond the capabilities and expertise of any one organization or scientific discipline: it requires co-ordinated and collaborative research.

The specific objectives of this framework are:

1. *To develop a comprehensive understanding of the anthropogenic processes and driving forces within the overall functioning of the carbon cycle at global and regional scales;*
2. *To understand human responses to changes in the carbon cycle that will facilitate development of scenarios for the future evolution of the carbon cycle;*
3. *To understand and predict the impacts of changes in the carbon cycle on individuals and societal groups.*

3 Research Questions

The overall goal of the research questions proposed in this framework is to develop an improved understanding of the human – environment system called the carbon cycle. As a priority, we seek to understand linked natural and human activity-related patterns and processes (as illustrated in Figure 1). The answers to these questions should enable us to identify, analyse and evaluate in quantitative terms the trends and variability and critical factors at different time scales (including uncertainty ranges). Finally, we aim to provide some assessment of what individuals and societal groups could do, what natural systems could do, and how they may interact, in the future.

To this end, several questions have been proposed that urgently require our attention in the current political and scientific arena. Each question has been framed to require substantial input from a variety of fields of study, and to be easily understood by non-specialists. The first question refers to the patterns and trends visible within the carbon cycle, the second to processes and causal mechanisms, and the third to possible future trajectories.

The terminology used in the research questions below is carefully selected, but in places differs from that commonly used by the community studying the biogeochemical component of the carbon cycle, or in the various social science disciplines. It is necessary therefore to define some of the terms in the glossary of this document.

QUESTION 1

What are the anthropogenic aspects of spatial and temporal patterns of carbon stocks and flows?

The behavior of the global carbon cycle is not homogeneous in space or time. Natural stocks are not evenly distributed, and exchanges between land, ocean, and atmosphere are complex and not yet fully understood. The role of humans within the last 100 years has become a significant aspect of the global carbon cycle that complicates the system further. Of critical importance from this perspective is the need to consider differences in economic welfare, production and consumption processes, lifestyles, culture and security, as well as the more conventional questions of biogeochemical interest.

Understanding the potential range or patterns of future behavior within this exceedingly complex system is necessary for the design of effective response measures and policy instruments. Documentation of our understanding of the patterns of stocks and flows, and improving our understanding of the reasons why such patterns exist, is therefore a priority task. The goal of this question is to provide a systemic and quantitative overview of spatial and temporal patterns of the range of production and consumption and institutional processes responsible for stability and changes of the stocks and anthropogenic flows. It covers natural and human activity-related processes responsible for these patterns.

- 1a Do patterns, trends, or cycles of anthropogenic and non-anthropogenic carbon emissions and other carbon flows vary across spatial and temporal scales?
- 1b What are the most important uncertainties in our understanding of these patterns?
- 1c Are there patterns in the way people use energy and change land use across spatial and temporal scales and are there reasons (e.g. welfare, demography, socio-economic activities) for these patterns ?
- 1d How important are anthropogenic emissions as a contribution to the total carbon emissions and how has this importance changed over time?
- 1e How do changes in the carbon cycle presently affect people and societies and what are the prospects for future strategies to respond to these impacts?

QUESTION 2

What processes determine human contributions to the levels of carbon emissions in the Earth's atmosphere?

The work of the Intergovernmental Panel on Climate Change (IPCC) and many thousands of scientists has provided a new and exciting picture of the natural and anthropogenic processes regulating one of the critical life support systems on Earth. Clearly the issue of the global carbon cycle has stimulated a vast number of scientific activities to increase understanding of its nature, dynamics and interactions with other natural and anthropogenic systems. However, our understanding of this complex system is still not adequate.

This question concentrates on building our understanding of the intimately coupled human – environment system. Such an approach explicitly includes the need to account for issues such as equity and governance as driving forces (an element of the work on human security, illustrated

in the centre of Figure 1), as well as to consider the inseparability of changes in the natural components and human components of the same system. These coupled responses or feedbacks, may be critical to the future behaviour of the global carbon cycle.

- 2a What are the causes of change to the socio-economic processes that affect the carbon cycle (e.g. changes in land use/cover, patterns of energy use, changes in ecosystem behavior, human population, consumption patterns, production systems, political systems, institutions) and what are the context-specific variables?
- 2b How can we account for socio-economic processes that control variations in atmospheric concentrations and carbon flows across space and time, cultures and countries?
- 2c What role do low probability, high consequence events (extremes) play in the functioning of the carbon cycle and in influencing the human activities within the carbon cycle?
- 2d How will non-anthropogenic and anthropogenic responses interact in their effect on stocks and flows of carbon²?
- 2e What are the possible response strategies (including institutional change, technological change, and lifestyle changes) to deal with the human contributions within the carbon cycle and what is their likely impact on the system at different temporal and spatial scales and in different socio-economic contexts?

QUESTION 3

What are the likely dynamics of the carbon cycle in the future?

The goal of this question is to explore a broad range of possible futures regarding the carbon cycle and the related environmental and climatic conditions and find out to what extent human choice could affect the plausible range of futures. In order to answer this question, we will need to examine areas such as equity and political processes, technological innovation, consumption and lifestyle choices, in Figure 1 covered by the terms “Institutions” and “Industrial Transformation”.

- 3a What are the likely development patterns in institutions, land use and industrial systems³ at different levels of social organisation that will affect the carbon cycle in the period until 2025, 2050, 2100 ?
- 3b How may changing societal perceptions of climate and global change influence institutional, land use, production, consumption and overall development patterns?
- 3c How will changes in the atmospheric CO₂ concentrations affect human systems in different regional contexts?
- 3d What are the likely prospects for feasible, effective, efficient, legitimate and equitable response strategies?
- 3e How will increasing scientific knowledge of biophysical source/sink processes and of climate/CO₂ impacts influence national and international policy processes?
- 3f How will global power structures affect the choice of policy instruments and how will choices of policy instruments affect the results of efforts to respond to changes in the carbon cycle?

² To answer this important question, we will need strong cooperation with our partners in IGBP

³ IHDP could make a large contribution by looking at the transportation system and the lifestyle choices re mobility

4 Existing IHDP structures - potential areas of collaboration for an interdisciplinary human dimensions research agenda on the global carbon cycle

IHDP has significant interests in carbon cycle research. The human dimensions of global environmental change comprise the causes and consequences of people's individual and collective actions, including the changes that lead to modifications of the earth's physical and biological systems, and the ways they affect human quality of life and sustainable development in different parts of the world. Through each of its four core projects, IHDP has great potential to contribute to an international research endeavour on the global carbon cycle.

Land Use and Land Cover Change

<http://www.geo.ucl.ac.be>

Land-use and land-cover change issues are central to the study of the global carbon cycle. The alterations to the surface of the earth contribute to changes in the biogeochemical cycles and hold major implications for sustainable development and livelihood.

Continuing changes in land cover will greatly increase stress on terrestrial ecological systems, in which carbon is retained in live biomass, decomposing organic matter, and soil. These systems play a crucial role in the global carbon cycle. The transformation of land use systems, e.g. urbanization or adaptation to environmental changes like land degradation, is a continuous process with a projected increasing tendency.

Major uncertainties still exist in our understanding of the behaviour of the terrestrial carbon cycle, and of our responses to those changes. The role of current and projected contributions of land-use change to carbon cycling is part of this uncertainty. So too, are the social, economic, and political causes of, and responses to, land use change.

The LUCC project analyses the sources of change in patterns of land use and the impact of those changes on patterns of land cover (IGBP Report 35 / IHDP Report 7; IGBP Report 48 / IHDP Report 10). Therefore, LUCC provides fundamental input to research on the global carbon cycle through its understanding and databases on the land-use change impacts on the terrestrial branch of the carbon cycle.

A major task is the derivation of general principles explaining the driving forces of land use and cover change worldwide. Building up a case study database and starting off comparative examination of case studies (e.g. on tropical deforestation, agricultural intensification) will improve our understanding of the major human causes of land-cover changes in different geographical and historical contexts. Since comparative efforts require compatibility between case studies, work on developing guidelines for the standardization of methodologies and experimental protocols has been started (Meeting in the Middle Workshop, proceedings will be published in the LAND-USE/LAND-COVER CHANGE Report Series (No. 5, 2001).

Assessment of rates of land cover changes will play a crucial role in modelling future carbon cycle scenarios. Through a historic land-cover database like BIOME 300 a more consistent picture of land-cover dynamics has been reached and will in turn improve understanding and modelling of land-use dynamics. The need for better land-cover mapping by improving characterisation systems for land cover and land use is the basis for another research emphasis of the LUCC project that will feed into modelling activities and comparisons, dealing with timing and magnitude of anthropogenic changes of the global carbon cycle.

Industrial Transformation

<http://www.vu.nl/ivm/research/ihdp-it/>

Industrial transformation research seeks to understand complex society-environment interactions, identify driving forces for change, and explore development trajectories that have a significantly smaller burden on the environment. It is based on the assumption that important changes in production and consumption systems will be required in order to meet the needs and aspirations of a growing world population while using environmental resources in a sustainable manner.

Through its research foci on Energy and Material Flows, Cities/Transportation, Governance and Transformation Processes numerous IT activities relate directly to the global carbon cycle theme (see Industrial Transformation Science Plan, Pier Vellinga and Nadia Herb (eds.), IHDP Report No.12; IHDP, Bonn: 1999 and IGBP / WCRP / IHDP Carbon Cycle Project - Industrial Transformation Research Questions by Pier Vellinga and Anna J. Wiczorek Amsterdam: September 2000, pp. 24)

Energy and Material Flows

The economic process is sustained by a flow of energy, materials, and ecosystem services from the environment. The economy in turn values and allocates resource use, and determines the worth of processing and the amount of energy and materials used. This focus addresses three basic questions: 1). What were the historical and are the present flows of energy and materials in physical and socio-economic terms? What are the driving forces for the present production and consumption system?; 2). What are the options for decoupling energy and materials flows from major interference in the carbon cycle, and what are the driving forces for change?; 3). What future trajectories of energy and materials can be envisaged and what are the opportunities, constraints and critical factors for transformation?

Cities / Transportation

There have been thousands of studies of individual systems that sustain cities - transportation systems, water supply systems, food systems - and thousands of studies of the environmental effects of the production and consumption systems that sustain cities - pollution, greenhouse gas emissions, waste, land use change, etc. What has been missing is an analytical design that situates cities fully in the global environment, one that connects environmental changes at all scales directly with such city systems as transportation and water supply. IT seeks to add to existing

work with research aimed at understanding how to de-couple the improvement of human well-being from the transport activities that sustain cities. Measuring the sources and flows of transportation energy, emissions types and levels, vehicle usage rates, modes of mobility, air pollution, the relationship of urban mobility and the carbon cycle will help to create an understanding of the system. Systems research will help to generate alternative patterns and processes of transport with a significantly smaller effect on the carbon cycle.

Governance and Transformation Processes

A major goal of human dimensions research is to understand the conditions under which substantial changes in society-environment relations might be achieved, as exemplified by such ideas as a 'de-linking' of economic development and environmental pressure, or major reductions in the energy, materials, and waste intensity of economic activity. This goal contains within it two critical research concerns. Firstly, how does such systemic change in nature-society relations occur, and what transformation processes are involved, both historically and in the present period, since countries are in different stages of development. Secondly, what structures of governance might facilitate and make permanent transformative dynamics in the context of other societal goals, such as increased equity and improvements in socio-economic welfare, and in ways that promote accountability and transparency of process.

Institutional Dimensions of Global Environmental Change

<http://www.dartmouth.edu/~idgcec>

The Institutional Dimensions of GEC represent a critical cross-cutting human dimensions issue of special policy relevance in today's world. The core of the IDGEC project is an analysis of the roles that social institutions play as determinants of the course of human/environment interactions. Institutions are systems of rules, decision-making procedures, and programmes that give rise to social practices, assign roles to participants in these practices, and guide interactions among the occupants of the relevant roles. Through its research foci on "Causality", "Performance", and "Design" the project seeks to serve as a mechanism to promote cross-fertilisation between the work of economists and political scientists concerned with multilateral environmental agreements (IHDP Report No. 9, 1999).

One of the great institutional challenge facing the world today is the need to design a complex system of regimes to control and ultimately to reduce emissions of greenhouse gases to fulfil the goal - articulated in Article 2 of the 1992 Framework Convention on Climate Change - of stabilising greenhouse gas concentrations in the atmosphere at a level that will not disrupt the Earth's climate system.

The institutional challenge here has two distinct components: initial design and subsequent implementation. What are the pros and cons of different counting rules, trading systems, and compliance mechanisms that could be developed to manage afforestation, reforestation, and deforestation (ARD) in the „Kyoto Forest“? Are some arrangements likely to prove preferable in practice because they are easier to implement, even though they may seem less attractive than others in principle ? To what extent can we scale up from experience with forest management

systems at the local or national level in designing a global carbon sequestration regime? IDGEC is currently in the process of implementing its flagship research activity dealing with the Institutional Dimensions of Carbon Management and addressing a variety of issues relating to the mechanisms required to operate the climate change regime (IDGEC Scoping Report 1, 2000)

The boreal forests of the Russian taiga, Fenno-Scandia, and the North American Sub-arctic and the tropical forests located around the equator are among the planet's largest carbon sinks. The fate of these forests will constitute a major determinant of levels of greenhouse gases resident in the Earth's atmosphere during the 21st century. In institutional terms, what makes this topic particularly interesting is the opportunity to study not only the performance of forest management regimes as such, but also the interplay between regimes dealing specifically with forest management and broader political and economic institutions which operate as underlying causes of deforestation and afforestation. IDGEC's study on the Political Economy of Boreal and Tropical Forests (*The Political Economy of Boreal and Tropical Forests*; Draft IDGEC Scoping Report No. 3; <http://www.dartmouth.edu/~idgEC>) should provide a vehicle for linking research of those who focus on local and regional arrangements, and those who analyse international institutions around common concerns like the impact of institutional interplay.

Global Environmental Change and Human Security

<http://www.gechs.org>

The GECHS research agenda focuses on the links between environmental degradation, impoverishment and the insecurities (negative impacts on health, greater biophysical risk, threats to biodiversity, and increasing vulnerability to extreme weather events and climate change) caused by both of these factors. Human security is achieved when and where individuals have the options necessary to end, mitigate, or adapt to threats to their human, environmental and social rights; have the capacity and freedom to exercise these options; and actively participate in attaining these options (IHDP Report 11, GECHS Science Plan, S. Lonergan, 1999)

Environmental change (such as climate change), environmental degradation and resource scarcity create inequities (or the perception of inequities) in resource distribution that often contributes to insecurity. This link appears in a variety of contexts such as food and water security, and global warming. Water shortages in China have caused a national decline in grain output, along with other factors such as population increase, and are expected to result in a growing demand for, and ultimately the need to import, grain. This will have impacts on the world grain markets and the ability of smaller, poorer countries to import grain. Therefore one can expect that water shortages in China may result in insecurities elsewhere in the world, moderated through links to agriculture, globalisation, and economic dependency.

GECHS research also examines the links between global warming and human security. The greatest impact of global warming and the associated extreme events would be on those groups in society that are most vulnerable to external stresses – the disenfranchised and impoverished, and those living in areas subject to floods and droughts. Sea-level rise will have significant impacts on low-lying regions and countries such as Egypt and Thailand. Coastal flooding, a constant problem in Southeast Asia, would increase both in terms of flood frequency and size or lev-

el of floods. This could cause population displacement and the related problems of environmental refugees. Periodic droughts in arid and semi-arid regions, already a cause of population displacement and conflict, could become more frequent and more long lasting.

Work on indicators under the GECHS research agenda has shown significant results. The GECHS Index of Human Insecurity (Loneragan et al., 2000) was developed to gain a better understanding of the forces (such as population growth and distribution, global warming and ozone depletion) that produce human insecurity, where the most insecure regions are now and how this may change over time.

5 BIBLIOGRAPHY

IDGEC Scoping Report 1: The Institutional Dimensions of Carbon Management. Dartmouth, 2000. <http://www.dartmouth.edu/~idgec>

IDGEC Scoping Report 3, Draft: The Political Economy of Boreal and Tropical Forests. <http://www.dartmouth.edu/~idgec>

IGBP Report 35 / IHDP Report 7: Land-Use and Land-Cover Change Science/Research Plan. Stockholm, 1995.

IGBP Report 48 / IHDP Report 10: Land-Use and Land-Cover Change / Implementation Strategy. Stockholm, 1999.

IHDP Report 9: Institutional Dimensions of Global Environmental Change / Science Plan. Bonn, 1999.

IHDP Report 11: Global Environmental Change and Human Security / Science Plan. Bonn, 1999.

IHDP Report 12: Industrial Transformation / Science Plan. Bonn, 1999.

IGBP / WCRP / IHDP Carbon Cycle Project - Industrial Transformation Research Questions by Pier Vellinga and Anna J. Wieczorek, Amsterdam; September 2000.

Lonergan, S.C., Gustavson, K., and Harrower, M. (2000). Mapping human insecurity. In S.C. Lonergan (ed.) *Environmental Change, Adaptation and Security*. Amsterdam: Kluwer Academic Publishers.

6 Glossary

Human Dimensions

“Human Dimensions” of global environmental change comprise the causes and consequences of people’s individual and collective actions, including the changes which lead to modifications of the Earth’s physical and biological systems and affect the human quality of life and sustainable development in different parts of the world.

Human Security

“Human Security” is achieved when and where individuals and communities

- have the options necessary to end, mitigate, or adapt to threats to their human, environmental, and social rights;
- have the capacity and freedom to exercise these options; and
- actively participate in attaining these options.

Moreover, human security will be achieved through challenging the structures and processes that contribute to insecurity (IHDP Report 11, 1999, p.29)

Industrial Transformation

“Industrial Transformation” research deals with the relationship between societal, technological, and environmental change. It focuses on systems and system changes that are relevant in view of the global environmental change. Industrial Transformation research relates produces and consumer perspectives, including the incentives and institutions that help in shaping these perspectives. This implies that the research aims to increase understanding of the relations of, and interdependencies between, the macro-level (governance and institutions at local, national, and international level), the meso –level (sectors, companies, and communities) and the micro-level (consumers and households) (IHDP Report 12, 1999, p. 2)

Institutions

“Institutions” are systems of rules, decision-making procedures, and programs that give rise to social practices, assign roles to the participants in these practices, and guide interactions among the occupants of the relevant roles. Institutions arise in all areas of human endeavour (IHDP Report 9, 1999, p. 14)

Land-use and land-cover changes

“Land Cover” is the biophysical state of the earth’s surface and immediate subsurface. Changes in land cover include changes in biotic diversity, actual and potential primary productivity, soil quality, and run-off and sedimentation rates. Land-cover change involves processes of conversion and modification. “Land use” involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation – the purpose for which the land is used (IGBP Report 35 / IHDP Report 7, 1995, p.17, 20).

Legitimacy

Legitimacy is a measure of the political acceptability or perceived fairness of a process to a user. A legitimate process has been conducted in a manner that allows users to be satisfied that their interests, concerns, views, and perspectives were included and given appropriate weight and consideration and that the process was a fair one.

Stock and Flows

“Stock” is used in this framework to describe the amount of carbon contained within a reservoir, or pool.

“Flow” is used to mean the transfer of carbon between two stocks.

The use of the “Stocks and Flows” terminology reflects the need to rethink the structure of the ‘carbon cycle’, as it is commonly perceived. It also encourages a ‘systems thinking’ approach, where emphasis is placed on the need to capture all of the important linkages within a system under investigation, not just part of the system. The “Sources and sinks” terminology used within the natural scientific community is appropriate when studying the release and uptake of carbon by natural systems, but does not allow for adequate consideration of the massive human influence over the rates of exchange between different stocks. Human-induced release of carbon from fossil fuels, for example, can be understood as a change in the rate of flow between two stocks (the fossil fuel and the atmosphere). Use of the stocks and flows terminology also focuses attention on the places where policy action can be most effective, by changing the rates at which human activity moves carbon between different stocks.

Vulnerability

Vulnerability to global environmental change has been conceptualized as the risk of adverse outcomes to receptors or exposure units (human groups, ecosystems, and communities) in the face of relevant changes in climate, other environmental variables, and social conditions. Vulnerability is emerging as a multidimensional concept involving at least exposure – the degree to which a human group or ecosystem comes into contact with particular stresses; **sensitivity** – the degree to which an exposure unit is affected by exposure to any set of stresses; and resilience – the ability of the exposure unit to resist or recover from the damage associated with the convergence of multiple stresses. The concepts of preparedness, coping reserve, and adaptive capacity are clearly important.