BEYOND THE HORIZON OF RIO+20

SCIENCE FOR SUSTAINABLE DEVELOPMENT

Royal Netherlands Academy of Arts and Sciences
PO Box 19121, NL-1000 GC Amsterdam
Telephone + 31 20 551 0700
Fax + 31 20 620 4941
knaw@knaw.nl
www.knaw.nl

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PREFACE

The 1972 book *Limits to Growth* had a remarkable impact on the public debate in the Netherlands, probably more than in any other country. It generated a strong awareness of the need to protect our environment. Many individuals and organisations became involved with these issues, and Dutch government delegations participated in a number of international, European and national summits and conferences, leading to various political declarations urging improvements in sustainable development.

At present, it has become clear that, despite the strong engagement of many, not all of the needed global change has been achieved, notwithstanding some remarkable successes where policy and science have come together, such as the protection of the ozone layer through a series of treaties and protocols. In the view of the Royal Netherlands Academy of Arts and Sciences, the successive summits and conferences over the last few decades have lacked the institutional framework for collaboration between the scientific, public and private sectors, as well as civil society, that is needed to make major progress.

The Academy therefore recommends that the Dutch delegation at the Rio+20 Summit should address these structural issues and urge the global scientific community to build new connections between the natural sciences, technology, social sciences and humanities by supporting virtual institutes that cooperate in an interdisciplinary mode. The Dutch scientific sector should continue and increase its contribution to sustainable development based on its proven thematic strengths in the areas of governance, modelling and assessment, water, energy, biodiversity, health, food and agriculture.

In the vision of the Royal Academy, the Rio+20 Summit should emphasise the importance of governance and the need for integrated assessment. Dutch scientists have the proven track record, capacity, and ambition to support, and in some areas even lead, the transitions towards the institutional innovation that are needed to bring about the required improvements in sustainable development. The Academy strongly believes that many of the required improvements can indeed be made, and that science has a strong role to play.

The Academy is grateful for the opportunity and support provided by the Ministry of Foreign Affairs to issue this report and to advise the Dutch delegation to the Rio+20 Summit.

Robbert Dijkgraaf
President
Royal Netherlands Academy of Arts and Sciences

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1. SUMMARY

1.1 Science for sustainable development

This advisory report has been prepared by an ad hoc committee of the Royal Netherlands Academy of Arts and Sciences (KNAW) in response to a request from the Netherlands Ministry of Foreign Affairs. The Ministry, which is preparing the national contribution to the Rio+20 Summit in Rio de Janeiro in June 2012, has approached many national organisations for input. As one of them, the KNAW was asked to provide insight into scientific contributions, particularly Dutch contributions, to sustainable development as formulated during the 1992 Rio Earth Summit. The Ministry of Foreign Affairs also challenged the KNAW to put together a forward look regarding the national science agenda, taking into account various aspects such as national strengths, national and European science policies, collaboration with developing countries and international cooperation in general.

The KNAW is very pleased with the opportunity provided by Ministry of Foreign Affairs to formulate and communicate its views on this complex, challenging and important matter. The Dutch scientific community, both university and non-university, but also the national government itself and the national private sector, have made efforts in recent decades to contribute significantly to sustainable development and are committed to continuing and increasing their efforts in the future.

As for the scientific community, important contributions have been made and can be clearly recognised. Many of these contributions are in the area of increased understanding of ‘System Earth’ at many levels. While the first system knowledge that emerged regarded separate subsystems, such as oceans, land, and atmosphere, this knowledge is increasingly being integrated into an understanding of interrelations between various levels, including, for instance, human influences – industry, transportation and population growth. An example of this increased scientific system understanding is represented by the four assessment reports that have subsequently been published by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations (UN). The IPCC, like many other examples of system assessment mentioned and described in this advisory report, is proof of how, globally, scientists of many different scientific disciplines have embarked on working together with a common goal, inspired by the ambition to contribute to sustainable development. This advisory report underlines a significant Dutch scientific contribution to system assessment. Moreover, Dutch scientists as well as national science policies are geared towards increasing it.

1.2 What needs to be done to achieve sustainable development

At global level, it has become obvious that a continuous stream of political declarations has failed to bring about the anticipated improvements in sustainable development (Agenda 21). The successive summits and conferences over the last few decades have made this clear. In these circumstances, far-reaching declarations are not very useful. What is needed more is a well-organised community of scientific practice that supports evolving and targeted policies set out within the UN framework. At present, an institutional framework for this community is mostly lacking. The Dutch delegation to the Rio+20 Summit should address this issue with the support of Dutch scientists.

A relevant aspect for Dutch science and technology at European level is the continuation of successful collaborative research programmes. The Grand Challenges defined in 'Horizon 2020' may even act as a catalyst for that continuation. Experience in the recent past has shown that Dutch researchers make considerable contributions to these international programmes. There are two reasons for this: the integrated mode of research and assessment is well-developed in the Netherlands, and the thematic strengths of the Dutch research community are well-suited to the Grand Challenges. The ongoing participation of Dutch researchers in international, integrated research efforts is therefore recommended.

At national level, past investments in the public knowledge infrastructure have given the Netherlands a prominent position in the field of sustainability science. These investments must be sustained if the Netherlands is to continue harvesting the results. This applies especially to research fields in which Dutch sustainability science contributes significantly to sustainable development at international level. The relevant Dutch research fields have a strong focus on environmental sciences, agricultural and food sciences, earth sciences and technology, and biology, as well as governance.

The science-push model has been replaced by new views on research, its organisation and its relationship with society. Nowadays, an interactive model involving co-creation by researchers and stakeholders from society is valid. The borders between the involved stakeholder groups in the sustainability agenda have become less clearly defined. The wide range of stakeholder groups, such as the scientific community, the business community, the government and civil society, including NGOs, is creating new opportunities to travel the road toward sustainable development. This new reality needs to be addressed at the Rio+20 Summit. This is something which Dutch researchers can accomplish, or perhaps even play a leading role in, at the Summit.

The Academy therefore recommends building on the strong points of Dutch sustainability science and investing in its further development. The government, the business community, the scientific community, and civil society can do this at three different levels:

- Support both the institutions and the skills and competencies necessary to keep developing human capacities in changing international networks. Targeting the strong research fields referred to in this advisory report will lead to the most effective international contribution.
- Support the further development of integrated assessment and its role in the adaptive integrative policies that feed the international agenda. The promotion of cooperation by Dutch researchers and institutes in EU programmes and other international research efforts aimed at some of the Grand Challenges will assist with the effective dissemination of Dutch expertise.
- Support institutional, process and intervention expertise for effective sustainability policies and incentives at global level. Stimulating a global interdisciplinary knowledge platform aimed at the analysis and assessment of global sustainability policies is a straightforward way of capitalising on the well-developed system of independent policy-oriented planning agencies in the Netherlands that support the Dutch government.

More specifically, the Academy recommends that the Dutch government places more emphasis on the process of agenda-setting by making use of the Dutch scientific community's experience in developing the needed knowledge base and supporting institutional provisions. Related to that, the Academy encourages the further strengthening of the institutions that make up the global science-policy interface to provide objective and credible information and analysis needed for agenda-setting in the various international fora. The Academy also recommends stimulating the further development of strong research fields as indicated, and utilising these to contribute to the goals of the Rio+20 Summit.

The Academy urges the scientific community to promote new connections between the natural sciences and technology, social sciences and humanities by supporting virtual institutes that co-operate in this interdisciplinary mode. In addition to that, the scientific community can help bridge the gap between societal stakeholders by actively involving them in transdisciplinary approaches to the issues that are key to the Rio+20 Summit.

The Academy recommends that the private sector maintains its involvement in long-term partnerships aimed at creating a green economy and that the scientific sector as well as the public and private sectors increase their efforts to include civil society in integrated assessment and institutional innovation. Governments can play a key role here, showing their commitment to addressing the issues of sustainability, as this will provide the predictive power and opportunities that businesses and indeed citizens need to invest in providing new solutions.

The Academy also recommends that civil society contribute actively to sustainable development. To support this, the scientific community as well as the public and private sectors need to include societal groups and NGOs in integrated assessment and institutional innovation.

The Netherlands has a very strong scientific basis for helping to develop solutions for the many issues identified through scientific monitoring and understanding, as well as through policy assessments. The scientific strengths formulated in this advisory report, integrated technology institutes and engineering consultancies, have made important contributions in such fields as agriculture, civil engineering, water technologies and renewable energy. The strong international orientation of Dutch scientific institutes that is realised through many international programmes is an important factor in knowledge and technology transfer to the benefit of the development of sustainable technologies. In fact, only when the scientific, public and private sectors and civil society work together, such goals can be achieved. While this seems evident, it is clear that achieving such cooperation is a complex task. Interestingly enough, this area can particularly benefit from science, i.e. the social sciences. As it turns out, this is one of the many strengths of Dutch science. Dutch scientists are therefore committed to doing their part in, for instance, supporting international agenda-setting, researching modes of cooperation and providing both integrated assessments (tools) as well as forward looks (methods).

1.3 The Netherlands' scientific contributions to sustainable development

Generally speaking, the most important contributions that science and technology have made over the last twenty years with regard to sustainable development as formulated during the 1992 Rio Earth Summit (Agenda 21) have been: 1) the rise of sustainability science, 2) bridging the gaps between science and society, 3) better understanding of the dynamic character of sustainable development, and 4) science-policy assessment reports. Many integrated assessments, collaborative efforts and interdisciplinary and transdisciplinary research programmes together constitute a strong body of proof for this.

Dutch researchers have put a widely recognised effort into these general scientific contributions to Agenda 21 over the last two decades. They have done so in both quantities and qualities that are high in relation to the Netherlands' size and economy. Part of this is attributable to the characteristics of the scientific community and the science-society interface. The Netherlands has:

- a relatively large and diversified national scientific sector;
- many national institutions that link the scientific sector with the private and public sectors;

- a large number of inter-university and interdisciplinary research schools; and
- a strong emphasis on sustainable development in university and non-university (including private sector) mission statements and research programmes.

Many examples of Dutch contributions to international research programmes underscore this.

Some Agenda 21 items correspond to a large number of Dutch research specialties as indicated by bibliometric analysis. These Agenda 21 items include:

- population change and sustainable settlement;
- atmospheric protection;
- protecting fragile environments;
- conservation of biological diversity; and
- international institutions.

One strength of the Dutch contribution to international global environmental change programmes has been its focus on combining several scientific approaches. Dutch researchers and research groups, most notably in environmental sciences, agricultural and food sciences, earth sciences and technology, and biology, as well as governance, but not excluding other disciplines, have made significant contributions to a better level of understanding of the processes underlying sustainable development. Furthermore, the Dutch public knowledge infrastructure and its researchers fulfil an important role worldwide in the education of, amongst others, postgraduate researchers. The Dutch scientific community is actively involved in capacity-building for sustainable development. This holds true for both non-university research institutes and universities. Dutch science should continue this investment. Looking at the needs of developing countries with respect to sustainable development, Dutch scientists could bring to fruition the results of their best practices in this field. By bringing in the best available science and technology, developing countries can leapfrog a number a development stages that were needed for early innovators and adopters to arrive at the current level of best practices.

Science can help to identify facts and non-facts. Science can reach out by providing integrated assessment techniques that reveal the consequences of stakeholder choices. It can also help to understand when and why stakeholders agree, disagree, or agree to disagree. An important issue here is the decoupling of economy and ecology, which may entail a decisive departure from the idea that all economic growth leads to environmental damage. Many stakeholders now agree that economic growth is a prerequisite for ecological diversity and environmental protection. Integrated assessment related to the research agenda-setting processes is a field where Dutch science has also established a solid foundation for further investments. Since integrated assessment forms a linking pin between research and policy by clarifying the consequences of stakeholder choices in the area of sustainable development, it can play an important role beyond the horizon of the Rio+20 Summit.

The agenda for future knowledge development must be consistent with other relevant knowledge agendas that are currently being developed, such as the agenda related to the Top Sectors approach by the Dutch government and the Grand Challenges in the European Union 'Horizon 2020' programme. There is an emerging consensus in the Netherlands that, in addition to the central goal of fostering leading edge research from the bottom up, European research and innovation policies should also focus on tackling sustainability, which often form strategic economic opportunities at the same time.

Taking into account the science policy of the Dutch government, themes that should be considered for further cooperation and collaboration should indeed build upon the main strengths of Dutch science, including a conceptual understanding of global cooperation between the scientific, public and private sectors and civil society, reliable long-term global partnerships, scientific excellence as the required basis for integrated assessment and the embedding of national research in European and global initiatives supporting sustainable development. The focus should be beyond the horizon of the Rio+20 Summit, hence the title of this advisory report. These strengths are in many scientific disciplines, leading to widely recognised applications in a number of areas that are crucial to sustainable development, such as the following:

- **Governance**: international institutions, earth system governance, environmental governance, regime shifts, corporate social responsibility, population change and sustainable settlement
- **Modelling and assessment:** climate change, adaptation and mitigation, modelling complex ecosystems, ecological risk assessment, alternative stable states in ecosystems, life cycle assessment and input-output analysis of environmental impacts, ecological modernisation
- **Water:** drinking water and waste water treatment, water management, virtual water footprint, microbiology and biotechnology for water
- **Energy:** biomass gasification and biofuels, impact of biofuels on land use, experience curves in energy, microbiology and biotechnology for energy
- **Biodiversity:** conservation, taxonomy and biogeography, protecting fragile environments
- **Health and agrofood:** socio-economic status and health, infectious diseases, chemical industry, agriculture and sustainability, soil science.

Given the Dutch Top Sector policy that is currently being implemented, the sustainability orientation in those Top Sector programmes that have the most potential deserve further bolstering. These are: 1) Water; 2) Energy; 3) Agrofood; 4) Chemistry, and 5) Life Science and Health. With regard to the EU Framework Program in 'Horizon 2020', Dutch scientists should particularly engage in all themes in which sustainable development is an issue. Within the European Union, partners can best be identified within the 'Horizon 2020' framework. With regard to developing countries and new economies (BRICs), Dutch scientists would do well to maintain and expand their existing working relationships. Internationally, Dutch science should continue to build on existing collaborative platforms.

1.4 Beyond the horizon of Rio+20

If, as is hoped, the Rio+20 Summit leads to further emphasis of the importance of governance and the need for integrated assessment, Dutch scientists have the proven track record, the capacity and, last but not least, the ambition to support, or even lead, some of the transitions towards the required institutional innovation.

2. INTRODUCTION

This advisory report is a response to a request from the Ministry of Foreign Affairs to the Royal Netherlands Academy of Arts and Sciences on the role of (Dutch) science and technology in achieving the goals set at the first Earth Summit in Rio de Janeiro in 1992. The nations that gathered in 1992 will be reconvening in Rio de Janeiro in 2012 for the Rio+20 Summit. The objective of this Summit is to assess the progress that has been made since 1992 and to formulate redefined goals and guidelines on how to proceed.

2.1 Questions put to the Academy

In order to prepare for the Dutch contribution to the Rio+20 Summit, the Ministry of Foreign Affairs has established an interdepartmental Task Force. It has also launched the 'National Platform Rio+20' networking platform, which generates and connects contributions from societal organisations, networks and businesses on the subject of a green economy.

The Ministry has also requested the Royal Netherlands Academy of Arts and Sciences to advise on the contribution of science and technology to the developments since the 1992 Rio Earth Summit. The Ministry has put four specific questions to the Academy. The first two aim at gaining insight into the historical contributions of science and technology and the specific role of the Dutch scientific community, while the second two aim at providing information that can be used to create an agenda for future action.

1. What have been the most important contributions of science and technology over the last twenty years to sustainable development as formulated during the 1992

Rio Earth Summit? More specifically, what has been the contribution of Dutch science? This might be reviewed using the Agenda 21 items that were adopted during the 1992 Rio Earth Summit.
2. What are the current strengths of Dutch science with respect to the items of Agenda 21? Both in terms of content development (theme: green economy in the context of sustainable development and poverty eradication) and in terms of the organisation of knowledge and institutions (theme: institutional framework for sustainable development)?
3. What are the most important issues on the agenda for future knowledge development? In which areas of sustainable development should Dutch science invest? How does this agenda relate to other agendas, such as the one for the Dutch Top Sectors and the European Grand Challenges?
4. How effective is the collaboration with knowledge institutes from developing countries in the field of sustainable development, and – given the Dutch focal points and knowledge agenda – around which themes and with which partners should cooperation be best organised?

Answering these four questions forms the core of this advisory report.

2.2 Focus of the Rio+20 Summit

In the past several decades, the UN's focus has shifted from more general discussions on global environmental issues in the 1970s and 1980s to Agenda 21 in the 1990s to the two themes that are key to the Rio+20 Summit:
- The green economy in the context of sustainable development and poverty eradication; and
- An institutional framework for sustainable development.

With regard to the first theme, UNEP (2011a) utilises the following working definition of a green economy:
'An economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.'

Given this definition, the notion of a green economy, with its focus on economic activities, narrows down the more inclusive notion of sustainable development. At the same time, it tries to present a practical framework for the various different pathways to achieve sustainable development.

The second theme of the Rio+20 Summit refers to the need for an institutional framework to achieve sustainable development that comprises appropriate national and international management and regulatory systems. Relevant topics with respect to the institutional framework for sustainable development include strengthening the science-policy interface with the full and meaningful participation of developing countries and encouraging synergies between compatible multilateral environmental agreements.

2.3 Structure of the advisory report

This advisory report aims to help the Dutch delegation prepare for the Rio+20 Summit by reviewing the contribution of science and technology over the last two decades to the developments since the 1992 Rio Earth Summit. Special attention will be given to the specific role of the Dutch scientific community. The advisory report focuses on those areas in which Dutch science and technology can make a relevant impact in the near future.

The subsequent chapters relate to the four questions that were put to the Academy.

Question 1 is addressed in Chapter 4, question 2 in Chapter 5, question 3 in Chapter 6 and question 4 in Chapter 7. The issue of Dutch strengths in science and technology is addressed both in questions 1 and 2, which is why both Chapters 4 and 5 relate to it. However, the Committee has chosen to summarise the answer regarding Dutch strengths in science and technology regarding sustainable development in the final section of Chapter 5. The recommendations of the advisory report are given in Chapter 8.

2.4 Preparation of the advisory report

On the advice of the Chairmen of both the Council for Earth and Life Sciences (Professor R. Rabbinge) and the Council for Social Sciences of the Academy (Professor M.A.P. Bovens), the Board of the Academy appointed a Rio +20 Committee in October 2011 consisting of the following academics:

- Dr S.A.P.L. Cloetingh (Chair; KNAW Professor of Tectonics, Utrecht University)
- Dr J.T.A. Bressers (Professor of Policy Studies, Twente University)
- Dr M.C.E. van Dam-Mieras (Professor of Sustainable Development and Innovation Education, Leiden University)
- Dr M.G. Faure (Professor of Environmental Law, Maastricht University)
- Dr M.A. Hajer (Professor of Political Sciences, University of Amsterdam)
- Dr P. Hooimeijer (Professor of Demography, Utrecht University)
- Dr A. Kuyvenhoven (Professor of Development Economics, Wageningen University)
- Dr R. Leemans (Professor of Environmental Systems Analysis, Wageningen University)
- Dr R.A. van Santen (Professor of Catalysis, Eindhoven University)
- Dr H. Speelman (Board Member of the Wadden Academy; former TNO programme director for sustainable development)

The Board of the Academy also set up a drafting group consisting of N.R.J. Deen, J. Kuiper, Dr H.C. van Latesteijn, F.J.G. van de Linde and Dr A. Vollering.

Reviewing the contribution of science and technology in the Netherlands to the developments since the 1992 Rio Earth Summit is a complex activity, not in the least because of the differences between the contributions made by different scientific disciplines. The members of the Rio +20 Committee have different scientific backgrounds, reflecting the diversity of disciplines involved in the developments since the 1992 Rio Earth Summit. The different scientific contributions came to the fore on a regular basis in the discussions of the Rio +20 Committee. In addition, the committee also thoroughly discussed its shared overarching and multidisciplinary views.

The Rio +20 Committee has based its findings on relevant literature concerning international research into policy issues related to sustainable development. Furthermore, with respect to the second and fourth questions of the Ministry of Foreign Affairs, the Rio +20 Committee asked the Dutch Rathenau Institute (department of science system assessment) to analyse the structure and development of scientific fields relevant to sustainability (Rathenau Institute, 2012).

The Rio +20 Committee finalised the draft advisory report in early March 2012. Through their chairmen, the Councils for Life and Earth Sciences and Social Sciences of the Academy provided the peer review of this draft with four separate and independent reviews. The peer reviewers were Professor J. Bouma, Professor J.M. van Groenendael, Professor J.W. Gunning and Professor J. Gupta. Although the reviewers provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations, nor did they see the final draft of the report before its release. The final advisory report was approved in the Board of the Academy on 16 May 2012.

3. BACKGROUND TO THE QUESTIONS

In this chapter, the Committee elaborates on the changing conditions that have played a crucial role in the efforts to achieve sustainability. Looking back over a period of twenty years, the most striking aspect has been the radical change in economic, social and political conditions on a global scale.

3.1 Changing perspectives

In 1992, the first UN Conference on Environment and Development (UNCED) was held in Rio de Janeiro. During the conference an agenda was adopted for environment and development in the 21st century: 'Agenda 21: *A Program of Action for Sustainable Development*'.

Agenda 21 contains the Rio Declaration on Environment and Development (in short: Rio Declaration), which recognises each nation's right to pursue social and economic progress and assigns to states the responsibility of adopting a model of sustainable development. Agreements were also reached at the Convention on Biological Diversity and the Framework Convention on Climate Change. Through Agenda 21, the heads of state expressly and broadly acknowledged the urgent need for a comprehensive change in consumption and production patterns. The spirit of the conference was captured by the expression 'Harmony with Nature' that formed an important aspect of the first principle of the Rio Declaration:

'Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.'

The Rio Declaration builds upon the notion of sustainable development as it was originally proposed in the report 'Our Common Future' by the Brundtland Commission (WCED, 1987). The report wove together social, economic, cultural and environmental issues and provided global solutions for these issues by advocating the need for sustainable development:
'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

This notion of global interdependence brought together the need for development – especially for the poor – and the need to safeguard the environment as well as the need to devote attention to the social conditions of all people involved in an intragenerational and intergenerational context. The report gave rise to an enormous increase in attention to the interrelated domains of economics, the environment and the social conditions in the dynamics of development.

BOX 1:
Conceptualising sustainable development

The Brundtland definition of sustainable development has given rise to an extensive body of literature in which efforts are made to further refine and operationalise the concept. Some authors emphasise the dynamic nature of the concept, and argue that societies and their environments are continuously changing as a result of developments in technology, cultures, aspirations and values (Scientific Council for Government Policy, 1995; Bell and Morse, 1998; Bossel, 1999). This is in conflict with the ambition to come up with unambiguous, effective and efficient indicators of sustainable development. Parris and Kates (2003) describe this ambition as being based on the perceived need for simple measures to support decision-making, management, advocacy, participation, consensus-building, research and analysis.

Agenda 21 is an effort to capture sustainable development in a comprehensive, albeit limited, set of goals. In four sections, some forty societal goals are put forward which, taken together, should constitute a developmental path for providing for the needs of current and future generations:
- *Social and Economic Dimensions:* Combating poverty, changing consumption patterns, promoting health, change population and sustainable settlement.
- *Conservation and Management of Resources for Development:* Atmospheric protection, combating deforestation, protecting fragile environments, conservation of biological diversity (biodiversity), and control of pollution.
- *Strengthening the Role of Major Groups:* The roles of children and young people, women, NGOs, local authorities, business and workers.

- *Means of Implementation:* Science and technology transfer, education, international institutions and financial mechanisms.

In 2000, at the United Nations Millennium Summit, the international community reached consensus on working to achieve eight critical economic and social development priorities by 2015. These Millennium Development Goals (MDGs) form part of the Millennium Declaration, signed by 189 countries, including 147 Heads of State and Government, to achieve eight specific goals (see Appendix A). Although the MDGs are fewer in number than the societal goals in Agenda 21, their scope is considered to be more or less equal.

BOX 2:
Millennium Ecosystem Assessment

As part of the follow-up to the Millennium Development Goals, UN Secretary-General Kofi Annan called for a system of Millennium Ecosystem Assessment (MA), aimed at assessing the consequences of ecosystem change for human well-being and developing the scientific basis for possible actions to improve the sustainable use of those ecosystems. The reports that were produced as part of the MA made it very clear that achieving the MDGs needed more than concisely crafted goals. For example, when describing the implications of the observations for achieving the MDGs, Wall and Rabbinge (2005) revealed structural difficulties. They pointed out that a dramatic acceleration of efforts will be needed to achieve the 2015 goals, that vital knowledge is still lacking, that a sequence of single actions will not lead to the desired results and that the existence of several different drivers that affect environmental change is complicating matters even further. Moreover, they concluded that the complexity of the underlying human/nature interactions makes it difficult to formulate quantitative targets.

Recent observations made by the UNEP (2011b) pointed out that the complexity of reaching the goal of sustainability has only grown over the last two decades. Appendix B provides an overview of various developments that have contributed to this growing complexity. Just a few examples are listed below to illustrate this (categorisation by the Committee):

Supporting sustainable development

- Energy consumption per capita has decreased in the developed world (-15%), but increased in the developing world (+15%).

Hampering sustainable development

- The global use of natural resources has increased by over 40%; the use per capita by 27%.

- CO_2 emissions have increased by 36% worldwide; 8% in developed countries and 64% in developing countries, mainly Brazil, India and China.
- Food production has increased by 45%, exceeding the population growth of 26%.

Influence on sustainable development uncertain

- Biofuel production has shown an exponential increase (e.g. biodiesel increased by 3000 times) but raises issues related to biodiversity, resource efficiency and land use.
- More than 3.5 billion people now live in urban areas. This is more than half the world's population and this fraction is increasing. The rate of urbanisation is especially high in China.
- Per capita GDP in the developing world has increased by 80%, and in the developed world by 33%.

It is clear that the world has changed considerably since 1992. At present, the highest economic growth is located in some of the former developing countries, while a larger part of the developed countries are dealing with financial and social crises. International trade, access to online information and the possibilities afforded by international business, transport and travel have led to substantial changes in international relations. The 230-fold increase in the number of mobile phone subscriptions and the 290-fold increase in the number of Internet users over the last twenty years (UNEP, 2011b) illustrate this.

This changing world has also had a major impact on the political take-up of the original goals set out in Agenda 21 and on the Millennium Development Goals. In the successive meetings and summits that followed the 1992 Rio Earth Summit, the sometimes conflicting aspects of Agenda 21, as well as the differences between the 'developed' and 'developing' world, in particular the rise of the BRICs made it increasingly difficult to come up with common – let alone unanimous – declarations on a large number of issues, including the prioritisation of Agenda 21 items. In particular, combating poverty through economic development and accepting the inevitable short-term effects on the physical environment turned out to conflict with environmental goals that stemmed from global sustainability challenges such as accelerated climate change, ongoing biodiversity loss, accelerating changes with respect to land use, and population growth in relation to carrying capacity.

3.2 Science and technology

The potential impact of science and technology depends on the context of the societal challenge in question. With respect to these challenges, three situations can be distinguished:

1. If the situation one wants to improve is characterised by gaps in knowledge and technology, the answer will be investment in the generation of new knowledge and improved technology.

2. If scientific knowledge and technology are available but the relevant institutions and organisations are unable to use or implement it, investment in organisational and institutional capacity will be required.
3. If the knowledge, know-how and institutional setting are all in place but effects cannot be observed, this will generally be due to a lack of effective incentives and regulations.

These three situations indicate that assessing the contribution of science and technology is extremely difficult. First, it is not just knowledge creation and technology development that are relevant to sustainability. Second, the application of knowledge and technology needs a stable institutional environment and an effective incentive structure. If these two preconditions are lacking, investment in new knowledge and technology will not be efficient. However, institutions and incentives change over time. This is clearly the case in rapidly developing countries, where the improvement in the general conditions has changed the context. Third, developed countries' views on poverty eradication and environmental protection differ from those of developing countries. There is no well-balanced set of institutions and incentives that takes these differing views into account.

In retrospect, Agenda 21 lacked the notion that values related to sustainable development vary in importance according to the economic, geographic, cultural and social orientation of the different countries and regions involved. The notion of several plural normative realities that underpin the perceptions and ambitions of different cultures and regions is one of the many new insights that the evolving 'community of scientific practice' has brought (Bouma, 2005).

New scientific knowledge and improved technology will almost always have contributed to sustainable growth. For example, improved food production and energy efficiency are largely the result of progress in science and technology. But science and technology of course are never the sole contributors to achieving any of the goals that were set in Agenda 21. Some goals have been met as a result of unforeseen economic growth in the BRICs, whereas other successes are primarily the result of targeted policy, as is the case with the ban on ozone-depleting substances. Many initiatives in the private sector have also made significant contributions. The Committee has taken this reality into account in the following chapters.

4. CONTRIBUTIONS OF SCIENCE AND TECHNOLOGY TO AGENDA 21

Question 1 posed by the Ministry of Foreign Affairs is as follows:

- What have been the most important contributions of science and technology over the last twenty years to sustainable development as formulated during the 1992 Rio Earth Summit?
- More specifically, what has been the contribution of the Dutch academic community?
- This might be reviewed using the Agenda 21 items that were adopted during the 1992 Rio Earth Summit.

4.1 Transitions in the role of science and technology

Since roughly the 1990s, the linear, science-push model that describes the transfer from scientific research to societal benefits has been replaced by new views on research, its organisation and its relationship with society. An interactive model in which research is co-created in a joint effort by researchers and societal stakeholders has replaced the linear model. One pioneering way to describe this relationship between science and society is the 'triple helix' model for the transformation processes in university/industry/government relations (Etzkowitz and Leydesdorff, 1998). In this model, the three spheres (university, industry and government) interact with each other in an iterative and productive fashion to bring about innovation. Because of this intensive interaction, the borders between the institutional spheres of university, industry and government are becoming less clearly defined and have become centres of knowledge creation. This insight on the part Dutch scientists has made a significant contribution towards understanding the role of science in sustainable development.

New forms of collaboration and co-creation to achieve innovative actions often follow this 'triple helix' model. Particularly important is the extension of the triple helix to a quadruple helix, in order to include civil society (Leydesdorff, et al., 2012). This new form of collaboration is visible in the 'Grand Challenges' that are closely interrelated with the recently proposed research and innovation strategy of the European Union's 'Horizon 2020' (see also Chapter 5). The recent 'Top Sector' approach adopted as part of the Dutch government's economic and innovation policy employs a 'golden triangle' of collective efforts by researchers, government and industry to develop innovations and foster economic growth. Recently, these overlapping areas between the three spheres have been taken up by the business sciences as the key driver for further development and innovation. Several business analysts regard the quest for sustainable development as the only real basis for further development, even for profit-driven enterprises (Nidumolu, et al., 2009).

BOX 3:
Transdisciplinary approach towards the Dutch agricultural sector

The TransForum programme was a public-private partnership that led to innovations in the Dutch agricultural sector by co-creating new modes of production that comply with various societal, environmental and economic demands (Fisher, et al., 2012). While working on these innovations, scientific progress was made in a number of disciplines that contributed to the understanding of the complexity involved in developing the new modes of production. Societal actors were added in these experiments as an important fourth stakeholder group to the triple helix approach. Such new approaches in the Dutch agricultural sector have resulted in an evidence-based decoupling of economy and ecology. In other words, agricultural production has grown, while detrimental effects on the environment have been reduced, for instance by intensifying land use and decreasing energy consumption.

Nowadays, there are multitudes of different stakeholder groups that want to influence the sustainability agenda. First, the private sector is making important contributions to the key issues for the Rio+20 Summit. Business leaders from multinational corporations such as Unilever, DSM and Philips and the tax and advisory services firm KPMG and consultancy firms such as McKinsey currently have a keen interest in setting the sustainable development agenda (see for example WEF, 2010). Second, civil society, which includes societal groups and NGOs, is seeking to influence the sustainability agenda. Its role in sustainable development issues has recently been recognised as part of the emerging 'knowledge democracy' (In 't Veld, 2010).

Expanding stakeholder involvement will further complicate the journey towards sustainable development even as it creates new opportunities to embark on that journey. This new reality needs to be addressed at the Rio+20 Summit.

4.2 Transitions in international scientific collaboration on issues of sustainable development

Over the past few decades, not only has the UN's focus shifted from more general discussions on global environmental issues to the two themes that are key to the Rio+20 Summit, but the international global environmental change research community has also revised the type of questions it has addressed. This is evident from an analysis of both international global environmental change programmes and global assessment studies.

International global environmental change programmes

Since 1992, scientists have increased their understanding of how individual aspects and processes in the natural and social science domains underpin the answers to questions concerning sustainable development. The international interdisciplinary and transdisciplinary scientific collaboration that has been initiated to address global environmental change has resulted in several international research programmes.

- The World Climate Research Program (WCRP) was established in 1980 in response to the need to organise and facilitate international climate research. The Dutch contribution to the WCRP was coordinated by the Royal Netherlands Meteorological Institute (KNMI) and involved innovative studies on climate variability, land/atmosphere interactions and marine research.
- The International Geosphere-Biosphere Program (IGBP) was set up in 1987 in order to link the biological and physical sciences more effectively. Dutch research on the carbon and nitrogen cycles, climate change impacts, agriculture and forestry and land-use models has been crucial to achieving the goals of this programme. Several earlier established programmes, such as the International Lithosphere Program (ILP) – set up in 1980 – are linked to IGBP.
- DIVERSITAS was established in 1991 in order to build a global programme in biodiversity science. Dutch researchers have contributed significantly to this programme and have helped quantify ecosystem services and their links to human well-being.
- The International Human Dimensions Program on Global Environmental Change (IHDP) was created in 1996 in order to foster international interdisciplinary research in the social sciences. The VU University Amsterdam took a lead in the IHDP's Industrial Transformation project, which brought together researchers from many disciplines and nationalities.

Nowadays, most of these international programmes – all of which have the International Council for Science (ICSU) as one of their sponsors – are highly international and interdisciplinary in scope. In these programmes, disciplinary experts from different backgrounds work closely together to come up with solutions for the Rio+20 Summit.

In the late 1990s it became apparent that these programmes could not individually address the complex questions at hand. In response, the programmes were combined into the Earth System Science Partnership (ESSP). The ESSP integrally studies the Earth System, the ways that it is changing and the implications for global and regional sustainability. The ESSP achieves this through a number of activities, including Joint Projects, capacity-building, integrated regional studies, open science conferences, and contributions to environmental assessments and international conventions.

BOX 4:
Understanding the Earth System

Scientists have tackled questions relating to the components of the Earth System – a very complex coupled system with myriads of feedbacks. Answering such questions has already necessitated international, interdisciplinary collaboration. For example, establishing the cause and effect relationships of the Antarctic ozone hole required international collaboration among atmospheric chemists and physicists, while understanding the causes and consequences of acid rain involved collaboration between chemists, atmospheric scientists and ecologists from all over the world. Innovative interdisciplinary research has increased the understanding of these problems.

Worldwide scientific cooperation and coordination enable an improved understanding of Earth as an integrated, complex and dynamic system. However, the Earth System is not yet fully understood. Earth's atmosphere, lithosphere, hydrosphere, cryosphere and biosphere need to be understood as a single connected system. Earth is changing on spatial and temporal scales. Earth scientists are developing a scientific understanding of the Earth System and its responses to natural and human-induced changes in order to improve the prediction of climate, weather and natural disasters, such as floods, landslides, earthquakes and volcanic activity. There is also the challenge of developing new sources of energy, including geothermal energy, that may have a minimal impact on climate (Cloetingh, et al., 2010). Over the last few decades many research projects within the international global environmental change programmes have flourished. They have contributed greatly to understanding many aspects of the Earth System, climate change and sustainability. Scientific advisers and funding agencies throughout the world are now calling for improved public recognition of science and better integration and transparent communication of research results in order to cope with current environmental challenges. As a result, the ICSU, together with other scientific bodies and funding agencies, is initiating international research collaboration along these lines. These organisations envision a ten-year initiative, 'Future Earth, research for global sustainability' (Holm, et al., 2012).

With respect to global food security, the Consultative Group on International Agricultural Research (CGIAR) plays a central role. In 2009 a major collaborative endeavour between the CGIAR and their partners and the ESSP was established through the CGIAR Challenge Program 'Climate Change, Agriculture and Food Security (CCAFS)'.

Global science-policy assessments

The insights generated by the international global environmental change programmes have been synthesised in various science-policy assessment studies. These integrated assessments focus on synthesising the scientific knowledge and understanding of specific issues of relevance to society by reviewing the scientific literature, developing scenarios and assessing other sources of information. They help policymakers learn about the relevant issues and their urgency and mitigation, as well as adaptation measures and the consequences of failing to act.

The Ozone Assessment in the 1980s was the first assessment and, after publication, immediately led to policy measures to protect the ozone layer (NASA, et al., 1985). Since then, policies have been tightened and based on updates of this influential assessment. The Intergovernmental Panel on Climate Change (IPCC) was established in 1998. In its lifespan of nearly two and a half decades, the IPPC has published four major assessment reports and several special reports. The United Nations Framework Convention on Climate Change (UNFCCC) has used these reports extensively, as have national and international policy bodies. At the same time, the vigorous public debates that accompanied the findings and conclusions of the IPCCs Fourth Assessment Report (AR4) have revealed that an assessment study – because it also translates the scientific facts into conclusions with important societal impacts – appeal to many relevant stakeholder groups.

A number of different assessments are currently being undertaken and some have already been finished, including the following:

- The Global Environmental Outlook (GEO)
- The Millennium Ecosystem Assessment (MA)
- The World Water Assessment Program (WWAP)
- The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD)
- The Arctic Climate Impact Assessment (ACIA)
- The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

All of these assessments have brought together scientists from many different countries and cultures – including many Dutch scientists – to provide the necessary policy-relevant knowledge to the international (UN) bodies and its members.

4.3 Engagement of the scientific community in the sustainability discourse

The growth of research in the field of sustainability science has been the subject of analysis in the recent past. One of the few efforts to produce quantitative results at global level that illustrate this growth was recently published by Bettencourt and Kaur (2011). They have analysed some 20,000 scholarly papers that were published between 1974 and 2010 and that mentioned 'sustainability' in the title, abstract or keywords. The analysis involves some 37,000 authors. They conclude that a major contribution of science and technology to the understanding of sustainable development marks the development of the field of sustainability science.
Sustainability science has three distinguishing characteristics:

1. An unusual geographical spread combining the developed and the developing world.
2. A disciplinary spread with the emphasis on the management of human, social and ecological systems.
3. The emergence of a massive scientific collaboration.

The analysis reveals that Australia, the UK, Brazil, China, India, South Africa, Nigeria, Kenya, Turkey and the Netherlands are very well represented in this field of research, in terms of both quantity and in quality.

Over the past few decades, the scientific community has become increasingly involved in capacity-building for sustainable development. The variety of scientific disciplines represented in Bettencourt and Kaur's analysis indicates that collaborations between formerly unrelated fields constitute the basis for the further development of sustainability science. The disciplinary breakdown of the 20,000 scholarly papers is given in Figure 1. Noteworthy are the dominance of social sciences (about 34%) and the relatively strong position of biology (about 25%) and civil engineering (about 22%). The fact that they focus exclusively on scholarly papers that use the word 'sustainability' in the title, abstract or keywords may explain why a high proportion of the papers they have retrieved belong to the social sciences (Rathenau Institute, 2012). Bettencourt and Kaur's approach identifies scholarly papers explicitly stating that the results are relevant for sustainability or that study sustainability. By excluding all papers that do not mention the word 'sustainability' in the title, abstract or keywords, they may overlook relevant papers in the same field of scientific endeavour, such as the technical development of biofuel cells and organic solar cells, as well as, for instance, chemistry. This can be considered to be an omission in their analysis.

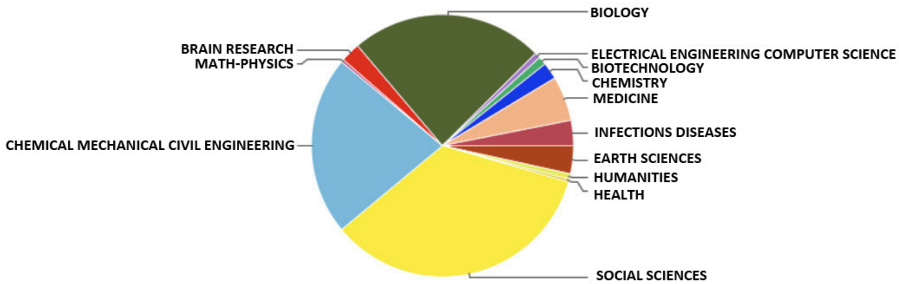

Figure 1. Breakdown into disciplines of 20,000 scholarly papers on sustainable development.
Source: Bettencourt and Kaur (2011).

While interdisciplinary research drives sustainability science, the role of individual disciplines must not be underestimated. Fundamental progress in science still has its roots in the disciplinary research that aims to expand the borders of human understanding. For example: international research programmes such as WCRP, IGBP, DIVERSITAS and IHDP were originally set up in a disciplinary mode. These programmes have made significant contributions to the development of sustainability science. This illustrates that a proper disciplinary basis is needed for any interdisciplinary field to flourish. This also is true for the research in the field of sustainability science. Without a sound basis and a continuous expansion of the bodies of knowledge from disciplinary fields, interdisciplinary approaches will run dry.

4.4 Dutch contributions to sustainability science

Individual Dutch researchers are well represented in global environmental change research programmes. Many young Dutch researchers have also matured by contributing research in the context of these programmes' international networks. There are four major reasons behind this. First, the Netherlands is proud to have an active, large and diversified scientific sector – albeit one that lacks the kind of large multidisciplinary institutions that some other countries (such as Germany) have – Dutch researchers have spent centuries collaborating internationally in interdisciplinary and transdisciplinary teams (Speelman, 2006). Second, the Netherlands has a decades-long history of working with many successful institutions that link the scientific sector with both the private and public sectors. Third, the KNAW, NWO and the Dutch universities have worked together to establish a large number of inter-university and interdisciplinary research schools, in which PhD students, amongst others, pick up the skills required not only for scientific collaboration between disciplines, but also for bridging the gaps between the scientific sector on the one hand and the private and public sectors on the other. This latter point is elaborated upon in Section 5.4. Last but not least, a strong emphasis on the ambition to contribute to sustainable development is embodied in both the mission statements and the research programmes of nearly all of the fourteen Dutch universities.

Dutch researchers have contributed to methodologies to quantify unsustainable developments, have developed ways to measure consequences of growth in the traditional way, have been pivotal to the global assessment by the global scientific community and have contributed to the development of scenarios and various options for balanced growth. Even in the earliest days of sustainable development, unifying concepts were developed and action perspectives were implemented in the domains that characterise sustainable development, food security, energy supply, water use and availability, management of natural resources and safeguarding biodiversity. This last approach, in particular, is still seen as original.

Within the context of public research investment, the Netherlands Organisation for Scientific Research (NWO) funds thousands of top researchers at universities and non-university knowledge institutes, steering the course of Dutch science by means of subsidies and research programmes. With respect to international global environmental change programmes (such as WCRP, IGBP, DIVERSITAS and IHDP), NWO took the lead in financing and establishing project offices for these programmes. An example is the project office of Land-Ocean Interactions in the Coastal Zone (LOICZ), a core project of the International Geosphere-Biosphere Program (IGBP) and the International Human Dimensions Program on Global Environmental Change (IHDP); the LOICZ secretariat was hosted for 10 years by NIOZ on the Dutch island of Texel.

WOTRO Science for Global Development, a part of NWO, has executed and is preparing several large research programmes focusing specifically on issues of sustainable development such as water, biodiversity, environment and deltas. The integrated programmes of WOTRO also afford PhD students from developing countries the opportunity to focus more specifically on sustainable development.

In addition, the Dutch climate-change research programme (NOP-klimaat) in the 1990s and, more recently, the FES projects 'Knowledge for Climate', 'Climate Changes Spatial Planning' and 'Energy Transitions' have greatly enhanced the involvement of the Dutch scientific community in sustainable development issues.

The Dutch Ministry of Education, Culture and Science has established the International Group of Funding Agencies for Global Change Research (IGFA) to improve the coordination of funding for the international global environmental change programmes' infrastructure and research. Some IGFA members also established the Belmont Forum a few years ago to further strengthen these research efforts.

BOX 5:
Three typical Dutch contributions to sustainability science and technology

A first example concerns the large-scale biospheric and atmospheric measuring campaigns such as the 'Hydrologic Atmospheric Pilot Experiment' (HAPEX) in the Sahel region and the 'Large-Scale Biosphere-Atmosphere Experiment' (LBA) in Amazonia, in which both universities and non-university knowledge institutes have participated, including Alterra, KNMI and TNO.

A second example refers to globally integrated models such as the 'Integrated Model to Assess the Global Environment' (IMAGE) for the analysis of global change issues at PBL working in collaboration with universities (Wageningen University, Utrecht University and VU University Amsterdam), CPB and KNMI. The IMAGE model has been particularly instrumental in the development and quantification of many plausible future global environmental scenarios, because it integrates energy and land use (including biofuels and deforestation) with other components of the Earth System (including the economics of the human/societal sub-system). It is also the only model that is used in all IPCC working groups and in many applied interactive science policy dialogues, while the results have been simultaneously published in high-impact scientific journals.

A third example is about saving rainwater in the multi-reservoir system in Singapore. Scarcity of fresh water of sufficient quality is the world's most pressing water problem. It threatens people's health and well-being and restrains economic development. Saving as much rainfall as possible, keeping this water in good condition and optimising its use are therefore of vital importance. The non-university knowledge institute Deltares, in collaboration with its partners in Singapore, has developed methods and tools to optimally operate combinations of storage reservoirs (surface and underground) and to use natural vegetation to keep the water in surface reservoirs clear and healthy. This technology is ready to be applied in other countries, including more arid ones.

4.5 Response to the question

What have been the most important contributions of science and technology over the last twenty years to sustainable development as formulated during the 1992 Rio Earth Summit?

The rise of sustainability science has been the most important contribution that science and technology have made towards achieving sustainable development. In particular, sustainability science has helped to better understand what really needs to be discussed with stakeholder groups, including the scientific community, in multilateral forums. While this may seem an obvious statement to some, the fact that science and scientific disciplines were to a large extent separately operating entities in 1992 proves that it is not.

In 1992, gaps between the scientific sector on one hand and the private sector, the public sector and civil society on the other prevented the kinds of integrated assessments and consorted actions that are needed to bring about the changes that Agenda 21 calls for. Since 1992, scientists and many others have worked on **bridging the gaps between science and society.**

The development of a global scientific community that is involved in a collective effort to **better understand the dynamic character of sustainable development** has therefore been an important feature in the decades since the presentation of Agenda 21.

Furthermore, an important contribution of science and technology to Agenda 21 has been the synthesis of the insights implemented by the international global environmental change programmes into **science-policy assessment reports.** Assessments have helped policymakers learn about many issues related to sustainable development, the urgency of these issues, mitigation and adaptation measures and the consequences of failing to act.

In short, the most important contributions of science and technology over the last twenty years to sustainable development as formulated during the 1992 Rio Earth Summit have been:
- the rise of sustainability science;
- bridging the gaps between science and society;
- a better understanding of the dynamic character of sustainable development;
- science-policy assessment reports.

Many integrated assessments, collaborative efforts and interdisciplinary and transdisciplinary research programmes, some of which are mentioned in the previous sections of this chapter, together constitute a strong body of proof for the above statement. A non-exhaustive list of such programmes:
- The World Climate Research Program (WCRP)
- The International Geosphere-Biosphere Program (IGBP)
- DIVERSITAS
- The International Human Dimensions Program on Global Environmental Change (IHDP)
- The Global Environmental Outlook (GEO)
- The Millennium Ecosystem Assessment (MA)
- The World Water Assessment Program (WWAP)

- The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD)
- The Arctic Climate Impact Assessment (ACIA)
- The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

More specifically, what has been the contribution of Dutch science with respect to the items of Agenda 21?

Dutch researchers have contributed to the rise of sustainability science, bridging the gaps between science and society, a better understanding of the dynamic character of sustainable development and science-policy assessment reports. They have done so in a manner that is globally recognised in terms of quantity and quality that is high in relation to the Netherlands' size and economy. Part of this is attributable to characteristics of the scientific community and the science-society interface. The Netherlands has:

- a relatively large and diversified national scientific sector;
- many national institutions that link the scientific sector with the private and public sectors;
- a large number of inter-university and interdisciplinary research schools; and
- a strong emphasis on sustainable development in university and non-university (including private sector) mission statements and research programmes.

More specific contributions of Dutch science to Agenda 21 will be summarised in the final section of the next chapter.

The Dutch contribution might be reviewed using the items of Agenda 21 that were adopted during the 1992 Rio Earth Summit.

The response to this suggestion will be summarised in the final section of the next chapter, which also addresses strong points of Dutch research for Agenda 21.

5. STRONG POINTS OF DUTCH RESEARCH FOR AGENDA 21

Question 2 posed by the Ministry of Foreign Affairs is as follows:

- What are the current strengths of Dutch science with respect to the items of Agenda 21?
- Both in terms of content development (theme: Green economy in the context of sustainable development and poverty eradication) as in terms of the organisation of knowledge and institutions (theme: Institutional framework for sustainable development)?

5.1 The science base in the Netherlands

Dutch knowledge production is characterised by outstanding levels of quantity as well as quality (NOWT, 2010). Since the year 2000, the publication output volume has increased by 47%, and in 2008 Dutch scientists together produced almost 30,000 scholarly papers (NOWT, 2010). The Netherlands produces 2.8% of all scholarly papers within 18 benchmark countries that are either among the most advanced countries worldwide in terms of R&D performance, innovation and economic competitiveness or are showing very rapid improvement, such as China. In contrast, the Netherlands accounts for only 0.8% of the total population in these benchmark countries. Moreover, judging from the citation impact of Dutch scholarly papers within the international scientific and scholarly literature, the science base in the Netherlands is of outstanding quality. The Netherlands ranks fourth, closely following top performers Switzerland, Denmark and the United States (NOWT, 2010).

In the latest edition of the Global Competitiveness Report (WEF, 2011) ranks the Netherlands 7th, after Switzerland, Singapore, Sweden, Finland, the United States and Germany. On the Innovation Union Scoreboard (EC, 2012), the Netherlands ranks first on the 'open, excellent and attractive research systems' indicator and high on the 'intellectual assets' indicator.

In recent decades, with the development of the EU Framework Programs, research and research training in the field of sustainability science in the Netherlands has been increasingly embedded in European perspectives. Many of the European programmes and research initiatives have been carried out with strong Dutch participation and leadership (Cloetingh, et al., 2007; OECD, 2012).

In addition, the establishment of the European Research Council (ERC) in 2007 has led to a strong position for basic research from the bottom up in all domains of physical and engineering sciences, life sciences, social sciences and humanities, preparing the ground for future breakthroughs in these domains , many of which are important for sustainable development. Dutch researchers have been very successful in the international competition for ERC grants, ranking fourth amongst the EU Member States, after the United Kingdom, France and Germany, and ranking first per capita (ERC website).

The ERC Proof of Concept (PoC) grant aims at supporting an ERC grant-holder during the pre-demonstration phase to prepare a 'package' for presentation to venture capitalists, companies or social entrepreneurs that might invest in the technology and take it through the early commercialisation or roll-out phase. At present, the Netherlands comes in first place with respect to receiving PoC grants (ERC website). As many of these PoCs relate to sustainable growth in some way or another, the Dutch impact on utilisation of ERC results are expected to be significant.

5.2 Sustainability science in the Netherlands

A recent bibliometric analysis of more than 40,000 Dutch scholarly papers from the period between 1996 and 2010 presented the current strengths of Dutch scientific research of relevance for sustainability (Rathenau Institute, 2012). The analysis was conducted on the basis of specialties, a specialty being defined as a set of scholarly papers that are highly similar in their use of title words and in their references to other literature. Researchers within a specialty study the same research topic from the same cognitive background. The Rathenau Institute identified 36 specialties of high relevance for sustainability (see Appendix C). All 36 specialties have experienced an increase in output over the last 15 years.

All 36 specialties in sustainability science fit the aggregate picture of Dutch scientific output: scholarly papers involving researchers from the Netherlands tend to attract more citations than the world average. Over the past 15 years, most specialties recorded gains in the relative rate of citation. Furthermore, almost 12 percent of the EU27 scholarly papers in the 36 specialties were written by Dutch authors/co-authors, whereas almost 7 percent of the total EUR27 scholarly papers were written by Dutch authors/co-authors. The specialties are therefore better represented in the Netherlands than in other EU27 countries.

The specialties in Dutch sustainable science have a strong orientation towards environmental sciences, agricultural and food sciences, earth sciences and technology, and biology. Almost all Dutch universities make contributions to the specialties. In addition, specialised know-how is present in non-university segments of the public knowledge infrastructure in the Netherlands (for example at Deltares, DLO, TNO, KNMI, PBL, RIVM, Wetsus, ECN, NIOO, NIOZ, ITC, ISS and UNESCO-IHE). The many successes of Dutch consultancy activities derive from a strong science and technology base and includes many universities and non-university research institutes (for instance WUR and Deltares), and, in particular, many globally operating engineering consultancy firms, such as DHV, Arcadis and others. Transdisciplinary consultancy is a Dutch asset that is widely recognised in both developing and developed countries and covers themes such as spatial planning, transportation systems, agricultural systems, sanitation and water management.

Four larger groups of specialties may considered to be the most characteristic strengths of Dutch sustainability science: 1) biodiversity; 2) climate change, adaptation and mitigation; 3) agriculture and sustainability; and 4) soil science. For each of these four groups, the citation rate of Dutch publications is far higher than that for EU27 publications (Rathenau Institute, 2012). This means that the average quality of Dutch publications in these groups, according to professional peers, is well above the EU27 average. It should be noted, however, that citation is not the only measure for high quality and excellence of scientific output. There are very different time horizons involved in these groups of specialties. For example, biodiversity losses and climate change are slow and hard to control effectively, whereas agricultural land use and soil fertility are easier to control effectively within a shorter period.

A number of specialties, for example in medical sciences, social sciences and chemical sciences, infectious diseases, socio-economic status and health and agrofood, amongst others in the chemical industry (DSM, AKZO-Nobel), have not been revealed by the Rathenau Institute bibliometric analysis, due to the keywords used as well as the papers researched. Also, industrial research often remains hidden from open literature. It may also be due to the fact that Thomson Reuters Web of Science – the source of the Rathenau Institute analysis – underestimates the output of disciplines that produce more books or technology than scholarly papers. This can also explain why comparatively few specialties are found that relate to such issues as social inclusion and global poverty on one hand, or water treatment on the other. For example, international law, policy sciences, international relations, and the methodology of poverty mapping are highly regarded fields of science, but the output in these fields hardly shows up in the Web of Science.

The Committee was challenged to deal with the limitations of bibliometric research within the constraints of time and budget.

Examples of Dutch emergent specialties, with even higher average annual growth than worldwide, are:

- Impact of biofuels on land use and greenhouse gas emissions: Dutch annual growth 45% (world annual growth 29%).
- Regime shifts and alternative stable states in ecosystems: Dutch annual growth 39% (world annual growth 24%).
- Corporate social responsibility: 37% annual growth of Dutch scholarly papers (world annual growth 31%).
- Earth system governance and environmental governance: Dutch annual growth 36% (world annual growth 23%).
- Virtual water footprint: Dutch annual growth 34% (world annual growth 20 percent).
- Technological learning and experience curves in energy: Dutch annual growth 33% (world annual growth 12%).
- Ecological modernisation and environmental governance: Dutch annual growth 32% (world annual growth 22%).

Dutch sustainability science will most likely be relevant for some of the 'Grand Challenges' in the European Union 'Horizon 2020' programme (to be started in 2014), in particular for (1) conservation and management of natural resources, (2) sustainable consumption and production, and (3) climate change and clean energy. Within the 36 specialties, the themes of 'water', 'energy' and 'governance' act as a cross-cutting link between the different fields of research. These three themes also play a significant role in the three aforementioned 'Grand Challenges'. Moreover, at the March 2012 'Planet under pressure' conference in London, (environmental) governance was emphasised as probably the most important issue to be dealt with. The Academy is happy to observe that, given the Dutch research strengths, Dutch scientists will be able to further advance this issue.

5.3 Dutch scientific contributions to science-policy assessments

For several decades, Dutch scientists have made a major contribution to the development of integrated assessment. For example, the RAINS model ('Regional Air Pollution INformation and Simulation') was developed for the formalisation of policy on transboundary air pollution and acidification. The RAINS model is still being used to determine European targets for air pollution. Dutch researchers, being the initiators of RAINS, have therefore had a major impact on policy developments.

The use of integrated assessment models also has a lengthy tradition in climate and sustainability research. Here the contribution of Dutch research is evident as well. During the 1990s, researchers from the Netherlands Environmental Assessment Agency (PBL) developed the TARGETS model ('Tool to Assess Regional and Global Environmental Health Targets for Sustainability'). This model and its mode of operation have contributed significantly to environmental research in a global context (Rotmans and De Vries, 1997). The same institute also developed the integrated IMAGE/TIMER ('Targets IMage Energy Regional simulation model') assessment model. As one of the very few international models to do so, this model combines a detailed description of land, energy, emissions and climate. International organisations such as UNEP (for its Global Environmental Outlook), the OECD (for its OECD Environmental Outlook) or the IEA (for its Energy Outlook) regularly draw on this Dutch capacity for their scientific assessments.

Expertise in the fields of integrated modelling, monitoring and evaluation is strongly developed in the Netherlands. An example of this type of work is the Sustainability Monitor for the Netherlands 2011 (CBS, CPB, PBL and SCP, 2011). In this Monitor, Statistics Netherlands (CBS) and the three planning agencies (CPB, PBL and SCP) draw on a large number of indicators to outline how the situation in the Netherlands is developing with respect to sustainability. This is an attempt to develop a broad understanding of the degree to which current Dutch policies are robust for future developments while sustainability is consciously meant to be more than ecology only, i.e. also including economic growth.

Integrated assessment techniques are also used to develop forecasting studies to support environmental policy. Here, the Netherlands has acted as a pioneer as well. At present, these techniques are applied worldwide, amongst others at the European Environmental Agency, the UNEP and at the OECD. Dutch scientists have a prominent role in contributing to the outlook reports by these organisations. As an example, in its environmental outlook towards 2050 (OECD, 2012), the OECD has painted a grim picture of many trends regarding sustainable development, in particular fossil energy. The demand for energy will grow, worldwide, by 80% as we approach 2050. At the same time, OECD countries are spending USD 45 to 75 billion annually on energy tax reductions. Developing countries and emerging economies (such as the BRICs) are spending as much as USD 400 billion on energy tax reductions. Clearly, this emphasises the fact that significant progress can be made through governance, and, again, the Netherlands (science) is poised to play its role in this.

5.4 Human resources

At the start of the 1990s, an important innovation took place in Dutch universities with the introduction of research schools. Research schools concentrate research efforts and provide training to young researchers who have finished a master's degree and are studying for a doctorate (i.e. PhD students). The start of the concept of research schools meant a break with the traditional 'master/pupil' relationship: postgraduate researchers are put through an active training programme.

The Dutch system of research schools has indisputably contributed to an improvement in the quality and structure of the training of research assistants. As a result, the Netherlands is ahead of many other countries with its researcher training programmes. At present, there are almost seventy KNAW-accredited research schools in the Netherlands, ranging from the humanities, social sciences and natural sciences to the technical and medical sciences. There are also a number of research schools in the field of sustainability science, in such fields as biodiversity, integrated solid earth science, socioeconomic and natural sciences of the environment, and resource studies for development. The KNAW research school accreditation committee (ECOS) closely monitors the quality and the development of Dutch research schools.

Since the late 1990s, the absolute and relative number of postgraduate researchers from other countries has increased substantially. This is also due to the relatively good worldwide reputation that Dutch research schools enjoy. In some areas, more than half of the research school PhD students are from abroad.

Education for sustainable development calls for innovative learning environments which enable students to experience different perspectives on a problem and different levels of scale. This is particularly well-organised in Dutch research schools, including vast ICT facilities that support international communication, also with developing countries.

5.5 Response to the question

What are the current strengths of Dutch science with respect to the items of Agenda 21? Both in terms of content development (theme: Green economy in the context of sustainable development and poverty eradication) as in terms of the organisation of knowledge and institutions (theme: Institutional framework for sustainable development)?

The Dutch contribution to the scientific study for sustainable development has been substantial, leading to cutting-edge research results in both the social and the natural sciences. The main strength of the Dutch contribution to international global environmental change programmes has been the strong focus on combining several scientific approaches. Dutch researchers and research groups, most notably in environmental sciences, agricultural and food sciences, earth sciences and technology, and biology, but not excluding other disciplines, have made significant contributions to the field of sustainable development that have led to a better level of understanding of the underlying processes, including:

- Impact of biofuels on land use and greenhouse gas emissions
- Regime shifts and alternative stable states in ecosystems
- Corporate social responsibility
- Earth system governance and environmental governance
- Virtual water footprint
- Technological leaning and experience curves in energy
- Ecological modernisation and environmental governance

Furthermore, the Dutch public knowledge infrastructure and its researchers fulfil an important role worldwide in the education of, amongst others, postgraduate researchers. The Dutch scientific community is actively involved in capacity-building for sustainable development. This holds true for both non-university research institutes and universities.

Agenda 21 listed some forty societal goals in four sections. These goals are summarised below in Table 1. The Committee has not been able to closely follow the suggestion of the Ministry of Foreign Affairs (see question 1, last bullet, of the Ministry of Foreign Affairs in the previous chapter) to review the contribution of Dutch science along the lines of Agenda 21, given the time and budget constraints imposed on the Committee. However, in response to this suggestion, the table below also lists the sustainability science specialties that the Rathenau Institute found in its bibliometric research.

As crude as Table 1 is, the following two observations can be made. First, some Agenda 21 sector goals are not matched with Dutch research specialties ('blanks' in Table 1). Examples of such 'blanks' are combating poverty and combating deforestation, most of the sector of strengthening certain societal groups and financial mechanisms. Possible explanations for this are the keywords that the Rathenau Institute used or the journals that were researched. In other words, it cannot be concluded from the table above that, for instance, Dutch chemical research, which is strong, does not contribute to Agenda 21. Another explanation may be that some of these 'blanks' indeed illustrate that Dutch research does not excel in these areas. Additional research would be required to substantiate such explanations.

A second observation that can be made is that some Agenda 21 items are matched with many Dutch research specialties. These are:

- population change and sustainable settlement;
- atmospheric protection;
- protecting fragile environments;
- conservation of biological diversity; and
- international institutions.

To the Academy, these five items do indeed reflect some of the strengths of Dutch sustainability science. The Academy recognises these strengths, including in terms of being logical consequences of Dutch scientific orientations and in reflecting historical underpinnings, as well as national and global ambitions. Being a densely populated country, the Netherlands has a keen interest in researching population and settlement. Since the seventies, the Netherlands has been a leader in atmospheric protection, through energy research amongst other means, including biomass gasification, geothermal energy and GRIDS. As the Netherlands has very limited natural environment itself, it is both interested in protecting the little that it has and in studying the natural environments of other countries. This argument holds true for conservation of biological diversity as well. Finally, reflecting the core of the previous sections, the items of international institutions again illustrate the increased and still-growing interest of Dutch researchers in the area of governance, in line with the belief that only when institutions are innovated can the needed transitions in governance towards sustainable growth be made.

Transitions in governance include further elaborations on how the government, the business community, the scientific community and civil society can globally work together towards sustainable development. This will be further elaborated upon in the next chapter, which focuses on issues for future knowledge development.

Table 1. Matching of Agenda 21 sectors and summary of goals with Dutch research specialties

Agenda 21 sectors and goals	**Dutch research specialties**
Social and Economic Dimensions	
Combating poverty	
Changing consumption patterns	Consumption patterns and environmental load; Life cycle assessment
Promoting health	Malaria vector control
Population change and sustainable settlement	Spatial (urban and rural) planning (urban and rural) planning; Environmental assessment and use of space; Sustainable land use and farming systems; Landscape ecology and planning
Conservation and Management of Resources for Development	Ecological modernisation and environmental governance; Common pool resources and collective action; Natural resources and growth; Ecosystem services
Atmospheric protection	Technological learning and experience curves in energy; Impact of biofuels on land use and greenhouse gas emissions; Exergy analysis; Biomass gasification; Microbial fuel cells
Combating deforestation	
Protecting fragile environments	Water management; Flooding and waterlogging; Modelling and simulation of the water balance; Modelling of sedimentation and flood plain in rivers; River restoration and flood plain rehabilitation; Nutrient management in agriculture; Soil fertility in Sub-Saharan Africa; Soil organic matter and carbon sequestration in agriculture; Anaerobic treatment of domestic waste water; Fish diversity and eutrophication in Africa; Aquaculture
Conservation of biological diversity	Landscape quality and diversity; Biodiversity and conservation, agri-environmental schemes, and biological control
Control of pollution	Recycling
Strengthening the Role of Major Groups	

Children and youth	
Women	
NGOs	
Local authorities	Corporate social responsibility
Business	Corporate social responsibility
Workers	
Means of Implementation	
Science and technology transfer	
Education	
International institutions	Earth system governance and environmental governance; Sustainability and sustainable development; Regime shifts and alternative stable states in ecosystems; Innovation systems and transition
Financial mechanisms	

6. IMPORTANT ISSUES FOR FUTURE KNOWLEDGE DEVELOPMENT

Question 3 posed by the Ministry of Foreign Affairs is as follows:

- What are the most important issues on the agenda for future knowledge development?
- In which areas of sustainable development should Dutch science invest?
- How does this agenda relate to other agendas, such as the one for the Dutch Top Sectors and the European Grand Challenges?

6.1 The need for integrated assessment

The 1992 Rio Earth Summit and the resulting Agenda 21 led to a great number of scientific efforts to develop evidence-based decision-support tools. In most cases these tools are based on the concept of ecological carrying capacity. By determining the carrying capacity of the environment, constraints can be defined for the various activities that impose a burden on it. In turn, these constraints can be used to determine the necessary changes in order to support sustainable development.

Carrying capacity has operational value when applied to a particular system level only. At global level, scientific data can help to signal risks. While influential scientists have warned that the thresholds of 'Planet Earth' are in sight (Rockström, et al., 2009), it remains very difficult to define thresholds or 'tipping points' in advance in all domains.

Although sometimes these thresholds are at stake, most of the time the policy debate focuses on some type of compromise. Sustainable development in those situations requires striking the right balance between the people, planet and profit, also known as the 'triple-P bottom line' (Elkington, 1998). As pointed out by the Netherlands Scientific Council for Government Policy, finding this balance requires an in-depth analysis of the consequences of political positioning in the sustainability debate (Scientific Council for Government Policy, 1995).

BOX 6:
Different action perspectives for sustainable development

In its report 'Sustained Risks: a Lasting Phenomenon', the Netherlands Scientific Council for Government Policy examines the various ways in which the concept of sustainable development can be manageably translated into policy terms (Scientific Council for Government Policy, 1995). This approach centres on the notion that the operationalisation of this concept cannot circumvent the uncertainties associated with the interdependence of the environment and society. The resulting risks for the environment and the economy will need to be weighed against one another.

The report argues that it is impossible to work with an objectively fixed elaboration of sustainable development. In order to elaborate the concept of sustainability as a genuinely operative policy concept, normative choices in relation to the identified risks and uncertainties must be made explicit. Insight into existing uncertainties makes it possible to enter into a discussion as to how these risks should be handled. Various action perspectives have been worked out in the report as an elaboration of the various directions in which a development may be regarded as sustainable. In this respect, it is not just differing perceptions of environmental risks that are a factor, but also divergent perceptions of social risks, namely attitudes towards society's ability to cope with processes of change.

On the basis of the differing weight attached to facts, uncertainties and risks with respect to the environment and society, each of these approaches – elaborated upon in the report as 'action perspectives' – may at first sight be justifiably labelled as 'sustainable'. The consequences of these differing weights, perceptions and acceptances of risks are very great. The elaboration of each of these action perspectives based on sustainability into long-term scenarios brings this into sharp focus and may result in the tightening or adjustment of the action perspectives.

Using scenario techniques can illustrate the consequences of policy positions – and thus the different notions of sustainable development. This mode of analysis does not simplify the complex nature of sustainable development, but builds on the different positions that are present in the debate. The use of these techniques will be essential in the future debate on global sustainable development.

Given its two main themes ('Green economy' and 'Institutional framework'), the Rio+20 Summit will be the right event at which to promote the types of analyses that will illustrate the consequences for sustainability goals of the different positions advocated by the stakeholder groups involved. Such 'integrated assessment techniques' will not lead to yet another 'Action Plan'. Instead, this type of analysis can show how changing stakeholder positions will lead to different pathways toward sustainability. This could lead to a more in-depth debate on different motives for action and the need to harmonise these motives with one another. It will also stimulate the creativity of all the stakeholders involved to come up with new answers to new challenges.

It should be recognised the world is a very different place than it was in 1992. At that time the Rio Earth Summit was indeed a meeting amongst political leaders. Nowadays, the awareness of the sustainability crisis has spread. What is more, in several domains, it is the business community and societal groups that seem to be the most convinced that action is needed. In 1992, governments invited NGOs and business to the Rio Earth Summit. In 2012, civil society, including societal groups and NGOs, and the business community are all very well aware of the problems, while the political world is having difficulty acting on this new awareness. The strategic question seems to be how to align those interests. The idea of the 'triple helix' describing effective interaction among the public sector, the private sector and the scientific sector, may be of great value in this context.

Compared to 1992 there is now a much better understanding of the complex way in which several issues of sustainability and development interact (biodiversity, land use, climate, development) and of the high costs that may be involved if action is not taken (the 'costs of inaction'). This knowledge of the interaction of social, economic and natural processes has itself produced new knowledge interests, in particular regarding (1) strategies that help identify pathways to move to a more sustainable development, as well as on (2) the respective roles that the public sector, the private sector and civil society can play, and (3) at what level most progress can be expected. The Rio+20 Summit is an opportunity to bring the different groups together and develop a joint perspective that will allow all of the actors to move ahead. Scientific knowledge has contributed to the spread of the awareness of the economy's dependence on resources, both biotic and abiotic. And while a political consensus on action may be difficult to achieve, the true challenge may lie in the creation of the preconditions upon which business and industry, producers and consumers, can readjust to make the greening of the economy into a reality. This, of course, goes well beyond an agenda of institutional renewal of the UN and would call for new research into the business opportunities and welfare scenarios that lie in a concerted action on the predicaments that were first sketched in 1992 and which will now be reiterated at the Rio+20 Summit in 2012.

6.2 Investments in the institutional framework

As new international research programmes are established in the period ahead, the Dutch scientific community will be in a good position to participate in the formulation and execution of these programmes, and – equally as importantly – in the communication of the results. Cooperation with the different stakeholder groups in the different processes and stages will be a major challenge for all concerned.

A particularly promising role for Dutch science and technology in a global perspective can be played with respect to:
- capacity-building;
- research agenda-setting processes and integrated assessments; and
- institutions and instruments for effective sustainability policies.

Capacity-building

A professional and open research and education community is a necessary precondition for science and technology when set in a global perspective. Several Dutch universities have long-standing relationships with developing countries to help them develop the needed skills and competencies. These relationships are also fed through the intensive participation of Dutch scientists in EU programmes and, in general, international contacts and collaborations, including in the public and private sectors, in which the Dutch participate. The positive track record of the Dutch education system (including good facilities such as research schools, ICT and Open Access) can provide strong support for building the required capacity.

Research agenda-setting process and integrated assessments

The reorientation towards sustainable development calls for political attention at all levels. Science can play a role both in enhancing the understanding of the complexities of biophysical and societal relationships and in enabling effective political responses at local and regional levels. The changing approach towards sustainable development, best characterised by the shift from top-down goal setting and implementation to distributed cooperation and co-creation, also calls for a different way of setting the research agenda. Flexibility and bottom-up working methods then become relevant. Such modes of operation are firmly embedded in the Dutch scientific community. Particularly in the field of sustainability science, there is a strong tradition of interdisciplinary and transdisciplinary collaboration. This is especially needed to get results in sustainable development (Holm, et al., 2012). The Netherlands' combined natural and social science-based research programmes and the strong relationship between technical sciences and engineering and governance issues are also noteworthy. Dutch expertise in the field of integrated modelling, monitoring and evaluation can be further developed and brought to the attention of other countries and stakeholders.

It could also be of great value to use science as a basis for negotiation and decision-making in a global arena marked by fragmentation.

At the same time, there is a growing awareness that 'science for policy' calls for more than just knowledge input at the beginning. There is a growing recognition of the value of 'adaptive' policies where there is more appreciation of the importance of local and regional contexts for policy success. The Dutch scientific community in this field can contribute to developing that method of working by sharing its expertise and experience with others. This calls for a continuing investment strategy to deepen the know-how base and promote collaboration skills, together with a strong international position in the research agenda-setting processes.

Institutions and instruments

The future of institutional arrangements will be discussed at the Rio+20 Summit. It is recommended that the positive role that science can play in furthering a more sustainable development is also taken into account. At international and global level, the range of organisations capable of delivering the necessary background information is highly fragmented and no international system of policy support agencies has yet been established. What is needed in particular is the creation of a global science-policy interface to provide objective and credible information and analysis to the variety of fora in which decision-making is to take place. This may take the form of collaboration of institutes on a science panel devoted to bringing the best available knowledge to the various policy fora at which strategic choices are to be made. A scientific panel for sustainable development, independent but with a steering committee made up of policymakers, may be the best way forward. The well-developed system of independent policy-oriented planning agencies supporting the Dutch government can be used as a model for the strengthening of international institutions.

6.3 Relationship with relevant knowledge agendas

Global

As mentioned in Chapter 4, the international research community is preparing a new, ten-year international research initiative entitled 'Future Earth, research for global sustainability'. This initiative is to be presented at the Rio+20 Summit. It is recommended that the Dutch government ensures that the emphasis on strategic fields of development of scientific knowledge described here is further fed into the design of the Future Earth research project.

BOX 7:
Future Earth, research for global sustainability

Future Earth arises from the convergence of the ICSU-ISSC (International Social Science Council) Earth System Visioning during 2009-2011 with the Belmont Forum of funding agencies' drive to deliver knowledge in support of human action and adaptation to regional environmental change, as described by the 'Belmont challenge'. Through a wide consultation process, the Visioning process identified five Grand Challenges (Forecasting, Observing, Confining, Responding and Innovating) and determined that a new overarching structure was needed for effective integrated research. Future Earth is being established by a broad alliance: ICSU, ISSC, and the Belmont Forum, as well as UNESCO, UNEP and the United Nations University (UNU); the World Meteorological Organisation (WMO) is an observer.

The transition team, appointed in June 2011, is leading the design phase of the initiative.

It comprises members of the scientific community, the public knowledge infrastructure and financiers and the private sector and other stakeholders, with a wide variety of backgrounds and experience from around the world.

Europe

The recently proposed 'Horizon 2020' programme for research and innovation of the European Union, running from 2014 to 2020 with a (proposed) EUR 80 billion budget, is the financial instrument implementing the 'Innovation Union' aimed at securing Europe's global competitiveness. In this context, the European Research Council (ERC) has a prominent role in promoting scientific excellence.

The 'Grand Challenges' are an important part of 'Horizon 2020'. There is an emerging consensus in the Netherlands that European research and innovation policies should focus strongly on the 'Grand Challenges':

- Health, demographic change and well-being
- Food security, sustainable agriculture, marine and maritime research and the bio-economy
- Secure, clean and efficient energy
- Smart, green and integrated transport
- Climate action, resource efficiency and raw materials
- Inclusive, innovative and secure societies

There is also a strong relationship with the Forward Look on sustainable development, 'Responses to Environmental and Societal Challenges for our Unstable Earth

(RESCUE)', recently published by the European Science Foundation (ESF) (Holm, et al., 2012). This publication addresses the societal and scientific challenges related to global environmental change, including its human dimensions.

The Netherlands

The Dutch government recently decided to set up an economic and innovation policy aimed at what it refers to as the 'Top Sectors'. The Top Sector approach is geared towards providing a well-developed exchange between businesses, universities and non-university knowledge institutes and the government (the 'golden triangle'). The government has invited business representatives and scientists to draw up action plans. The Dutch government has stated that the Top Sectors need to be developed with the concept of a green economy clearly in mind. This may lead to a decoupling of economic development from environmental degradation using new approaches and redesigned activities to help reduce the amount of resources such as water or fossil fuels. Further improvements can be made if the experiences are linked to the Grand Challenges in the European Union 'Horizon 2020' programme and to the activities of the Netherlands Directorate-General for International Cooperation in the selected target countries.

In the recent past, the Netherlands Organisation for Scientific Research (NWO) contributed to 'Sustainable Earth' by supporting research ranging from climate change to resource conflict and complex system analysis. In the period ahead, NWO will be investing in, for example, water research (Delta Technologies), energy research (sustainable fuels: biomass, geothermal energy and GRIDS) and governance for sustainability. The first programme to start will be 'Urbanising Deltas of the World', to be conducted in close cooperation with the Dutch Ministry of Foreign affairs. The programme is aimed at widening the scientific expertise on delta regions in the Global South and Asia.

BOX 8:
Mega-cities as sustainable cities

Rapid global urbanisation is offering new challenges and opportunities for sustainable development. At first glance mega-cities, often located in the major deltas of the world, are huge concentrations of both poverty and environmental stress, including natural disasters. Yet cities do not make people poor, they attract poor people because economic opportunities are clearly better than they are in rural areas, where rising productivity decreases the demand for labour. The per capita ecological footprint of city-dwellers is much smaller than that of suburban or rural dwellers in the same wealth bracket.

Economies of scale create the basis for covering the fixed costs of the infrastructure required for more sustainable development, such as high-quality public transportation and smart energy systems, while urbanisation advantages create opportunities for small entrepreneurs to escape desperate poverty.

Building scenarios for the development of sustainable cities is one of the major challenges for research into the more distant future. If the densely populated Chinese and Indian cities were to develop into car-based societies like many modern American cities, emissions would explode. An alternative scenario, based on efficient public transport and zero-emission real estate, might be more innovative, cost-effective and socially sustainable than mass-suburbanisation and car ownership (Batty, 2005).

6.4 Response to the question

What are the most important issues on the agenda for future knowledge development?

Sustainable development calls for the application of science within the context of controversies among stakeholders. In this respect, more attention should be given to the observation that sustainable development is also a matter of different choices by stakeholder groups (including the scientific community), based on different perceptions of environmental and social risks. Science can help to identify facts and non-facts. It can also help to understand when and why stakeholders agree, disagree, or agree to disagree. An important issue here is the decoupling of economy and ecology, which entails a decisive departure from the idea that all economic growth leads to environmental damage. Many stakeholders now agree that economic growth is a prerequisite for ecological diversity and environmental protection. Science can reach out by providing integrated assessment techniques that reveal the consequences of stakeholder choices. These assessments lead to a more in-depth debate on sustainable development and invite involved stakeholders to develop common ground.

In which areas of sustainable development should Dutch science invest?

Dutch science should continue to invest in capacity-building in developing countries. Dutch scientists' vast experience and positive track record can help to keep building on the most efficient building block for sustainable development: human competencies and skills.

Integrated assessment relating to research agenda-setting processes is a field where Dutch science has also established a solid foundation for further investments. Since integrated assessment forms a linking pin between research and policy by clarifying the consequences of stakeholder choices in the arena of sustainable development, it can play an important role beyond the horizon of the Rio+20 Summit. In other words, if , as is hoped, the Rio+20 Summit identifies integrated assessment as a crucial scientific skill meriting further development and implementation, Dutch university and non-university scientists have the proven track record, the capacity and, last but not least, the ambition to support the initiatives necessary for achieving the goal.

How does this agenda relate to other agendas, such as the one for the Dutch Top Sectors and the European Grand Challenges?

This agenda for future knowledge development is consistent with other relevant knowledge agendas that are currently being developed, such as the Top Sectors approach by the Dutch government and the Grand Challenges in the European Union 'Horizon 2020' programme. There is an emerging consensus in the Netherlands that, in addition to the central goal of fostering leading edge research from the bottom up, European research and innovation policies should also focus on tackling societal 'Grand Challenges', which often form strategic economic opportunities at the same time.

In short, the Dutch scientific community should continue to build on its various aforementioned strengths (see also the last section of the previous chapter), including conceptual understanding of global cooperation between the scientific, public and private sectors and civil society, long-term, reliable global partnerships, scientific excellence as the required basis for integrated assessment and the embedding of national research in European and Global initiatives supporting sustainable development.

7. DYNAMICS OF RESEARCH PARTNERSHIPS WITH THE DEVELOPING WORLD

Question 4 posed by the Ministry of Foreign Affairs is as follows:

- How effective is the collaboration with knowledge institutes from developing countries in the field of sustainable development?
- Given the Dutch focal points and knowledge agenda, around which themes and with which partners should cooperation be best organised?

The previous chapters have shown that the relationship between developing and developed countries in the field of sustainable development is a dynamic one. For example, BRIC countries such as China and Brazil were considered developing countries twenty years ago. Nowadays, China has top laboratories and innovation initiatives in several cities, while Brazil has developed a level of plant breeding in a context that can be directly transferred to Africa. These changes have had a considerable effect on the research collaboration with developing countries since 1992. Moreover, the role of the private sector in international collaboration aimed at sustainable development has also gained influence. Interesting examples can for example be found within the World Food Program, where collaboration has been set up with Dutch companies such as DSM and Unilever. However, since the questions deal with collaborations with knowledge institutes, the focus of this chapter will be on international cooperation in research.

7.1 Types of research collaboration

Collaborations of Dutch researchers and research groups with partners from developing countries are widespread:

- Every Dutch university has several bilateral and multilateral programmes with developing countries. The mode of cooperation can vary from collaborative programmes with partners in countries like Mozambique or South Africa to an influx of individual students from third countries who finance their own education.
- Internationally respected non-university knowledge institutes in the Netherlands such as ITC (with a focus on geo-information science and earth observation) and UINESCO-IHE (with a specific focus on water) collaborate with partners from developing countries on the basis of more or less formal relationships.

BOX 9:
A typical example of Dutch research collaboration with developing countries: the case of Wageningen University

Institutionally, Wageningen University has developed interesting formulas for research collaboration with emerging and developing countries. In the 1990s, the university drew a clear distinction between these two groups of countries. The relationship with developing countries was mainly based on capacity-building through the transfer of knowledge. This was different in the case of the emerging countries: both partners should benefit from the collaboration, based on the assumption that local knowledge and experience was gathered on location, and Wageningen University provided the methodological knowledge.

A decade ago Wageningen University established a special core-budgeted Interdisciplinary Research and Education Fund. Since then, relationships with international partners – and in some cases with the private sector – and multiple knowledge institutes in developing countries have become a preferred policy for international cooperation. This combination of activities continues to lead to marked benefits for all partners, and also includes capacity-building, albeit at a higher level.

Within the system of Dutch specialised agencies that facilitate the use of science-based information, organisations such as Netherlands Organisation for International Cooperation in Higher Education (NUFFIC, with motto: Linking Knowledge Worldwide) and WOTRO Science for Global Development (a part of the Netherlands Organisation for Scientific Research / NWO) are involved in scientific collaborations between researchers from the Netherlands and developing countries. NWO also has some specific programmes, which focus on collaboration with developing countries, for example the Conflict and Cooperation over Natural Resources in Developing Countries (CoCooN) programme.

It is, however, important to stress the role of informal relationships and collaborations between individual Dutch scholars and scholars from developing countries, which may in many cases be just as important as the more formal structures. For example, over the past fifteen years there appears to have been a growing degree of collaboration by Dutch researchers with researchers from the fifteen partner countries of the Dutch government development assistance programmes (these are: Afghanistan, Bangladesh, Benin, Burundi, Ethiopia, Ghana, Indonesia, Yemen, Kenya, Mali, Mozambique, Uganda, West Bank and Gaza Strip, Rwanda and Sudan) than with similar researchers in other countries (Rathenau Institute, 2012).

The various formal and informal relationships and collaborations between Dutch scientists and their colleagues in the developing countries form the core of an effective means of capacity-building in developing countries. Preconditions for capacity-building in the developing world are investing in local human capital, making use of modern ICT and social media.

7.2 Shift toward multilateral cooperation

Research cooperation between developed and developing countries is increasingly moving away from purely bilateral relationships. This change not only reflects a recognition of the complexity of the current research issues, necessitating capabilities that a single country cannot always provide, but also the desire to ensure the wider international dissemination of knowledge.

At European level, the Joint ProgramProgramming Initiatives (JPIs) play an important role. The overall aim of JPIs is to pool national research efforts in order to make better use of Europe's public R&D resources and to tackle common European challenges more effectively in a few key areas, such as addressing climate change, ensuring energy and food supply and promoting the healthy ageing of citizens. These European challenges are challenges for the developing countries as well.

At global level, donors are increasingly supporting approaches such as those illustrated by the EU's Africa programmes. The same shift can be seen in the funding policies of globally operating private funds, such as the Bill and Melinda Gates Foundation and the Rockefeller Foundation. Good examples of multi-country cooperation are a number of the new programmes of the Consultative Group on International Agricultural Research (CGIAR), which utilise the best expertise from developed (and developing) countries and often involve entire regions in the developing world. Institutions in the participating countries provide local data, knowledge capacity, and are instrumental in using and disseminating research results.

7.3 Response to the question

How effective is the collaboration with knowledge institutes from developing countries in the field of sustainable development?

Over the last twenty years, the Dutch, European and global collaboration with knowledge institutes from developing countries in the field of sustainable development has become more intensive. The Committee acknowledges that the previous chapters lack the required data to answer this question in detail. Part of this stems from the fact that most of the changes in developing countries have been brought about by non-scientific drivers. It is felt by the Committee however, that probably the most important contribution is in terms of scientific capacity-building in the developing countries themselves. Just as an example, the KNAW China programme is now involved in capacity-building in a new laboratory in Dalian for Renewable Energy, involving 1400 researchers. The Dutch water sector in particular is engaged in many countries and regions worldwide to manage many aspects regarding water, including safe drinking water, waste water treatment and sanitation and combating floods. Such regions include many deltas worldwide.

Given the Dutch focal points and knowledge agenda, around which themes and with which partners should cooperation be best organised?

This question is indeed interpreted in terms of taking Dutch thematic strengths and research agenda as a starting point. In addition to this 'supply mode' of operation, the demand side should also be considered. In terms of demand – in other words, what developing countries need and can do for sustainable growth – Dutch strengths should also be used to understand this important demand aspect and to consciously use a supply and demand approach.

Taking into account the policy of the Dutch government, themes that should be considered for further cooperation and collaboration should build upon the existing strengths of Dutch science. These strengths are in many disciplines, such as biology, agriculture, environmental sciences, earth sciences, technology, international law, medical sciences, social sciences, chemical sciences, policy sciences, international relations, leading to widely recognised applications in a number of arenas that are crucial to sustainable development (non-exhaustive list, also taken from Chapters 5 and 6):

- **Governance:** international institutions, earth system governance, environmental governance, regime shifts, corporate social responsibility, population change and sustainable settlement
- **Modelling and assessment:** climate change, adaptation and mitigation, modelling complex ecosystems, ecological risk assessment, alternative stable states in ecosystems, life cycle assessment and input-output analysis of environmental impacts, ecological modernisation
- **Water:** Drinking water and waste water treatment, water management, virtual water footprint, microbiology and biotechnology for water, sanitation
- **Energy:** Biomass gasification and biofuels, impact of biofuels on land use, experience curves in energy, microbiology and biotechnology for energy
- **Biodiversity:** Conservation, taxonomy and biogeography, protecting fragile environments

- **Health and agrofood:** socio-economic status and health, infectious diseases, chemical industry, agriculture and sustainability, soil science

Strong Dutch scientific fields are also listed in the KNAW research agenda (2011). In this agenda, strong areas related to sustainable development are:
- earth, climate, energy and bio-environment;
- health and food; and
- society and resilient institutions.

In addition, given the Dutch Top Sector policy, those Top Sector programmes that have a strong orientation on sustainable development are of specific relevance. These are:
- water;
- energy;
- agrofood;
- chemistry; and
- life science and health.

With regard to the EU Framework Program in 'Horizon 2020' and sustainable development, Dutch scientists should engage in all areas, perhaps most of all in sustainable agriculture:
- Health, demographic change and well-being
- Food security, sustainable agriculture, marine and maritime research and the bio-economy
- Secure, clean and efficient energy
- Smart, green and integrated transport
- Climate action, resource efficiency and raw materials
- Inclusive, innovative and secure societies

Particularly when looking at the needs of developing countries with respect to sustainable development, Dutch scientists could bring to fruition the results of their best practices in the field of sustainability science. By bringing in the best available science and technology, developing countries can leapfrog a number a development stages that were needed to arrive at the current level of best practices. For Dutch science and technology to maintain this contribution to sustainable development in a meaningful way, continued investments in the strong Dutch research fields identified will be needed.

The question regarding the partners can be answered as follows. Within the European Union, the partners can best be identified within the 'Horizon 2020' framework. With regard to developing countries and new economies (BRICs), Dutch scientists would do well to continue and expand their existing working relationships. Internationally, Dutch science should continue to build on existing collaborative platforms. If, as is hoped, the Rio+20 Summit leads to a further emphasis of the importance of governance and the need for integrated assessment, Dutch scientists could engage in, or even lead, some of the transitions towards the required institutional innovation.

8. RECOMMENDATIONS

At global level, it has become clear that a continuous stream of political declarations has failed to bring about the anticipated improvements in sustainable development (Agenda 21). The successive summits and conferences over the last few decades have made this clear. In these circumstances, far-reaching declarations are not very useful. What is needed more is a well-organised community of scientific practice that supports evolving and targeted policies set out within the UN framework. At present, an institutional framework for this community is mostly lacking. The Academy recommends that the Dutch delegation to the Rio+20 Summit addresses this issue with the support of Dutch scientists.

At European level a relevant aspect for Dutch science and technology is the continuation of successful collaborative research programmes. The Grand Challenges defined in 'Horizon 2020' may even act as a catalyst for that continuation. Experience in the recent past has shown that Dutch researchers make a considerable contribution to these international programmes. There are two reasons for this: the integrated mode of research and assessment is well-developed in the Netherlands, and the particular strengths of the Dutch research community are well-suited to the Grand Challenges. The ongoing participation of Dutch researchers in international, integrated research efforts is therefore recommended.

At national level, past investments in the public knowledge infrastructure have given the Netherlands a prominent position in the field of sustainability science. These investments must be sustained if the Netherlands is to continue harvesting the results. This applies especially to research fields in which Dutch sustainability science contributes significantly to knowledge on sustainable development at international level. The relevant Dutch research fields have a strong orientation towards environmental sciences, agricultural and food sciences, earth sciences and technology, and biology. The science-push model has been replaced by new views on research, its organisation and its relationship with society. Nowadays, an interactive model involving co-creation by researchers and stakeholders from society is valid. The borders between the involved stakeholder groups in the sustainability agenda have become less clearly defined. The wide range of stakeholder groups, such as the scientific community, the business community, the government and civil society, is creating new opportunities to travel the road toward sustainable development. This new reality needs to be addressed at the Rio+20 Summit. This is something which Dutch researchers can accomplish, or perhaps even play a leading role in, at the Summit.

The Academy therefore recommends building on the strong points of Dutch sustainability science and investing in its further development. The government, the business community and the scientific community can do this at three different levels:

1. Support both the institutions and the skills and competencies necessary to keep developing human capacities in changing international networks. Targeting the strong research fields referred to in this advisory report will lead to the most effective international contribution.
2. Support the further development of integrated assessment and its role in the adaptive integrative policies that feed the international agenda. The promotion of cooperation by Dutch researchers and institutes in EU programmes and other international research efforts aimed at some of the Grand Challenges will assist with the effective dissemination of Dutch expertise.
3. Support institutional, process and intervention expertise for effective sustainability policies and incentives at global level. Stimulating a global interdisciplinary knowledge platform aimed at the analysis and assessment of global sustainability policies is a straightforward way of capitalising on the well-developed system of independent policy-oriented planning agencies in the Netherlands that support the Dutch government.

More specifically, the Academy recommends that the Dutch government places more emphasis on the process of agenda-setting by making use of the Dutch scientific community's experience in developing the needed knowledge base and supporting institutional provisions. Related to that, the Academy encourages the development of a global science-policy interface to provide objective and credible information and analysis needed for agenda-setting in the various international fora. The Academy also advises stimulating the further development of strong research fields as indicated in this advisory report, and utilising these scientific strengths to contribute to the goals of the Rio+20 Summit.

The Academy urges the scientific community to promote new connections between the natural sciences and technology, social sciences and humanities by supporting virtual institutes that co-operate in this interdisciplinary mode. In addition to that, the scientific community can help bridge the gap between societal stakeholders by actively involving them in transdisciplinary approaches to the issues that are key to the Rio+20 Summit.

The Academy advises the business community to maintain its involvement in long-term partnerships aimed at transition and to organise active stakeholder involvement, including the government, the scientific community and civil society.

Finally, the Academy recommends that civil society (societal groups and NGOs) contribute actively to sustainable development. To support this, the scientific sector as well as the public and private sectors need to include societal groups and NGOs in integrated assessment and institutional innovation.

9. LITERATURE

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APPENDICES

APPENDIX A: MILLENNIUM DEVELOPMENT GOALS

In 2000, at the United Nations Millennium Summit, the international community reached consensus on working to achieve eight critical economic and social development priorities by 2015. These Millennium Development Goals (MDGs) form part of the Millennium Declaration, signed by 189 countries, including 147 Heads of State and Government, to achieve eight specific goals:

1. Eradicate extreme hunger and poverty.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria and other diseases.
7. Ensure environmental sustainability.
8. Develop a global partnership for development.

APPENDIX B: A SELECTION OF FACTS FROM 'KEEPING TRACK'

The UNEP report '*Keeping Track of Our Changing Environment: From Rio to Rio+20 (1992-2012)'* contains a large number of facts that indicate a dramatic change in many global issues over the last two decades.

- The world's population has grown by almost 1.5 billion people.
- More than 3.5 billion people (more than half the world's population) are living in urban areas. The rate of urbanisation is especially high in China.
- The proportion of urban dwellers living in slums has declined, but their absolute numbers have risen.
- The average global citizen has shifted from a diet based on basic foods to the consumption of meat (+26%) and fish and seafood (+32%).
- GDP per capita in the developing world has increased by 80%, and in the developed world by 33%.
- The Human Development Index has grown by 2.5% annually, but there remain huge regional differences.
- International trade has tripled.
- The global use of natural resources has increased by over 40%; the use per capita by 27%.
- The efficiency of materials use has improved, leading to a decline in emissions per unit of output.
- The consumption of ozone-depleting substances has decreased by 93%, leading to a slow recovery of the Antarctic ozone hole.
- CO2 emissions have increased by 36% worldwide; 8% in the developed countries and 64% in the developing countries, especially Brazil, India and China.
- Emissions of CO2 per GDP have decreased on average by 1.6% per year, indicating that production processes are becoming more energy-efficient.
- The atmospheric concentration of CO2 has increased by 9%.
- The average ocean temperature has increased, and the average sea level rise has been 2.5 mm per year.
- The annual loss of glacier mass has shifted from 0.4 metres per year to 0.7 metres per year.
- Forest cover has decreased by 300,000,000 hectares (an area larger than Argentina).
- Forest plantations have increased at an annual rate of 2.2% or 4,600,000 hectares.
- Drinking water coverage has increased by 13%, meeting the target set in the MDGs.
- Sanitation coverage has increased by 13%, but is lagging far behind the MDG target.
- The Living Planet Index has declined by 12% at global level, but by 30% in the tropics.
- Protected areas have increased to 13% of land surface, 7% of coastal waters and 1.4% of oceans.

- Oil spills from tankers have decreased by some 75%.
- Production of slowly decomposing plastics has increased by 130%.
- Multilateral environmental agreements have increased by 330%.
- The number of ISO standards on environmental management in the private sector has increased 15-fold.
- Total foreign aid has increased from US$ 145 billion to US$ 215 billion , but the share of this sum spent on environment aid has dropped from around 7% to less than 4%.
- Food production has increased by 45%, exceeding the population growth of 26%.
- The total area under irrigation has increased by 21%, leading to higher yields but also to increased pressure on water availability.
- Fish stocks are increasingly fully or even over-exploited.
- Global aquaculture production has increased by 245%, most of it China.
- Energy consumption per capita has decreased in the developed world (-15%), but increased in the developing world (+15%).
- Although electricity production has increased by 66%, 1.44 billion persons still have no access to the grid.
- Renewable energy sources account for 13% of energy supply, but only 0.3% stems from solar and wind.
- Biofuel production has shown a dramatic exponential increase (e.g. biodiesel increased 3000-fold) but this raises issues related to land use.
- Investments in sustainable energy have increased by 540%.
- Passenger transport by airplane has increased by 230% and freight air transport has doubled.
- International tourism measured in arrivals has increased by 90%.
- There has been a 230-fold increase in the number of mobile phone subscriptions and a 290-fold increase in the number of Internet users.

APPENDIX C: NUMBER OF PUBLICATIONS PER SPECIALTY

Specialty	1996-2000	2006-2010
1. Sustainability and sustainable development		
Innovation systems and transition	51	340
Water management	75	287
Spatial (urban and rural) planning	54	177
Virtual water footprint	3	54
Ecological modernisation and environmental governance	12	187
Common pool resources and collective action	8	43
Earth system governance and environmental governance	8	175
Sustainability and sustainable development	348	1028
Natural resources and growth	10	30
Environmental assessment and use of space	43	182
Landscape quality and diversity	56	269
2. Biodiversity		
Biodiversity and conservation, agri-environmental schemes, and biological control	74	477
Flooding and waterlogging	109	159
Ecosystem services	122	503
3. Remote sensing and climate modelling		
Modelling and simulation of the water balance	304	636
Modelling of sedimentation and flood plain in rivers	64	243
4. Climate change, adaptation and mitigation		
Landscape ecology and planning	124	481
Technological learning and experience curves in energy	3	51
Impact of biofuels on land use and greenhouse gas emissions	2	80
5. Ecological risk assessment		
River restoration and flood plain rehabilitation	36	102
6. Agriculture and sustainability		
Nutrient management in agriculture	295	511
Sustainable land use and farming systems	337	901
7. Soil science		
Soil fertility in Sub-Saharan Africa	66	202
Soil organic matter and carbon sequestration in agriculture	93	201
8. Drinking water and waste water treatment		
Anaerobic treatment of domestic waste water	72	127

Specialty	1996-2000	2006-2010
9. Life cycle assessment and input-output analysis of environmental impacts		
Life cycle assessment	59	166
Consumption patterns and environmental load	28	104
10. Modelling complex ecosystems		
Regime shifts and alternative stable states in ecosystems	2	55
11. Biomass gasification and biofuels		
Exergy analysis	27	49
Recycling	61	120
Biomass gasification	33	80
12. Biodiversity conservation, taxonomy and biogeography		
Fish diversity and eutrophication in Africa	7	28
13. Microbiology and biotechnology for water and energy		
Microbial fuel cells	2	43
14. Work and business		
Corporate social responsibility	4	91
15. Aquaculture		
Aquaculture	19	105
16. Malaria		
Malaria vector control	50	172

Source: Rathenau Institute (2012).

APPENDIX D: LIST OF DUTCH ABBREVIATIONS

AKZO-Nobel	Dutch multinational chemical company
Arcadis	Dutch multinational engineering consultancy
CBS	Central Bureau of Statistics
CPB	Central Planning Bureau
Deltares	Delta Research Institute
DHV	Dutch multinational engineering consultancy
DLO	Agricultural Research Service
DSM	Dutch multinational life sciences and materials company
ECN	Energy Research Centre
ECOS	KNAW Research school accreditation committee
FES	National Fund for the Enhancement of the Economic Structure
GRIDS	Innovative electrical grid structures
ITC	Geo-informational Science and Earth Observation Faculty –University of Twente
ISS	Institute for Social Studies
KNAW	Royal Netherlands Academy of Arts and Sciences
KNMI	Royal Netherlands Meteorological Institute
KPMG	Dutch consultancy firm
NIOO	KNAW Institute for Ecology
NIOZ	NWO Royal Netherlands Institute for Sea Research
NVAO	Dutch-Flemish Accreditation Organisation
NWO	Netherlands Organisation for Scientific Research
PBL	Netherlands Environmental Assessment Agency
Philips	Dutch Multinational Electronics Company
RIVM	Netherlands Institute for Public Health and Environment
SCP	Social and Cultural Planning Bureau
TNO	Netherlands Organisation for Applied Scientific Research
Unilever	Dutch Multinational food and personal care company
Wetsus	Centre of Excellence for sustainable water technology
WOTRO	NWO Science for Global Development
WUR	Wageningen University and Research Centre