Science System Assessment

Mapping sustainability science in the Netherlands 1996-2010

Analysis in support of KNAW advisory committee ‘RIO +20’

May 2012

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1 Introduction

This report provides input for the work of the Advisory Committee RIO+20 of the Royal Netherlands Academy of Arts and Sciences (KNAW), specifically with respect to two of the questions the Committee was asked to answer.

1. “What are currently the strengths of Dutch science with respect to the items on Agenda 21, both in a substantive sense (theme Green economy in the context of sustainable development and poverty eradication) and from the perspective of knowledge and institutions (theme Institutional framework for sustainable development)?”
2. “How effective is the collaboration with knowledge institutes from developing countries in the field of sustainable development and, given the core areas in research and the knowledge agenda of the Netherlands, in which areas and with which partners can collaboration best be organised?”

The Rathenau Instituut has developed scientometric methods that make it possible to analyse the structure and development of scientific fields. We have used these methods to provide information that can help the Committee answer the above questions. Using a set of publications from the Web of Science, we have:

1. identified scientific specialties (i.e. clusters of publications) that represent strengths in Dutch scientific research relevant to sustainability;
2. examined the strength of each specialty in relation to worldwide sustainability science; and
3. examined for each specialty to what extent Dutch researchers collaborate with researchers from the EU-27, the BRICS, and a selection of preferred developing countries.

The second section provides an overview of the data and methods. The third section presents the main results. In the fourth section we draw conclusions based on the findings.

2 Data and methods

This section gives a brief explanation of the data, methods and definitions used in this report. On request of the Advisory Committee we have kept the technical explanation to a minimum.

2.1 Data

The analysis is based on bibliometric data from Thomson Reuters Web of Science. We have used the five science citation indexes: Science Citation Index Expanded (SCI-EXPANDED); Social Sciences Citation Index (SSCI); Arts & Humanities Citation Index (A&HCI); Conference Proceedings Citation Index- Science (CPCI-S); and Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH). The analysis is limited to citeable documents only, namely articles, conference proceedings papers, letters, notes, and reviews. All other document types - editorial materials, meeting abstracts, book reviews, etcetera – have been excluded.

2.2 Delineation of sustainability science

The first and most important step is to delineate sustainability science. The first possibility is to use an existing delineation. The second possibility is to produce a new delineation.

Bettencourt and Kaur (2011) have studied the development and structure of sustainability science by collecting from Thomson Reuters Web of Science all publications that mention “sustainability” in the title, abstract or keywords. Their approach captures publications that explicitly state that the results are relevant for sustainability or that study sustainability. Their delineation of sustainability science is problematic in two respects. First, Bettencourt and Kaur’s delineation of sustainability produces a dataset that underestimates the importance of scientific output that is relevant for sustainability. They overlook publications that do not mention the word “sustainability” in title, abstract or keywords but that belong to the same specialties as the publications that do use “sustainability”. Also, the fact that they focus exclusively on publications that use the word “sustainability” in title, abstract or keywords may explain why a large proportion of the publications they have retrieved belongs to the social sciences in which sustainability is an object of analysis. Second, they ignore conference proceedings, which are particularly important for technical fields such as engineering and computer science. In short, the dataset of Bettencourt and Kaur is biased towards the social sciences that study sustainability science and does not adequately cover the science that through research aims to contribute to sustainability and sustainable development.

We have instead applied a much broader range of search terms that capture scientific publications that are directly or indirectly relevant. Directly relevant publications concern research explicitly done to support or advance sustainability. This is where, like Bettencourt and Kaur, we find “sustainability” and “sustainable development” in the title, abstract or keywords. Indirectly relevant publications contain results that may support the achievement of a more sustainable society without explicitly aiming to do so, e.g. the technical development of biofuel cells and organic solar cells. The publications in the two groups can belong to the same specialties, but a broader set of search terms is needed to also find the indirectly relevant publications. A second important point is that delineation is an iterative process, combining different approaches (e.g. starting with specific journals or a small set of search terms) and mobilising experts to verify and then adjust the results. We have used the Advisory Committee as an expert group. On three occasions members of the Committee were asked to provide input or feedback. First, they were asked to propose terms that define sustainability science. They produced search terms for the ecological dimensions as well as the economic, social and governance dimensions of sustainability. Second, they gave feedback on the results of the analysis of the first dataset that was produced by means of their suggested search terms. Third, they gave feedback on the results of the analysis of the final, adjusted dataset.

2.3 Finding specialties in a dataset

Once a dataset has been created, specialties are determined ‘automatically’ by applying two algorithms. First, we calculate similarities between publications using a method developed by Van den Besselaar and Heimeriks (2006). This method measures the similarity between two publications in terms of title words – indicating the subject of research – and cited references – indicating the cognitive background and community of peers. The result is a similarity matrix, a network of publications in which each connection between two publications indicates to what extent they are similar.

Second, we use an algorithm developed by Blondel et al. (2008) to identify clusters in the similarity matrix. Each cluster consists of publications that are more similar to each other than to publications outside the cluster. The result is a set of publication clusters that are more or less homogeneous in their use of title words and in their references to other literature.

A specialty is a set of publications that are highly similar in their use of title words and in their references to other literature.

The algorithm of Blondel et al. produces a hierarchical clustering. This means that we can identify large specialties in a field as well as smaller specialties within larger specialties. For example, water management is a specialty within the larger specialty of sustainability and sustainable development. Researchers in a specialty study the same research topic from the same cognitive background. For example, one of the specialties we find concerns the virtual water footprint, an area in which prof.dr. Arjen Y. Hoekstra is the most prominent researcher. Another specialty concerns modelling and simulation of the water balance, which involves work in the subject areas of agriculture and water resources. Researchers in both specialties use specific title words, refer to a common body of work (their cognitive background), publish in a specific set of journals, etcetera.

2.4 Determining the strength of a specialty

We define areas of strength as specialties in which the Netherlands makes a significant contribution to world output, produces high-quality output, and has a strong knowledge infrastructure.

2.4.1 Measuring individual specialties

We need to find out if a specialty is indeed a strength of Dutch sustainability science and to identify patterns of collaboration. This requires that we compare Dutch publications with worldwide publications. The keywords and title words in the publications in each selected specialty have been used to construct new search terms specific to each specialty. This produced a proxy for worldwide scientific output in each specialty in 1996-2000 and 2006-2010. The result recalls a larger proportion of relevant publications but may be less precise.

2.4.2 Significant contribution to world output

We examine the contribution of each specialty from two perspectives: relative specialisation in comparison to the rest of the world and relative development over time.

Researchers in a specialty make a significant contribution to world output if the percentage of publications involving researchers from the Netherlands is higher than the percentage share of total Dutch output in world output (c. 2.2% in both periods). When more than 2.2% of the publications in a specialty involves Dutch researchers, the Netherlands is relatively specialised in the specialty. When the share is lower than 2.2%, the Netherlands is not relatively specialised. We have examine what percentage of total world output and total EU27 output in a specialty has a Dutch address.

In addition, we examine trends in the level of output and in the worldwide and EU share of Dutch publications. Is the Dutch share in world output in a specialty increasing or decreasing? And does Dutch output in a specialty grow faster or slower than worldwide output in that specialty? Relatively faster growth equates an increase in percentage shares and can be considered a sign of relative strength.

2.4.3 High-quality output

Citations are generally considered a good indication of scientific quality. Good papers are in general cited more often than average papers. In many scientific fields, publications generated by Dutch scientists receive above-average citations. Is the same true for sustainability science? We are looking for an answer to two questions:

1. Are publications that involve authors from the Netherlands cited more than the average publication from anywhere in the world?
2. Has the relative quality of research involving authors from the Netherlands improved over time?

When using citations as an indicator for quality, two major issues must be considered. First, every scientific field has its own citation culture (Wouters, 1999). It is very difficult (and often impossible) to compare citation rates across the boundaries of scientific fields. Second, it takes time for publications to accumulate citations. In our sample, the most recent publications (published in 2006-2010) have received at most a few years worth of citations, while the older publications (published in 1996-2000) have had almost a decade and a half.

Therefore, we only compare citations per publication within each specialty. But we also need an indicator that is consistent over time. Rather than comparing lifetime citations per paper (which overestimate the impact or quality of older publications), our method is based on the average number of papers published in 1996-2000 and 2006-2010 that cite the publications in each specialty. In other words, we only look at citations made within each benchmark period. In principle, this makes the citation rates comparable over time.

The results is a proxy for the quality of Dutch output in each specialty. Changes over time in the relative citation rate can result from two developments:

1. The quality of Dutch output in a specialty may have changed, which has an impact on the citation rate.
2. The speed with which other scientists cite Dutch publications in a specialty may have changed. Dutch publications may attract citations sooner after publication than non-Dutch publications. This can also be considered a proxy for quality.

2.4.4 Strong knowledge infrastructure

Strength in a specialty can be based on the activities of a single research group or it can be distributed among different groups and institutions. In the first case, current strength is highly sensitive to short-term changes such as a reallocation of funding, changing institutional priorities, or the retirement or move of a prominent researcher.

By examining the institutions involved in producing Dutch output in each specialty, we have assessed how broad or narrow the knowledge infrastructure of the specialty is. Where the knowledge infrastructure is broad, publications are produced by many research groups in different institutions and there is no dominant player. Where the knowledge infrastructure is narrow, one or two dominant players are responsible for the bulk of Dutch output in the specialty.

2.4.5 International collaboration

Are Dutch researchers in a specialty less or more inclined to work with researchers from the three groups of countries than researchers from other countries? This question concerns the propensity of Dutch researchers to collaborate with researchers in three groups of countries: (1) the BRICS (Brasil, Russia, India, China, South Africa), (2) Preferred Less Developed countries (Afghanistan, Bangladesh, Benin, Burundi, Ethiopia, Ghana, Indonesia, Yemen, Kenya, Mali, Mozambique, Uganda, West Bank and Gaza Strip, Rwanda, Sudan), and (3) the EU27. Collaboration is measured using data on co-authorship.

A ratio was calculated that is:

1. higher than 1 if Dutch researchers collaborate with researchers in these countries to a higher extent than the worldwide average,
2. lower than 1 if Dutch researchers collaborate with researchers in these countries to a lesser extent than the worldwide average.

2.5 Workflow

The aim is to identify specialties in which the Netherlands is strong and to measure specific properties of Dutch research in each specialty.[1]

2.5.1 Step 1: Constructing a first dataset

The Advisory Committee was asked to provide keywords that define sustainability science. These keywords were used to construct and analyse a first dataset of 25,405 publications in the period 2006-2010.

2.5.2 Step 2: Expert feedback from the Advisory Committee

The results were presented to and discussed with the Advisory Committee. The members of the Committee served as experts, able to indicate the specialties they recognised as well as the ones they expected and did not find.

2.5.3 Step 3: Adjusting the dataset

The Committee's feedback was used to produce an adjusted set of search terms. This set of search terms was used to construct a dataset of all Dutch publications (40,974 publications in the period 1997-2011) in areas relevant for sustainability.

[1] The focus is on the strengths of Dutch scientific research. Finding areas in which the Netherlands is weak and other countries are strong requires a different approach.

2.5.4 Step 4: Selecting specialties that represent Dutch strengths

The focus is on areas that are relevant to sustainability or sustainable development. Following Bettencourt and Kaur, a specialty is only considered relevant if the words “sustainability” or “sustainable” occur in the abstracts of the publications. We have selected all specialties that contain a significant number of publications (at least 20 papers over a 15 year period) and in which at least 10% of the abstracts refer directly to sustainability.[2] In other words, specialties are counted as part of sustainability science only when a significant proportion of publications explicitly refers to sustainability. Thus, our approach also captures the indirectly relevant publications.

2.5.5 Step 5: Measuring strength and collaboration in a worldwide context 1996/2000-2006/2010

Keywords and title words have been used to construct new search terms specific to each individual specialty. This produced a proxy for worldwide scientific output in each specialty in 1996-2000 and 2006-2010. The resulting datasets allow us to examine the contribution of researchers from the Netherlands to world output and EU27 output, to measure the relative citation impact of Dutch publications in each specialty, to assess the strength of the knowledge infrastructure, and to measure the propensity of Dutch researchers to collaborate with researchers from the BRICS, Preferred Less Developed countries, and the EU27.

[2] The threshold of 10% is arbitrary. Working without a threshold would multiply the number of specialties and also cover a number of false positives (specialties that have been found with the search terms but do not actually belong to sustainability science).

3 Results

In this section we present the main results. First, we examine the size, composition and growth of specialities in sustainability science. Next, we examine to what extent each specialties makes a significant contribution to world output, produces high-quality output, and has a strong knowledge infrastructure. In the final section, we examine patterns of international collaboration.

3.1 Size and composition of specialties in sustainability science

A specialty is a set of publications (articles, conference proceedings papers, letters, notes, and reviews) that are highly similar in their use of title words and in their references to other literature. First, we examine the size and growth of each individual specialty (number of publications) and the composition of the entire portfolio in comparison to the total scientific output of the Netherlands and to the Grand Challenges of the EU.

3.1.1 Output volume

The specialties reported in the following tables represent areas in which the Netherlands appears to be strong and that contain a significant number of publications that explicitly refer to sustainability ("sustainability" or "sustainable" occur in the abstracts).

Table 1. Number of publications per specialty in 1996/2000 and 2006/2010 (specialties in which at least 10% of abstracts refer directly to sustainability)

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

Specialty	1996-2000	2006-2010
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
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

When we relax the 10% criterion more specialties come within view. The most important change is that some fields can be considered strengths at a higher level of aggregation or as groups of specialties, namely:

- Biodiversity
- Climate change, adaptation and mitigation
- Agriculture and sustainability
- Soil science

Additional specialties are found in other groups of specialties:

- Remote sensing

- Marine and freshwater biology
- Drinking water and waste water treatment
- Life cycle assessment
- Biomass gasification and biofuels

Some of the additional specialties in other areas may be false positives, that is, specialties that were found with the search terms but do not belong to sustainability science. Or they may define sustainability from a different perspective (e.g. in terms of quality of life):

- Several specialties on meta-analysis and systematic review of therapeutic evidence in clinical medicine (some of which define sustainability in terms of the quality of life of patients)
- Prevention of obesity in children and adolescents
- Job satisfaction (clusters with corporate social responsibility)
- Property rights, land tenure and housing
- Animal welfare
- Infectious diseases (antiretroviral therapy for HIV/AIDS, spread of infectious disease and epidemics)
- Teacher education (“educating the educators”)
- Socio-economic status and health (inequalities in health; effects on pregnancy and fetal growth; health effects of famine)
- Two clusters within biodiversity (microbial diversity; arabidopsis thaliana)
- Nutrition and patient care (willingness-to-pay and patient preferences; appetite and satiety)
- Sediment transport modelling
- Metabolomics, nutrigenomics and food safety

In the remainder of this section we will focus only on the specialties in Table 1.

3.1.2 Size and growth

Table 1shows that there are considerable differences in size among the specialties. In some cases it is quite clear that during the period under review new specialties have emerged that were virtually absent in 1996/2000. Some examples are:

- Technological learning and experience curves in energy
- Impact of biofuels on land use and greenhouse gas emissions
- Virtual water footprint
- Corporate social responsibility

For comparison’s sake the specialties have been classified into four categories depending on the average number of publications per year in each benchmark period:

- small: less than 10 publications per year
- medium-sized: 10 or more but less than 50 per year
- large: 50 or more but less than 100 per year
- very large: 100 or more publications per year

Table 2 shows how specialties shifted between size categories.

Table 2. Shifts between size categories between 1996/2000-2006/2010

		size of specialties in 1996-2000			
		small	medium	large	very large
size of specialties in 2006-2010	small	5	-	-	-
size of specialties in 2006-2010	small	5	-	-	-
	medium	12	9	-	-
	large	-	5	-	-
	very large	-	1	4	-

None of the specialties identified in this report has experienced a decline in output. Of the 36 specialties, 14 have remained within their size category, 21 moved into the next category up, and one went from a medium-sized to a very large specialty. The latter specialty – Ecosystem services – is interesting, because its considerable expansion was not accompanied by an increase in the share of Dutch publications in worldwide output (4.2% to 4.4%) or European output (11.6% to 9.9%). This is clearly a field that is rapidly developing internationally and not just in the Netherlands.

This brings us to the question of growth over time. Some specialties are larger than others; some grow faster than others; and some – large or small – are strong internationally. Table 3 makes an international comparison of growth in each specialty. It shows that all specialties experienced considerable growth and that in most but not all specialties Dutch output growth exceeds worldwide output growth.

Table 3. Average annual rate of growth in 1996/2000-2006/2010, the Netherlands and the world, and average annual rate of change in the share of the Netherlands in world output

specialty	**growth of world output**	**growth of Dutch output**	**rate of change in Dutch share in world output**
1. Sustainability and sustainable development			
Innovation systems and transition	19.1	20.9	1.5
Water management	13.5	14.4	0.7
Spatial (urban and rural) planning	11.8	12.6	0.7
Virtual water footprint	20.2	33.5	11.1
Ecological modernisation and environmental governance	21.9	31.6	7.9
Common pool resources and collective action	13.0	18.3	4.7
Earth system governance and environmental governance	22.6	36.1	11.0
Sustainability and sustainable development	14.9	11.4	-3.0
Natural resources and growth	10.5	11.6	1.0
Environmental assessment and use of space	16.0	15.5	-0.4
Landscape quality and diversity	15.2	17.0	1.5
2. Biodiversity			
Biodiversity and conservation, agri-environmental schemes, and biological control	17.2	20.5	2.8

specialty	**growth of world output**	**growth of Dutch output**	**rate of change in Dutch share in world output**
Flooding and waterlogging	5.2	3.8	-1.3
Ecosystem services	14.7	15.2	0.4
3. Remote sensing and climate modelling			
Modelling and simulation of the water balance	7.7	7.7	-0.1
Modelling of sedimentation and flood plain in rivers	10.4	14.3	3.5
4. Climate change, adaptation and mitigation			
Landscape ecology and planning	13.5	14.5	0.9
Technological learning and experience curves in energy	11.9	32.8	18.7
Impact of biofuels on land use and greenhouse gas emissions	28.8	44.6	12.3
5. Ecological risk assessment			
River restoration and flood plain rehabilitation	11.7	11.0	-0.6
6. Agriculture and sustainability			
Nutrient management in agriculture	8.8	5.6	-2.9
Sustainable land use and farming systems	11.2	10.3	-0.8
7. Soil science			
Soil fertility in Sub-Saharan Africa	7.3	11.8	4.3
Soil organic matter and carbon sequestration in agriculture	10.9	8.0	-2.6
8. Drinking water and waste water treatment			
Anaerobic treatment of domestic waste water	12.2	5.8	-5.6
9. Life cycle assessment and input-output analysis of environmental impacts			
Life cycle assessment	15.0	10.9	-3.5
Consumption patterns and environmental load	16.4	14.0	-2.0
10. Modelling complex ecosystems			
Regime shifts and alternative stable states in ecosystems	24.1	39.3	12.2
11. Biomass gasification and biofuels			
Exergy analysis	17.7	6.1	-9.8
Recycling	9.3	7.0	-2.1
Biomass gasification	16.5	9.3	-6.2
12. Biodiversity conservation, taxonomy and biogeography			
Fish diversity and eutrophication in Africa	11.8	14.9	2.7
13. Microbiology and biotechnology for water and energy			
Microbial fuel cells	34.1	35.9	1.4
14. Work and business			
Corporate social responsibility	30.8	36.7	4.5
15. Aquaculture			
Aquaculture	11.9	18.6	6.0
16. Malaria			
Malaria vector control	10.7	13.2	2.2

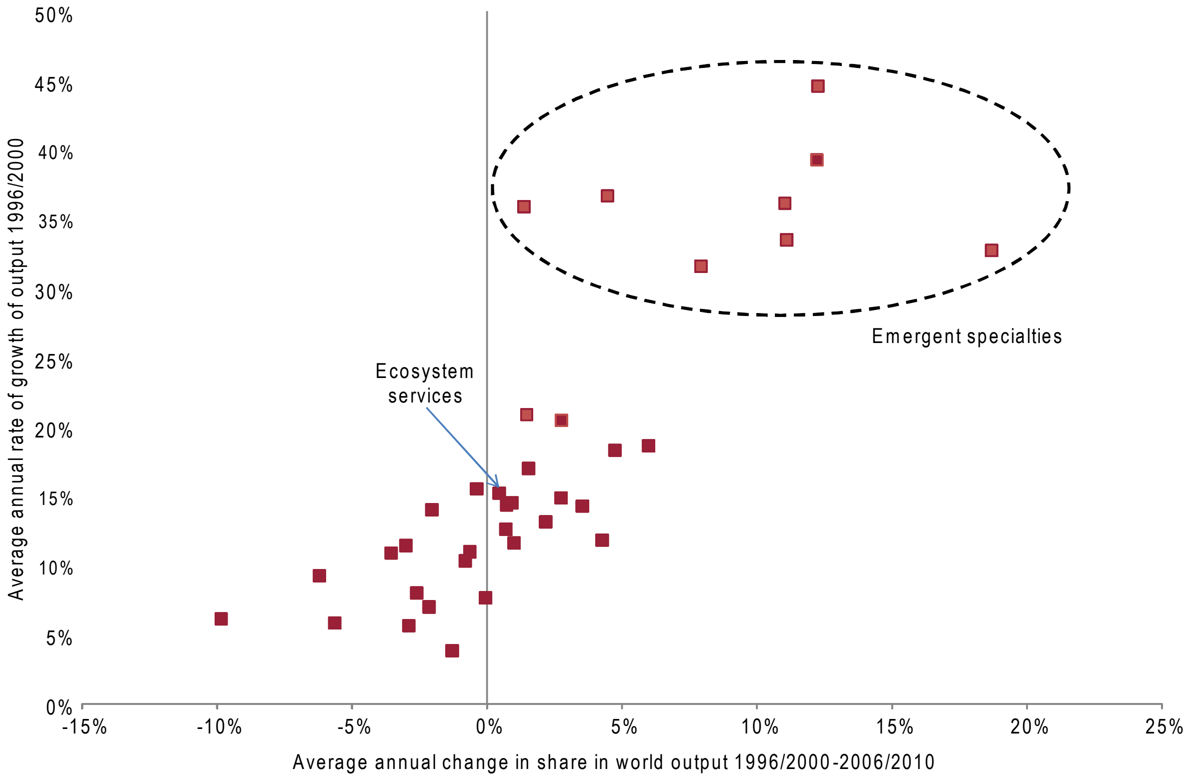

Figure 1. Comparison of the growth in output and the change in the share in world output per specialty, 1996/2000-2006/2010

When we compare the growth rate of Dutch output with the rate of change in the percentage share of Dutch publications in world output (Figure 1), it is possible to identify different types of specialties. Here, we focus on two types: emergent specialties and penalties of the pioneer.

1. Emergent specialties

The first type of specialties concerns emergent specialties. The fastest growing specialties in the top righthand corner of Figure 1 are emergent specialties, small in 1996/2000 and generally medium-sized in 2006/2010:

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

2. Penalties of the pioneer

The second type of specialties indicates areas in which the Netherlands suffers the ‘penalties of the pioneer’. The Netherlands was already strong in certain areas in 1996/2000. The development of these areas may provide a counterintuitive picture of sustainability science: while sustainability is becoming more relevant (and fashionable), these particular areas experience a decline in the share of Dutch output

in worldwide output. This may be a sign of early strength rather than weakness. In other words, in these specialties the Netherlands suffers the penalties of the pioneer.
The penalties of the pioneer are observed in four groups of specialties:

(1) Specialties that were large in 1996/2000 (50 publications or more per year) and experienced a decline in the share of Dutch publications in world output:

- Sustainability and sustainable development
- Sustainable land use and farming systems
- Nutrient management in agriculture
- Modelling and simulation of the water balance

(2) Specialties that were medium-sized in 1996/2000 (20 to 50 publications per year) and experienced a decline in the share of Dutch publications in world output:

- Life cycle assessment
- Water management
- Biomass gasification
- Anaerobic treatment of domestic waste water

(3) Specialties with a high citation rate (see Table 5) and that were medium-sized or larger in 1996/2000:

- Soil fertility in Sub-Saharan Africa
- Recycling

(4) Specialties with a high share in world output in 1996/2000 that declined thereafter:

- Exergy analysis

The remaining specialties are neither strong in 1996/2000 nor are they emergent.

3.1.3 Sustainability science in the aggregate scientific output of the Netherlands

How does sustainability science relate to overall scientific output in the Netherlands? We have extracted from Thomson Reuters Web of Science the number of publications in the main subject areas of each specialty (subject areas that account for at least 5% of total output). Using this selection, we have constructed estimates of the number of publications in the NOWT/CWTS classification of research areas (NOWT, 2010). The results do not provide full coverage of all research areas but can be considered a representative approximation. Figure 2 shows the distribution of output in the 36 specialties of sustainability science in 1996-2010. Figure 3 compares this distribution with the distribution of all Dutch output in 2010 among the categories of the NOWT classification. The results show a strong bias towards environmental sciences, agricultural and food sciences, earth sciences and technology, and biology.

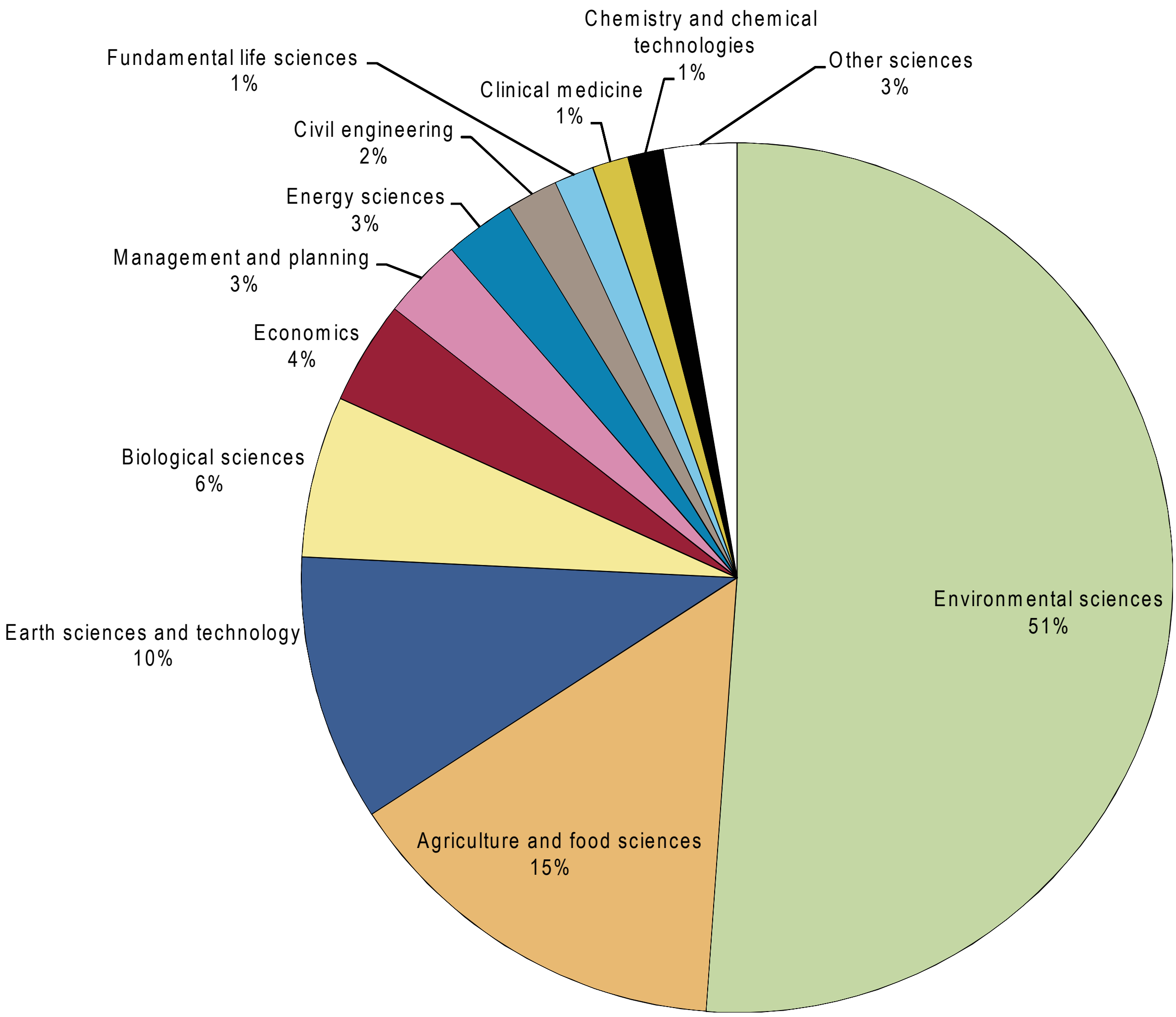

Figure 2. Distribution of publications in the identified specialties according to the NOWT classification of scientific output in the Netherlands

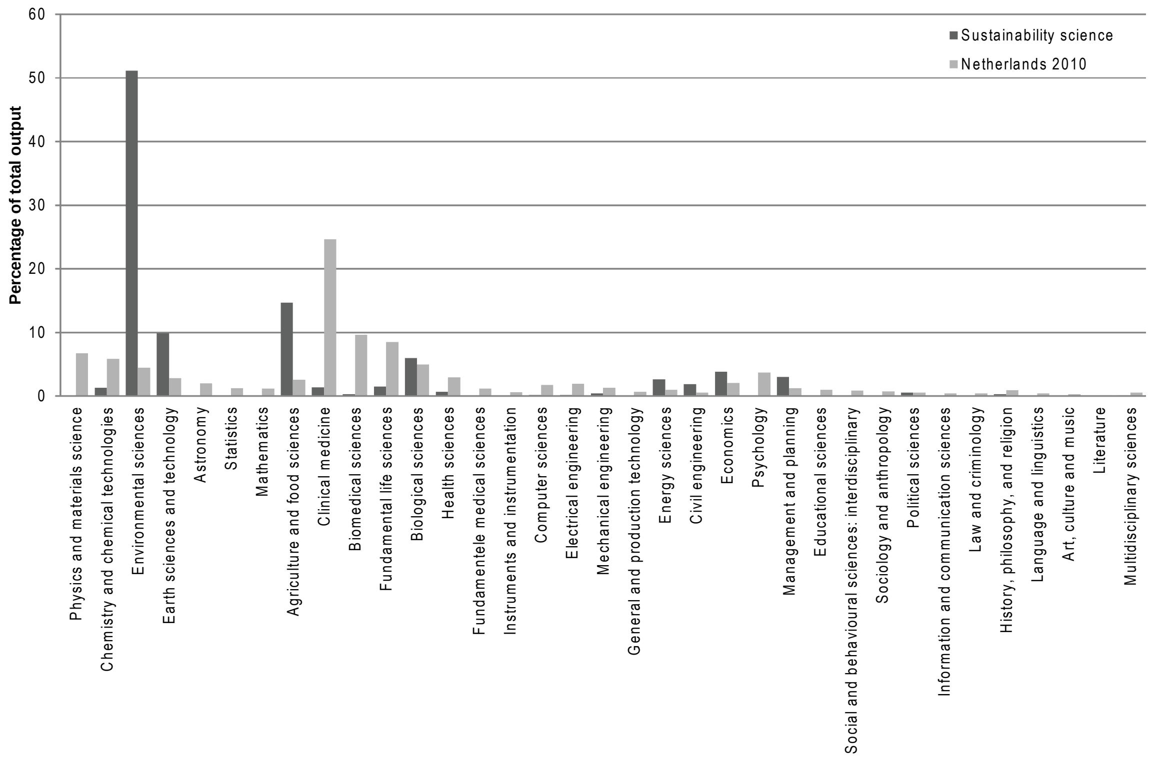

Figure 3. Distribution of publications according to the NOWT classification of scientific output: sustainability science compared to total Dutch output in 2010

3.1.4 Relation between specialties in sustainability science and EU Grand Challenges

To what extent do the various specialties contribute to the Grand Challenges of the European Union? The Grand Challenges are:

- Climate change and clean energy
- Sustainable transport
- Sustainable consumption & production
- Conservation and management of natural resources
- Public Health
- Social inclusion, demography and migration
- Global poverty and sustainable development challenges

The relation between each specialty and each Grand Challenge has been established by comparing author keywords and full publication titles with the substance of the Grand Challenges. Figure 4 and Figure 5 present a summary of the results. They show that Dutch sustainability science is relevant for each of the Grand Challenges, but particularly for:

- Conservation and management of natural resources (21 specialties)
- Sustainable consumption & production (13 specialties)
- Climate change and clean energy (8 specialties)

We find only a few specialties relating to the other four Grand Challenges. This does not mean that there is no relevant research in the Netherlands. The fact that we have not found these particular specialties may be due to two factors. First, we looked for an explicit link with sustainability or sustainable development. Perhaps this link is only implied in specialties that are relevant to the other Grand Challenges and therefore these have not been found. Second, Thomson Reuters Web of Science underestimates the output of the social sciences and humanities, especially in disciplines with a national or local focus (e.g. history or literature), in disciplines that produce non-journal outputs (e.g. architecture) and disciplines that produce more books than articles (e.g. history). This may be why we find comparatively few specialties in the area of social inclusion and global poverty. The contribution of the social sciences and humanities is clearly a topic for further research.

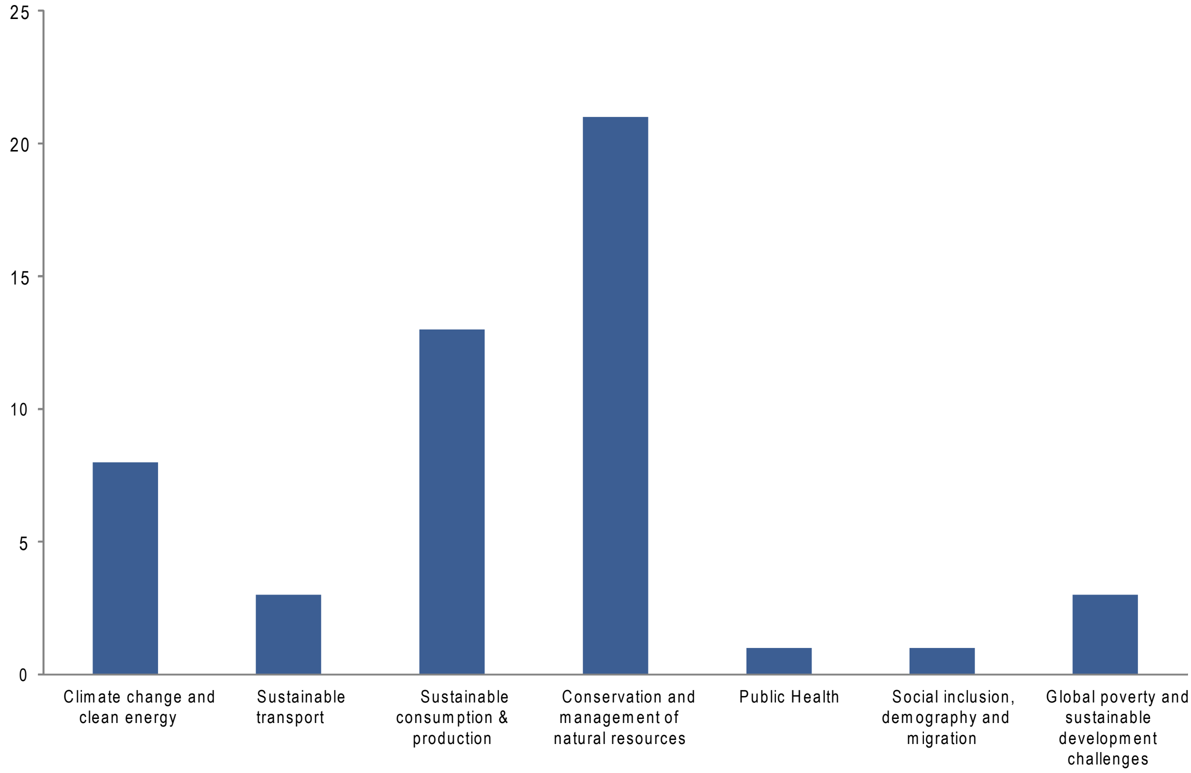

Figure 4. Number of specialties relevant for each of the EU Grand Challenges (numbers)

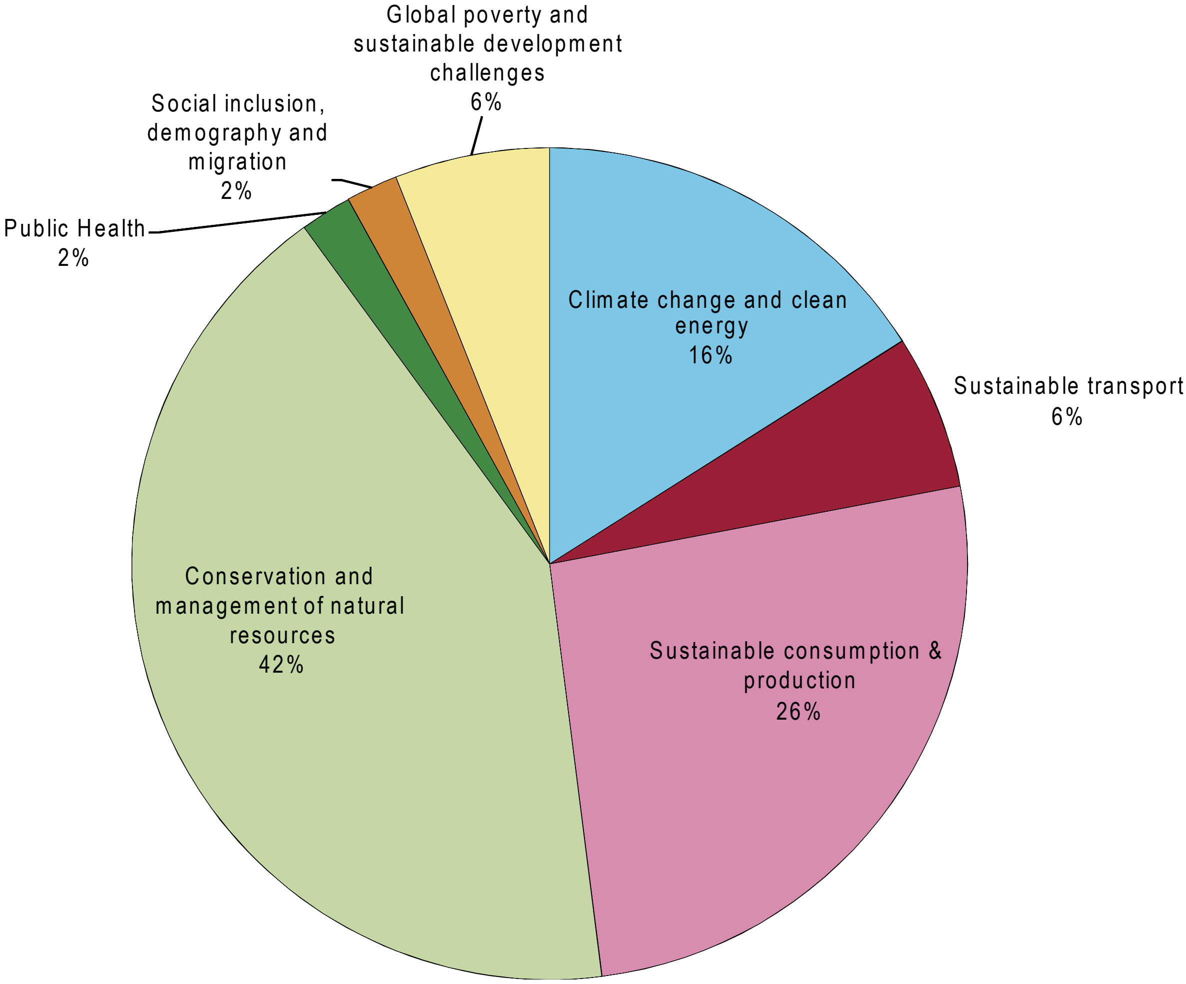

Figure 5. Distribution of specialties among the EU Grand Challenges (%)

3.2 A significant contribution to world output

In Table 4 we present the percentage share of publications involving researchers from the Netherlands in total world output and EU27 output. A specialty can be considered strong when it accounts for a higher percentage share than the average of all scientific output.[3] This means that the Netherlands is relatively specialised in this area.

On aggregate, the table shows that the Netherlands is relatively specialised in almost all identified specialties. In 1996/2000 *aquaculture* and *technological learning and experience curves in energy* and in 2006/2010 *aquaculture* should not be considered strengths. In these particular cases, the Netherlands accounted for less than 2.2% of world output in the specialty. However, the world output share of Dutch researchers is considerably higher in most other cases. The pattern of relative specialisation also applies to the EU27: in most specialties the Netherlands accounted for a much higher percentage of EU output than the overall average of Dutch output. In addition, we observe an increase in the share of Dutch publications in world output and a decline in the share in EU27 output.

[3] The share in world output of the total scientific output of the Netherlands in the Web of Science was 2.243% in 1996-2000 and 2.258% in 2006-2010.

A second observation is that emergent specialties did not necessarily begin as small from a Dutch perspective. In five small emergent specialties, the Netherlands was already relatively specialised in 1996/2000 (virtual water footprint; ecological modernisation and environmental governance; corporate social responsibility; impact of biofuels on land use and greenhouse gas emissions; microbial fuel cells). At the bottom of the list we find a number of specialties that illustrate the penalties of the pioneer.

Table 4. Share of Dutch output in total output in the world and in the EU27 (ranked in ascending order of the share in world output in 1996/2000)

	World			EU27	
Specialty	**1996/2000**	**2006/2010**		**1996/2000**	**2006/2010**
Aquaculture	1.1	1.9		3.4	5.5
Technological learning and experience curves in energy	1.4	7.7		3.8	17.8
Earth system governance and environmental governance	2.1	6.1		6.5	13.9
Regime shifts and alternative stable states in ecosystems	2.2	6.8		10.0	15.3
Virtual water footprint	2.3	6.5		5.5	16.6
Common pool resources and collective action	2.7	4.2		9.2	10.8
Landscape ecology and planning	2.8	3.0		8.2	7.8
Ecological modernisation and environmental governance	2.9	6.1		8.2	14.0
Biodiversity and conservation, agri-environmental schemes, and biological control	2.9	3.8		7.3	7.9
Recycling	2.9	2.4		7.1	6.6
Landscape quality and diversity	2.9	3.4		8.4	8.0
Corporate social responsibility	3.1	4.7		100	11.5
Impact of biofuels on land use and greenhouse gas emissions	3.1	9.8		6.3	18.7
Natural resources and growth	3.2	3.6		13.3	10.0
Microbial fuel cells	3.3	3.8		12.5	13.2
Malaria vector control	3.7	4.6		7.8	9.2
Soil organic matter and carbon sequestration in agriculture	4.0	3.0		9.3	7.0
Modelling of sedimentation and flood plain in rivers	4.0	5.6		10.0	13.7
Modelling and simulation of the water balance	4.1	4.1		10.8	10.1
Environmental assessment and use of space	4.1	4.0		9.6	8.6
Ecosystem services	4.2	4.4		11.6	9.9
River restoration and flood plain rehabilitation	4.4	4.1		12.0	13.0
Consumption patterns and environmental load	4.7	3.8		11.4	9.5
Sustainable land use and farming systems	4.7	4.3		12.8	10.9
Sustainability and sustainable development	4.8	3.5		13.2	9.3
Flooding and waterlogging	4.8	4.2		14.0	11.1
Nutrient management in agriculture	5.4	4.0		13.0	10.5
Innovation systems and transition	5.5	6.4		13.1	15.9
Spatial (urban and rural) planning	5.5	5.9		14.2	14.1
Fish diversity and eutrophication in Africa	5.9	7.8		15.9	15.3
Water management	6.0	6.4		18.7	15.9
Soil fertility in Sub-Saharan Africa	6.0	9.2		15.2	21.9
Life cycle assessment	6.5	4.5		13.2	9.7

	World			EU27	
Specialty	**1996/2000**	**2006/2010**		**1996/2000**	**2006/2010**
Anaerobic treatment of domestic waste water	7.5	4.2		14.5	10.8
Biomass gasification	7.7	4.1		13.1	10.3
Exergy analysis	8.5	3.0		21.1	13.0
Unweighted average	*4.2*	*4.9*		*13.4*	*11.9*
Overall share of Dutch output	*2.2*	*2.2*		*6.2*	*6.6*

3.3 High-quality output

The specialties in sustainability science fit the aggregate picture of Dutch scientific output: publications involving researchers from the Netherlands tend to attract more citations than the world average. In 2006/2010 all specialties had rates of citation higher than the world average. In 1996/2000 13 specialties scored below the world average, five of which are emergent specialties. At the top of the 1996/2000 ranking we find four small specialties with very high citation rates. Two of those – *technological learning and experience curves in energy* and *impact of biofuels on land use and greenhouse gas emissions* – are also emergent specialties. This shows that new fields can have very different beginnings. Some specialties, such as *common pool resources and collective action* and *soil fertility in Sub-Saharan Africa*, experienced a decline in relative citation rates. Although they remain above the world average, this development serves to remind us that Dutch science develops in a global context.

Table 5. Relative citation rate of Dutch research in each specialty in 1996/2000 and 2006/2010 (world average = 100; ranked in descending order for 1996/2000)

Specialty	**relative citation rate of Dutch publications (world=100)**		**percentage change in relative citation rate**	**relative size of specialties**	
	1996/2000	**2006/2010**		**1996/2000**	**2006/2010**
Fish diversity and eutrophication in Africa	350	208	-41	small	small
Technological learning and experience curves in energy	261	178	-32	small	medium
Impact of biofuels on land use and greenhouse gas emissions	244	143	-41	small	medium
Consumption patterns and environmental load	200	200	0	small	medium
Anaerobic treatment of domestic waste water	171	157	-8	medium	medium
Soil fertility in Sub-Saharan Africa	167	145	-14	medium	medium
Recycling	163	161	-1	medium	medium
Common pool resources and collective action	158	131	-17	small	small
Flooding and waterlogging	155	192	24	medium	medium
Ecosystem services	154	147	-5	medium	very large
Nutrient management in agriculture	152	180	18	large	very large
Virtual water footprint	147	161	10	small	medium
Malaria vector control	140	138	-2	medium	medium
Environmental assessment and use of space	139	215	55	small	medium
Soil organic matter and carbon sequestration	136	192	41	medium	medium

Specialty	relative citation rate of Dutch publications (world=100)		percentage change in relative citation rate	relative size of specialties	
	1996/2000	2006/2010		1996/2000	2006/2010
in agriculture					
River restoration and flood plain rehabilitation	128	168	32	small	medium
Biomass gasification	119	259	118	small	medium
Aquaculture	117	141	21	small	medium
Sustainability and sustainable development	114	187	64	large	very large
Sustainable land use and farming systems	112	167	49	large	very large
Biodiversity and conservation, agri-environmental schemes, and biological control	105	156	49	medium	large
Spatial (urban and rural) planning	102	162	58	medium	medium
Life cycle assessment	101	241	139	medium	medium
Modelling of sedimentation and flood plain in rivers	95	138	45	medium	medium
Modelling and simulation of the water balance	91	131	44	large	very large
Landscape ecology and planning	85	171	102	medium	large
Natural resources and growth	80	210	161	small	small
Earth system governance and environmental governance	80	109	36	small	medium
Innovation systems and transition	79	171	115	medium	large
Landscape quality and diversity	77	184	140	medium	large
Microbial fuel cells	71	423	496	small	small
Water management	71	171	142	medium	large
Ecological modernisation and environmental governance	56	121	117	small	medium
Exergy analysis	53	175	230	small	small
Corporate social responsibility	28	153	452	small	medium
Regime shifts and alternative stable states in ecosystems	10	110	965	small	medium

3.4 The knowledge infrastructure

How broad or narrow is the knowledge infrastructure of each specialty? In Table 6 the specialties have been classified into four categories depending on the distribution of output among knowledge institutes in the Netherlands. Where the knowledge infrastructure is broad, publications are produced by many research groups in different institutions and there is no dominant player. Where the knowledge infrastructure is narrow, one or two dominant players are responsible for the bulk of Dutch output in the specialty.

The specialties are more or less evenly distributed among the four categories. There are 10 specialties with a narrow knowledge infrastructure, 11 with a limited infrastructure, 9 with a fairly broad infrastructure and 6 with a broad infrastructure. It is noteworthy that 9 of the 10 specialties with a narrow knowledge infrastructure are either an emerging specialty or represent areas of early strength and subsequent relative decline. What's more, 21 of the 36 specialties have a narrow or limited infrastructure, indicating that their strength depends on only a few institutional concentrations of research. Perhaps areas of real strength develop on a narrow base.

We have also identified the main institutions in each specialty. We can deduce from Table 6 that Wageningen UR, TU Delft, and – to a lesser extent – the universities of Utrecht and Amsterdam form the backbone of sustainability science in the Netherlands. It must, however, be emphasized that this identification is tentative. There are inconsistencies in the spelling of institutional affiliations. A proper detailed analysis might find slightly different results.

Table 6. Assessment of the knowledge infrastructure for each specialty

Specialty	**Share in output of the largest institution**	**Share in output of the two largest institutions**	**Institutions with the highest output in 1996-2010**
Narrow	**52**	**71**	
Microbial fuel cells	68	115[a)]	WUR; WETSUS
Technological learning and experience curves in energy	35	58	UU; ECN
Regime shifts and alternative stable states in ecosystems	51	72	WUR; NIOO
Impact of biofuels on land use and greenhouse gas emissions	31	58	UU; WUR
Exergy analysis	46	69	TUD; Tue
Aquaculture	61	66	WUR; RUN
Anaerobic treatment of domestic waste water	61	82	WUR; TUD
Soil fertility in Sub-Saharan Africa	66	72	WUR; UU
Nutrient management in agriculture	55	62	WUR; UU
Sustainable land use and farming systems	48	54	WUR; VU
Limited	**35**	**51**	
Fish diversity and eutrophication in Africa	42	60	LEI; RUG
Virtual water footprint	34	54	UT; TUD
Biomass gasification	26	46	TUD; TUe
Ecological modernisation and environmental governance	32	43	WUR; UVA
Malaria vector control	35	55	UVA; WUR
Flooding and waterlogging	24	45	WUR; UU
Soil organic matter and carbon sequestration in agriculture	47	60	WUR; UVA
Landscape quality and diversity	40	49	WUR; UVA
Modelling of sedimentation and flood plain in rivers	28	48	UU; TUD
Biodiversity and conservation, agri-environmental schemes, and biological control	40	50	WUR; UVA
Landscape ecology and planning	40	49	WUR; UVA
Fairly broad	**27**	**41**	
Natural resources and growth	29	44	WUR; UvT
River restoration and flood plain rehabilitation	28	47	RU; UU
Earth system governance and environmental	29	41	WUR; VU

Specialty	Share in output of the largest institution	Share in output of the two largest institutions	Institutions with the highest output in 1996-2010
governance			
Environmental assessment and use of space	22	35	WUR; TUD
Spatial (urban and rural) planning	21	38	WUR; TUD
Water management	27	38	WUR; TUD
Ecosystem services	33	50	WUR; VU
Modelling and simulation of the water balance	29	41	WUR; UU
Sustainability and sustainable development	27	40	WUR; TUD
Broad	**17**	**31**	
Common pool resources and collective action	15	30	UvT; WUR
Corporate social responsibility	15	29	UVA; EUR
Consumption patterns and environmental load	13	26	TUD; RUG
Recycling	28	42	TUD; WUR
Life cycle assessment	15	29	WUR; TUD
Innovation systems and transition	16	29	WUR; TUD
a) The share is higher than 100% as a result of collaboration among the largest institutions.			

3.5 International collaboration

Are Dutch researchers in a specialty less or more inclined to work with researchers from the BRICS, Preferred Less Developed Countries, and the EU27 than researchers from other countries? A ratio was calculated that is:

- higher than 1 if Dutch researchers collaborate with researchers in these countries to a higher extent than the worldwide average
- lower than 1 if Dutch researchers collaborate with researchers in these countries to a lesser extent than the worldwide average

The estimates in Table 7 show that in 2006/2010 researchers from the Netherlands were more likely to collaborate with researchers from preferred LDCs than researchers from the rest of the world, while they were less likely to collaborate with researchers from the BRICS. Only in specific areas, such as biodiversity research, were they more likely to work with EU27 researchers. In 1996/2000 we find a similar pattern for the LDCs and the BRICS. However, in all but two areas Dutch researchers in sustainability science were less likely to collaborate with researchers from the EU27 than researchers from the rest of the world. In short, between 1996/2000 and 2006/2010 there appears to have been a stronger move towards collaboration with researchers from the preferred LDCs and the EU27 than among similar researchers in other countries.

Table 7. Propensity of Dutch researchers in sustainability science to collaborate with researchers in the BRICs, LDCs and EU27

	1996-2000				2006-2010		
Specialty	**BRICS**	**LDCs**	**EU27**		**BRICS**	**LDCs**	**EU27**
1. Sustainability and sustainable development							
Innovation systems and transition	0.28	0.00	0.11		0.07	1.75	0.59
Water management	0.00	0.00	0.56		0.58	1.88	0.94
Spatial (urban and rural) planning	0.00	0.00	0.22		0.37	1.23	0.69

	1996-2000				2006-2010		
Specialty	**BRICS**	**LDCs**	**EU27**		**BRICS**	**LDCs**	**EU27**
Virtual water footprint	44.00	0.00	0.85		0.70	5.12	0.85
Ecological modernisation and environmental governance	2.19	0.00	0.00		0.66	1.98	0.67
Common pool resources and collective action	0.00	0.00	1.91		0.00	5.07	0.86
Earth system governance and environmental governance	3.13	0.00	0.00		0.66	2.00	0.68
Sustainability and sustainable development	0.19	0.62	0.29		0.28	2.42	0.80
Natural resources and growth	0.97	0.00	0.95		0.00	1.08	1.46
Environmental assessment and use of space	0.00	0.00	0.30		0.34	3.07	0.95
Landscape quality and diversity	0.59	4.27	0.39		0.50	4.27	1.06
2. Biodiversity							
Biodiversity and conservation, agri-environmental schemes, and biological control	0.14	3.31	0.76		0.54	2.72	1.05
Flooding and waterlogging	0.20	0.00	0.74		0.37	2.72	1.07
Ecosystem services	0.37	1.39	0.89		0.58	2.35	1.25
3. Remote sensing and climate modelling							
Modelling and simulation of the water balance	0.29	2.85	0.50		0.64	4.18	0.93
Modelling of sedimentation and flood plain in rivers	0.18	0.00	0.35		0.57	4.30	0.83
4. Climate change, adaptation and mitigation							
Landscape ecology and planning	0.49	4.51	0.31		0.55	3.27	1.21
Technological learning and experience curves in energy	0.00	a)	0.94		0.47	0.00	0.77
Impact of biofuels on land use and greenhouse gas emissions	0.00	a)	0.00		0.75	4.38	0.82
5. Ecological risk assessment							
River restoration and flood plain rehabilitation	0.79	0.00	0.35		0.28	3.24	1.11
6. Agriculture and sustainability							
Nutrient management in agriculture	0.05	1.76	0.41		0.37	3.89	0.94
Sustainable land use and farming systems	0.27	1.28	0.37		0.43	2.91	1.05
7. Soil science							
Soil fertility in Sub-Saharan Africa	0.33	1.52	0.49		0.45	1.71	0.89
Soil organic matter and carbon sequestration in agriculture	0.74	0.00	0.64		0.34	3.01	1.21
8. Drinking water and waste water treatment							
Anaerobic treatment of domestic waste water	0.29	2.68	0.31		0.58	6.83	1.07
9. Life cycle assessment and input-output analysis of environmental impacts							
Life cycle assessment	0.53	0.00	0.28		0.22	3.39	0.75
Consumption patterns and environmental load	0.00	0.00	0.39		0.05	2.19	0.82
10. Modelling complex ecosystems							
Regime shifts and alternative stable states in ecosystems	0.00	a)	0.00		0.20	0.00	1.30
11. Biomass gasification and biofuels							
Exergy analysis	0.00	0.00	0.23		0.31	0.00	0.40

	1996-2000			2006-2010		
Specialty	**BRICS**	**LDCs**	**EU27**	**BRICS**	**LDCs**	**EU27**
Recycling	0.00	0.00	0.60	0.32	7.50	0.92
Biomass gasification	0.00	12.94	0.30	0.12	0.00	0.67
12. Biodiversity conservation, taxonomy and biogeography						
Fish diversity and eutrophication in Africa	0.48	1.69	0.46	0.36	1.84	1.08
13. Microbiology and biotechnology for water and energy						
Microbial fuel cells	0.00	a)	0.00	0.00	a)	1.41
14. Work and business						
Corporate social responsibility	0.00	0.00	a)	0.39	3.02	0.60
15. Aquaculture						
Aquaculture	0.79	0.00	0.88	0.15	9.91	1.00
16. Malaria						
Malaria vector control	0.52	0.36	1.04	5.64	15.10	15.39

a) No countries collaborate with this group of countries.

4 Conclusions

In this report we have mapped and analysed sustainability science in the Netherlands to provide input for the work of the Advisory Committee RIO+20 of the Royal Netherlands Academy of Arts and Sciences (KNAW). The input relates to two questions:

1. "What are currently the strengths of Dutch science with respect to the items on Agenda 21, both in a substantive sense (theme Green economy in the context of sustainable development and poverty eradication) and from the perspective of knowledge and institutions (theme Institutional framework for sustainable development)?"

2. "How effective is the collaboration with knowledge institutes from developing countries in the field of sustainable development and, given the core areas in research and the knowledge agenda of the Netherlands, in which areas and with which partners can collaboration best be organised?"

We have identified 36 specialties that may represent strengths in Dutch sustainability science. Some specialties are small (less than 10 publications per year). This was true for 17 of the 36 specialties in 1996/2000 and 5 in 2006/2010. The remaining specialties are medium-sized and all specialties have experienced growth between 1996/2000 and 2006/2010. It is quite likely that at this moment new specialties in sustainability science are emerging that our scientometric methods cannot yet identify.

A comparison of the distribution of the output of Dutch sustainability science among Web of Science subject areas with that of the aggregate output of the Netherlands shows that sustainability science is heavily biased towards environmental sciences, agricultural sciences, earth sciences and technology, and biology. Dutch sustainability science is relevant for each of the Grand Challenges, but particularly for four Challenges, namely conservation and management of natural resources, sustainable consumption & production, and climate change and clean energy.

We have defined areas of strength as specialties in which the Netherlands makes a significant contribution to world output, produces high-quality output, and has a strong knowledge infrastructure.

Significant contribution to world output

- The Netherlands is relatively specialised in almost all identified specialties. In most cases, the world output share of Dutch researchers in individual specialties was considerably higher than the aggregate output share of Dutch scientific output in the world or in the EU27.
- We observe an increase in the share of Dutch publications on sustainability science in world output and a decline in the share in EU27 output.
- When we take a wider perspective – including also specialties in which a lower percentage of publications refers to sustainability – four larger groups of specialties can be considered strengths, namely (1) biodiversity, (2) climate change, adaptation and mitigation, (3) agriculture and sustainability, and (4) soil science. This wider perspective also brings to light a number of specialties in medical science and the social sciences, such as prevention of obesity in children and adolescents, job satisfaction, animal welfare, infectious diseases, teacher education, and socio-economic status and health.

High-quality output

- The quality of output appears to be high. In 2006/2010 all specialties had rates of citation higher than the world average. Most specialties experienced gains in the relative rate of citation.

Strong knowledge infrastructure

- There are 10 specialties with a narrow knowledge infrastructure, 11 with a limited infrastructure, 9 with a fairly broad infrastructure and 6 with a broad infrastructure. It is noteworthy that 9 of the 10 specialties with a narrow knowledge infrastructure are either an emerging specialty or represent areas of early strength and subsequent relative decline.
- Of the 36 specialties, 21 have a narrow or limited infrastructure, indicating that their strength depends on only a few institutional concentrations of research. Perhaps areas of real strength develop on a narrow base. Wageningen UR, TU Delft, and – to a lesser extent – the universities of Utrecht and Amsterdam seem to form the backbone of sustainability science in the Netherlands.

International collaboration

- Between 1996/2000 and 2006/2010 there appears to have been a stronger move towards collaboration with researchers from the Preferred LDCs and the EU27 among sustainability scientists in the Netherlands than among similar researchers in other countries. In 2006/2010 researchers from the Netherlands were more likely to collaborate with researchers from preferred LDCs than researchers from the rest of the world, less likely to collaborate with researchers from the BRICS, and only in specific areas more likely to work with EU27 researchers.

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Who was Rathenau?

The Rathenau Instituut is named after Professor G.W. Rathenau (1911-1989), who was successively professor of experimental physics at the University of Amsterdam, director of the Philips Physics Laboratory in Eindhoven, and a member of the Scientific Advisory Council on Government Policy. He achieved national fame as chairman of the commission formed in 1978 to investigate the societal implications of micro-electronics. One of the commission's recommendations was that there should be ongoing and systematic monitoring of the societal significance of all technological advances. Rathenau's activities led to the foundation of the Netherlands Organization for Technology Assessment (NOTA) in 1986. On 2 June 1994, this organization was renamed 'the Rathenau Instituut'.