Chapter 7.

Selected science digests

Another potential function of the Global Sustainable Development Report may be to provide digests of recent scientific findings to government officials who follow the United Nations sustainable development debate.

A group of young researchers from State University of New York's College of Environmental Science and Forestry, Yale University, and Tufts University in the United States of America; Wageningen University in the Netherlands, and the Royal Institute of Technology in Sweden (KTH-dESA), contributed to this report. The group of young researchers was very international: the majority of them came originally from developing countries. They prepared, *inter alia*, a series of science digests/briefs that were validated by science peers from both developed and developing countries. The full text of the science digests is available on the United Nations website. As an example, Table 44 lists the briefs that were selected and prepared by team at Wageningen University in the Netherlands. Three of these briefs are presented as illustrative examples in this chapter: (a) ocean acidification; (b) marine microbial ecology and bioreactors; and (c) protein substitutes and the livestock sector.[314] The briefs introduce and explain the topics, describe the scientific debate and suggest issues for consideration. They have been minimally edited, in order to illustrate what can be realistically expected with this approach. If a wide group of young researchers were mobilized in this way across the world, a very useful library of high-quality briefs could be developed, possibly in a range of languages.

Table 44. Overview of science digests provided for this report by young scientists at Wageningen University

Rio+20 theme	Science digest
Oceans	Ocean acidification
	Marine microbial ecology and bioreactors
Sustainable consumption and production	Biocatalysis
	Electronic waste
Food security	Protein substitutes
	Large-scale land investments
	Phosphorus security

Source: Team of young researchers (December 2013)[315].

The potential value added of science digests is to shed light on specific aspects of broader themes highlighted in intergovernmental documents such as the Rio+20 outcome document, which are often not very detailed. For example, most of items in Table 44 were not mentioned in the Rio+20 outcome documents, including bioreactors, biocatalysis, protein substitutes and phosphorus security. It is interesting to note that the young researchers chose many issues that not only highlighted problems, but that were also scientific or technological solutions (e.g. bioreactors and protein substitutes). This is a very encouraging indication for the future.

The science digests were geared towards a public audience composed of senior government officials and policymakers who have an interest in learning more about new scientific insights on sustainable development. Authors first selected a broad topic (e.g. sustainable production and consumption of livestock products) based on personal background, interest and preliminary ideas on the impact of the issue regarding sustainable development. To check if the selected topics were in fact emerging within the scientific community, the topic was put into several scientific databases (e.g. Scopus, ISI Web of Knowledge, and Google Scholar). Within the broader topic, emerging issues were determined on the basis of findings in recent literature (from 2009 onwards) and exploratory interviews, and the emergence of the issue was once again checked with the graph resulting from the number of publications over time. The science digests were built on literature reviews and exploratory interviews with experts, and were conducted in person or via telephone or email, depending on the availability and location of the interviewee. The experts were chosen based on their background, expertise and knowledge on the topic, and some of them were authors of articles that had been part of the literature review for the digests. Experts were from both developed and developing countries. Expert interviews were also used as a method to validate the content of the digests.

If science digests become part of a global sustainable development report, attention must be given to the process used to prepare them, including who frames the question and what knowledge is included.

7.1. Ocean acidification

Ocean acidification was highlighted in §166 of the Rio+20 outcome document: *"We call for support to initiatives that address ocean acidification and the impacts of climate change on marine and coastal ecosystems and resources. In this regard, we reiterate the need to work collectively to prevent further ocean acidification, as well as to enhance the resilience of marine ecosystems and of the communities whose livelihoods depend on them, and to support marine scientific research, monitoring and observation of ocean acidification and particularly vulnerable ecosystems, including through enhanced international cooperation in this regard."* However, no reference was made to the extent of the problem or possible solutions to it. The following science digest provides an overview of scientific findings to support an informed discussion among decision-makers in the follow-up to Rio+20.[315, 316]

Introduction

The problem of ocean acidification, also called "the other CO_2 problem",[317] is seen as one of the largest threats to marine ecosystems and organisms.[318] Oceans have the natural ability to absorb CO_2. When CO_2 dissolves in the ocean, it forms carbonic acid, which leads to a reduction in seawater pH and thus more acidic conditions in the oceans. Since pre-industrial times, there has been a 30 per cent increase in ocean acidity.[319, 320, 321] This natural buffering is being used as a means to mitigate anthropogenic climate change, but the speed and magnitude of the ocean acidification process adversely affects marine ecosystems and species.[322]

The consequences of ocean acidification are far-reaching and multidimensional, affecting the marine environment directly and indirectly.[323] Ecosystems' functioning will be hampered due to ocean acidification, especially those who form shells and plates.[321]

Subsequently, other organisms that feed on them will face changes in the availability and composition of nutrients as a result of the increased acidity.[322]

Further it is expected that ocean acidification will affect various economic sectors such as fisheries, aquaculture and tourism,[324] and consequently food security.[325] Among the most affected are communities living in areas highly dependent on fisheries, mostly coastal communities in developing countries. Out of the 30 countries that are the most dependent on fish as a protein source, 26 are developing countries.[326]

Ocean acidification facts and figures

- Over the past 50 years, the oceans have absorbed between 24% and 33% of the CO_2 emissions.[327]
- There has been a 0.1 pH unit reduction since pre-industrial times, and an additional decrease of 0.4 pH is expected for the upcoming 100 years.[319]
- Especially organisms that form shells and plates, such as plankton, corals and coralline algae will be among the most affected.[317]

Source: Authors' compilation.

Scientific debate

Researchers already have been making efforts to find measures to adapt to and mitigate ocean acidification. There are several options to take action against ocean acidification, ranging from solar radiation management to improving ecosystem resilience. The options, "reducing CO_2 emissions" and "removing atmospheric CO_2" have the greatest potential.[323] However, the political and social feasibility of reducing CO_2 emissions raises concerns and therefore, depending on the viewpoint, feasibility can be considered relatively high or low.[323]

This is mainly because of the difficult positioning of ocean acidification in scientific and political debates. Ocean acidification is linked to the climate change agenda as well as to the marine pollution agenda.[328] In both regimes ocean acidification is partly regulated, but the problem in its entirety is addressed by neither. This phenomenon is called the "international twilight zone" in which ocean acidification is placed.[327, 329] It can be illustrated by looking at the positioning of ocean acidification within the climate change debates.

Ocean acidification is frequently linked to climate change in policy frameworks, since the climate system is defined to include the oceans.[328] What is important to stress out is that ocean acidification is not an effect of climate change, it rather shares the same cause as climate change: an increase of atmospheric CO_2.[328]

Consequently, actions to mitigate adverse effects of climate change do not necessarily contribute to mitigation of ocean acidification.[330] Current agreements do not prioritize reductions in CO_2 emissions, but work with overall reduction of GHG emissions.[323] Ocean acidification can only be tackled by a reduction in CO_2 emissions, and this has not been incorporated in current agreements. Therefore, these agreements may not necessarily lead to a reduction in ocean acidification.[328]

The geophysical processes of ocean acidification are generally well known.[331] Ocean pH has decreased by 0.1 units since pre-industrial times. Modelling shows that, with CO_2 emissions increasing at current trends, the ocean average pH will decrease a further 0.4 pH units by the end of the century and, by 2300, the pH at the ocean surface may decrease 0.7 units.[332] Although the ocean pH has varied in the past, those variations are thought to have occurred over millions of years. On the contrary, the future pH reductions from CO_2 emissions would be happening at an unprecedented speed, and marine species may not have time to adapt to these sudden changes in the ocean.[330, 331]

Presently, surface waters are saturated with respect to aragonite and calcite. This saturation is essential for calcifying organisms to produce their skeletons and shells as well as to keep these structures intact. But oceans become less saturated as their pH decreases. If the oceans reach undersaturation, existing shells and skeletons will start to dissolve and the oceans will become corrosive for these organisms, presumably with a ripple effect up the food chain and associated ecosystems.[330] As the ocean absorption of CO_2 is not evenly distributed spatially, some oceans are expected to reach this tipping point earlier than others. Projections suggest that large parts of the Southern Ocean and the Arctic Ocean may be affected as early as 2030-2060.[333, 334] Coral reefs are at risk of being affected by as early as 2050.[335]

Johan Rockström and co-authors[330] define a possible planetary boundary for the saturation threshold. However, their article also expresses the uncertainty of this planetary boundary, because the responses of organisms other than calcifying organisms, as well as of the overall ecosystems, are still unclear.

Indeed, although the magnitude of ocean acidification can be predicted with a high level of confidence, the impacts of acidification on marine organisms are less known. The impacts will likely differ per organism. As there is hardly any knowledge on the threatening level of acidification for each marine organism, it is difficult to define a "safe" level of atmospheric CO_2 to protect the oceans. For calcifying marine ecosystems such as continental shelves and coral reefs, scientists cautioned against levels of atmospheric CO_2 above 450-500 ppm.[332, 334]

Food for thought on ocean acidification

- Reducing CO_2 emissions is not the only way to take actions against ocean acidification, but a reduction in CO_2 emissions is the most effective.
- Mitigation of climate change does not necessarily equate to mitigation of ocean acidification.
- It is vital that ocean acidification be better incorporated in the climate change debate. This can easily be done by focusing more on CO_2 emissions reduction.
- There is a lot of uncertainty about which marine organisms are affected for each level of ocean pH. For continental shelves and coral reefs, scientists caution against levels of atmospheric CO_2 above 450-500 ppm.

Source: Authors' compilation.

Issues for further consideration

The following issues were suggested by the team of young researchers for consideration by policymakers:

- There is a need for extended research on the effects of ocean acidification focusing on interdisciplinary issues of ecological and socioeconomic impacts
- A larger emphasis should be placed on the reduction of CO_2 emissions by policymakers and within the current climate change debate
- There is a need for more knowledge on the impacts of acidification on marine organisms and their ecosystems.

7.2. Marine microbial ecology and bioreactors

The Rio+20 outcome document (§158) expressed a general commitment to protect and restore marine ecosystems: "*...We therefore commit to protect, and restore, the health, productivity* *and resilience of oceans and marine ecosystems…"* However, no reference was made to the marine microbial ecology or the potentials of bioreactors. The following science digest provides an overview of scientific findings to support an informed discussion among decision-makers in the implementation of the Rio+20 outcome.[336, 314]

Introduction

The oil spill in the Gulf of Mexico in 2010, where the equivalent of 4.9 million barrels of oil was released into the environment, attracted a lot of attention among policymakers and civil society. However, the impacts on the ecosystem turned out to be less catastrophic than expected due to marine microbes digesting the oil spill, even though there are signs of permanent damage.[337] This is a clear example of the adaptive properties of bacteria and the wide range of compounds they can feed on.[338] Microbes also have a very diverse range of substances they can produce and are at the base of healthy, stable, ecosystems all over the world. Marine microbial ecology, while still a relatively new field of research, is rapidly uncovering the importance of microbial life in nutrient availability in ecosystems. This is no different for marine environments in which, for example, processes such as nitrification[339] and CO_2 fixation[340] are mainly regulated by microorganisms. Considering that 90 per cent of the ocean's biomass is estimated to be microbial life,[341] it is no surprise that microbes play a crucial role in ecosystems. However, because this field has only become an important topic in the last 10 years or so,[342] in-depth research is still lacking and only general findings exist in terms of marine biodiversity[343] or in relation to human health.[344]

Marine microbial ecology and bioreactors: facts and figures
• Over 90% of marine biomass consists of microbial life. • An estimated 50-80% of all biomass is found under the ocean surface. • Microbial phytoplankton makes up the basis of the marine food chain and is responsible for producing 50% of the world's oxygen. • Microorganisms are also the main drivers behind nutrient availability in marine ecosystems. • However, microbial community dynamics are still poorly understood.

Source: Authors' compilation.

Scientific debate

Within the scientific community there is still debate on the determination of microbial species, because there is little genetic material to work with.[345] In addition, one of the difficulties is determining marine microbial biodiversity, as the sheer number of species is very high and data from different areas are not properly integrated.[346] There are also the technical difficulties of measuring a large area like the ocean, which naturally comes forth from the trade-off of either covering a large area or getting a detailed description.[345] However, it is becoming clearer that high microbial biodiversity is not necessarily the main reason for a healthy ecosystem. Rather, the composition of a certain microbial community may be a stronger indicator than biodiversity,[347] and microbial community dynamics change when influenced by other factors, such as an increase in CO_2 levels.[348] As such, a change in a microbial community might have a big effect on the ecosystem's nutrient cycles[349] and thus on the organisms living in it.

There have been suggestions of connecting the current assessments of marine biodiversity into a single global assessment on marine biodiversity. Such a systems approach is needed to establish the importance and function of microbial communities in ecosystems. This knowledge could be applied to increasing ecosystem resilience or assisting in ecosystem restoration, such as in the case of oil spills.[350] This would not only help in improving the current assessments on marine life, but also in linking the data on marine ecosystem health at different levels *"from microbes to whales, […] to entire ecosystems".*[345]

Where, on one hand microbial communities are to be studied and researched in order to determine their interactions with the ecosystem, on the other there is an ever-growing interest among the scientific community in bioreactors. A bioreactor is a machine that optimizes a natural environment for the growth of specific microbial species and communities. The marine bioreactors focus on microbial life that needs such specific living conditions (high salt concentrations, high pressure, etc.), that they cannot be cultured in a laboratory.[351] By positioning a bioreactor off the coast on the sea floor, the bioreactor's microbial life is able to thrive under its natural conditions. These bioreactors could even lead to a system in which the ocean is used in the sustainable production of medicine or other chemical substances, clean energy or even food.[351] Moreover, increased use of bioreactors could lead to production of energy or biological compounds in a sustainable manner without damaging the ecosystem where the bioreactor is positioned.

In short, more efficient research into microbial communities and their interactions with the environment can be attained through biodiversity assessments. This could lead to better use of bioreactor technology. Finally, a better understanding of microbial ecology can help us in many fields, from ecosystem resilience and restoration to even a higher yield in seafood production.[352]

Food for thought on marine microbial ecology and bioreactors
• Microbial communities, while not yet completely understood, are at the base of a healthy ecosystem. • A global biodiversity assessment network helps in understanding the dynamics in microbial communities. • A good understanding of microbial community dynamics can lead to new forms of ecosystem restoration and increasing resilience. • Bioreactors combine the "special talents" of certain microbial species with the native marine environment to produce chemicals and energy without damaging the ecosystem. • Stimulation of use of bioreactors can lead to an enhanced use of the ocean for sustainable production.

Source: Authors' compilation.

Issues for further consideration

The following issues were suggested by the team of young researchers for consideration by policymakers:

- Establish a global assessment on marine biodiversity, with special attention to microbial biodiversity
- Promote research on the application of bioreactors in marine environments
- Improve understanding and functioning of marine microbial communities.

7.3. Protein substitutes and the livestock sector

The Rio+20 outcome document expressed a general commitment to food security and nutrition in §108 to §118. However, no specific reference was made to protein substitutes and the livestock sector. The following science digest provides an overview of scientific facts to support an informed discussion among decision-makers in the implementation of the Rio+20 outcome.[353, 314]

Background

Livestock products have been, and continue to be important elements of the human diet. At the same time, the livestock sector is the agricultural sector with the highest negative impact on the environment and human health, particularly in countries where intensive agricultural methods prevail.[354] The sector is associated with nutrient losses, pesticide leakage and use of large tracts of agricultural land, water and fossil fuels. These systems contribute to GHG emissions[355] and climate change,[356] threatening sustainable development.

Facts and figures - protein substitutes

- The livestock sector is responsible for about 18% of the total worldwide GHG emissions; it uses about 70% of the available agricultural land; and it represents about 8% of global water usage.[357]
- Feed production is responsible for 50-85% of climate change, 64-97% of eutrophication potential, and 70-96% of energy use in the whole animal production system.[358]
- 2-15 kg of plant material is needed to produce 1 kg of animal products (low energy conversion).
- 40-50% of the global grain harvest is used for feed production.[359]
- Land use, eutrophication and acidification, and consumption of livestock products are responsible for 43%, 51%, and 60% , respectively, and impacts the entire food domain.[360]

Source: Authors' compilation.

However, in response to a rising demand for livestock products, intensive livestock production has expanded steadily in the last half century, both in developed and developing countries.[361] According to the FAO,[362] the global demand for animal products, and subsequently the demand for feed, is expected to double by 2050, due to an increasing world population, rising incomes and further urbanization. However, it will be constrained by climate change, which can negatively affect production. The increased competition for land for other applications will result in higher food and feed losses.[363]

Developed countries experience high levels of overconsumption and intensive production of livestock products; yet there is low growth or even stagnation in the sector. Conversely, developing countries experience an increase in production and consumption, and the sector is shifting from an extensive pattern towards an intensified one. Increasing numbers of people in developing nations express a desire for a more Western-style diet, and, consequently, the pressure on natural resources accelerates.[364]

In the livestock sector, feed production (cultivation, processing and transport) and livestock consumption represent the main sources of impacts in terms of GHG emissions and use of resources such as land, water, energy, nutrients and biodiversity.[358, 357, 365] This science digest aims to provide mitigation options, represented by sustainable protein substitutes for food and feed related to the livestock sector.

Scientific debate

The discussion revolves around how to combine reduction in the negative impact of the livestock sector using technological measures, and reduction in livestock production and consumption, without undermining food security.[356] In the entire chain of production and consumption of livestock products, feed production and livestock consumption by humans are by far the most important contributors to environmental impacts in the sector. This digest focuses attention on one of the new potential mitigation options: novel and/or more sustainably produced protein substitutes for food and feed that are now more widely available than ever before.[358, 366, 367]

A human diet based on the exchange of the meat portion in the diet with meat substitutes has lower climate and land-use related impacts than a diet with food products of animal origin.[368] Substitutes such as legumes, pulses, vegetables and cereals, eggs, or novel protein sources like insects, algae, duckweed and rapeseed, or products based on plant proteins present lower impacts compared to livestock products, and could completely replace these.[365, 369, 370, 371]

Food for thought - protein substitutes

- "Identification of new feed resources is crucial for sustainable animal production and future viability."[362]
- Protein intake in the European Union is 70% higher than the levels recommended by the World Health Organization.[372]
- Given the low energy conversion and the high demand for land associated with livestock production, reduction in livestock product consumption could reduce the need for more food.[355]
- A global transition towards low-meat diets may reduce the costs of climate change mitigation by as much as 50% in 2050.[373]
- The transition towards more sustainable food production and consumption requires the cooperation of multiple actors: policymakers, NGOs, traders, producers and consumer. This transition will encounter cultural, political and commercial resistance.[374]

Source: Authors' compilation.

It is also important to orient research towards the development of new feed substitutes that can replace cereals as the major source of nutrition for pigs, poultry, dairy cows and cattle.[375] Use of agricultural co-products, by-products, insects, duckweed, seaweed or microalgae that have less impact related to emission and resource use (e.g. land) than conventional feed, can provide alternatives for importing feed from other countries, and can transform an inedible product into an edible one.[358, 366, 370, 362, 376] Vaclav Smil states: *"assuming that the area now devoted to feed crops were planted to a mixture of food crops, and only their milling residues were used for feeding"*,[377] enough food could be produced for 1 billion people. Some co-products are already being used in diets of livestock. In 2007 in the Netherlands, 22 per cent of livestock diets were composed of co-products (e.g. beet tails).[378] The main barriers in the use of novel sustainable protein substitutes are legislation, technical and processing challenges, and limited knowledge about possible food safety hazards, including a range of contaminants.[366]

New technologies and innovations in food production needs to be combined with a shift in consumption, since technology and society cannot be considered to be independent of one another.[364] What is needed are increased awareness of the environmental impact of food, concrete choices in favour of alternative sources of protein and eco-friendly products, and a general global consensus on the importance of decreasing food waste and overconsumption.[356, 379, 380, 381, 382]

Further issues for consideration

The following issues were suggested by the team of young researchers for consideration by policymakers:

- Increase availability and presence in the market of protein substitutes in human food and animal feed through the use of policy instruments, subsidies, research for their development, improvements of legislation and regulation regarding safety and use aspects of new proteins

- Decrease impact due to feed production and increase awareness of farmers about the impact of different feeds

- Influence reduction in meat and dairy consumption in Western countries and raise environmental awareness about livestock product consumption, both in developed and in developing countries.