Ministry of Infrastructure and the Environment

Knowledge agenda for soil and subsurface

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This document is an extract from the Research Agenda for Soil and Subsurface (*Kennisagenda Bodem* en *Ondergrond*) of the joint group of Dutch government bodies. It summarises the knowledge needed for the sustainable use of soil and subsurface in resolving societal issues. The opening presents the setting for the next 25 years, and considers the trends, drivers and societal tasks that are decisive for the future use of the living environment.

1. Netherlands in 2040

In 2040, the subsurface will contribute to solutions for societal tasks, such as urban quality of life and adaptation to the climate by sustainable use of soil and subsurface, the soil and water system, and the physical space of the subsurface.

– Trends, drivers and societal tasks

Whereas civil society and government in the 1970s and 1980s concentrated on **protecting** the health and living environment of the population, their main objective today is **sustainable use** of the available space (in planning as well as economic terms). Underlying the policy focus for the sustainable use of the physical space are a number of trends, drivers and tasks. For example:

- Demographic changes: increase in world population; regional decline in the Netherlands. Continuing urbanisation of the delta area in the Netherlands;
- A shift in the Netherlands' economic development (with companies operating in clusters around key shipping ports and airports ('mainports'), and concentrations of horticulture ('greenports') and research and development organisations ('brain-ports')). The Netherlands as a gas and commodities hub;
- Building of infrastructure in combination with a regional approach to the economy and space;
- Sustainable regional development;
- Relocation to declining regions and assigning green functions to these areas;
- Transition from traditional energy sources to a sustainable energy supply;
- Other types of work (new-style working; integration of work and living environments);
- More sustainable initiatives from civil society;
- Continuing necessity for climate adaptation and mitigation;
- Global changes in the supply of and demand for food; threat of a food shortage;
- Increasing scarcity of raw materials, and hence changes in international economic relationships;
- Decentralisation of government tasks and powers; centralised where necessary and decentralised where possible;
- More attention to governance, as well as further individualisation and segmentation of the political landscape;
- Developing the relationship between the Netherlands, Europe and the rest of the world. Ongoing globalisation and trade agreements.

The above trends affect the tasks facing our society. Soil and subsurface are key aspects of the following themes (Dutch Soil Platform, DSP)[1]:

- Space, the environment and water;
- Urbanisation of the green delta area;
- The environment and health;
- Climate change and climate adaptation;
- Energy transition;
- Global food production.

– Three recurring issues

The above-mentioned trends, drivers and societal tasks are not independent of each other. They are related as regards the control aspect (governance) as well as content: the value of the soil in economic terms and as natural capital. Societal tasks on a variety of scales, from local to global, are also factors.

Three recurring issues are a constant theme of the trends and developments referred to: governance, the value of the soil, and the various scales on which trends, developments and issues appear.

i. Governance

All the above trends, drivers and tasks involve issues relating to governance: collaboration, allocation of control duties, roles, responsibilities and efficiency.
Government taking a back seat, collaboration with new stakeholders, and more autonomy for the market raise issues about new types and methods of public administration.

[1] DSP, 2008. The Soil as partner in sustainable development: A research agenda for the future

ii. The soil is valuable

Economic value

The subsurface provides goods and services for people and society. Examples of these ecosystem services[2] are clean drinking water, soil fertility, pest resistance, biomass, climate regulation, genetic sources, food, pollination and cleansing power. However, their value has still hardly been set out in economic terms.

Putting monetary and economic values on soil and subsurface provides insight into their value to society. Practical instruments such as cost-benefit analyses help increase the awareness of the economic value of soil and subsurface.

Apart from recognising the monetary value of the subsoil, advantages can be gained from a fair division of the costs and benefits that arise from using it. Questions relating to this division (How should the investing, including social capital, be organised? How can it be ensured that the persons benefitting also bear a share of the costs?) frequently arise within the societal themes.

Biological, physical, chemical and emotional value

As well as economic value, the subsurface also has biological, physical, chemical and emotional value. Soil and subsurface are home to much of the earth's biodiversity, and are the locations for unique raw materials. The soil and subsurface can tell us how the world came into existence and give shape to the landscape. They are the basis for nature and green areas, which (as 'vitamin G(reen)') promote health and well-being.

This natural capital is a recurring subject relating to the use of soil and subsurface.

> Netherlands in 2040: Conscious management and sustainable use of soil and subsurface creates a balance between economic and social developments, and the capacity of the natural system.

Ecosystem services

The designation and valuation of natural capital in terms of the contribution that soil and subsurface make to the quality of life is increasingly carried out using ecosystem services as a basis.

[2] Ecosystem services are the benefits that people obtain from the ecosystem (www.iucn.nl: Publicatie Mondiale Ecosysteemdiensten).

The classification of these services helps to decide between solutions needed for societal tasks. The conscious designation of ecosystem services clarifies the contribution that the sustainable use and management of soil and subsurface make to sustainable development. Figure 1 outlines a few of these ecosystem services.

Figure 1: Ecosystem services in the Netherlands (PBL, 2010)

Ecosystem services are more extensive than just those provided by the subsurface. They can be divided into four categories (Millennium Ecosystem Assessment, 2005). An overview of ecosystem services is given by figure 2.

Figure 2: Overview of ecosystem services (PBL, 2010)

Production services:
Products from eco-systems

- food
- wood
- water
- genetic sources
- ………..

Regulating services
Services provided by regulating processes within ecosystems

- pest elimination
- pollination
- water regulation
- cleansing power
- ………..

Cultural services:
Intangible services from ecosystems

- recreation
- health
- storage
- cultural history
- inspiration / ethical / religious / education
- ………..

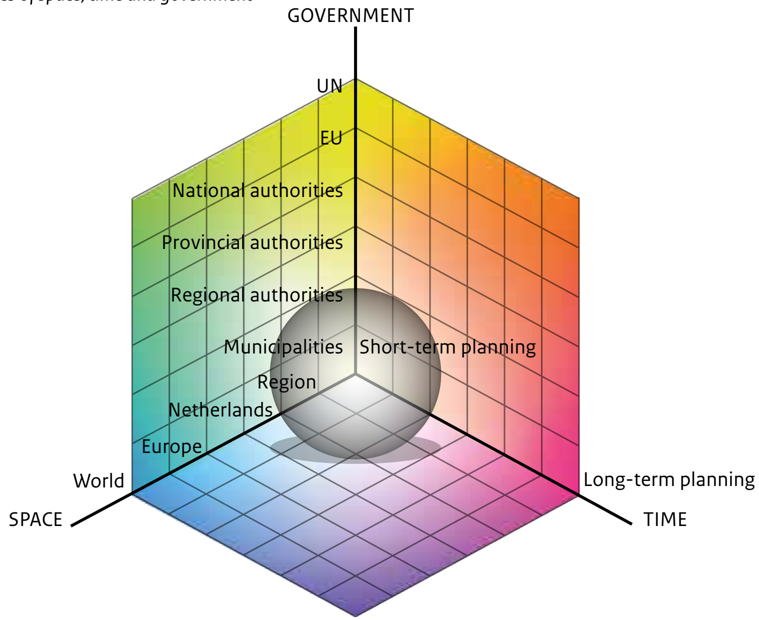
Supporting services
Services essential for production by all other ecosystem services

- nutrient cycle
- soil formation
- primary production
- ………..

iii. Scales

Societal themes appear on various scales, from local (home, garden and neighbourhood) to regional (area, municipality and/or province), national, and as far as global climate change. The different levels are reflected in the governing authorities (see figure 3), which vary from individuals, municipal and provincial bodies, national governments and the European Union, to global collaborative initiatives such as the WTO and the Kyoto Protocol.

Figure 3: Scales of space, time and government



The physical living environment also has the interconnected scales of space and time. Some interventions have a direct effect. For example, a reduction in emissions from industry and traffic directly improves air quality. Soil, subsurface and water soil, however, usually change slowly. The authors of the paper Ruimte uit 2006 ('Space in 2006') clarified this view by using the layered approach. The scales of the societal tasks and of sustain-able management are not mutually independent. Knowledge and understanding of the functioning of the soil are extremely important in connection with this.

- Vision for 2040

From the societal trends, drivers, and societal themes and tasks, a vision emerges for the use of the subsurface in 2040.

This vision is (provisionally) as follows:
The use of space in the Netherlands in 2040 is tailored to integrate the needs of living, work and recreation. Society has been organised along sustainable lines, with goods and services from soil and subsurface also being deployed and used sustainably. Surface functions and developments match the opportunities and potential of the natural system.

Consideration of spatial design is based on the value of the ecosystem services. In cities, the subsurface is utilised for functions considered undesirable as surface activities (parking and waste storage), for generating and storing energy, cooling and heat, with the soil surface carrying buildings and green spaces. The soil in rural areas is used for the sustainable production of food and commodities, in harmony with nature and habitat. Where necessary, subsurface services receive protection against threats, for example, in water catchment areas, nature reserves or archaeological sites. The soil is part of and contributor to a system of closed cycles.

The above vision has been further detailed from four standpoints.

Four standpoints

The above vision has been detailed from four standpoints, which are complementary and interdependent:

1. The area-oriented approach;
2. The Netherlands in relation to Europe and the world;
3. Construction based on the natural system;
4. Utilisation and allocation of public property.

2. Knowledge needs, today and tomorrow

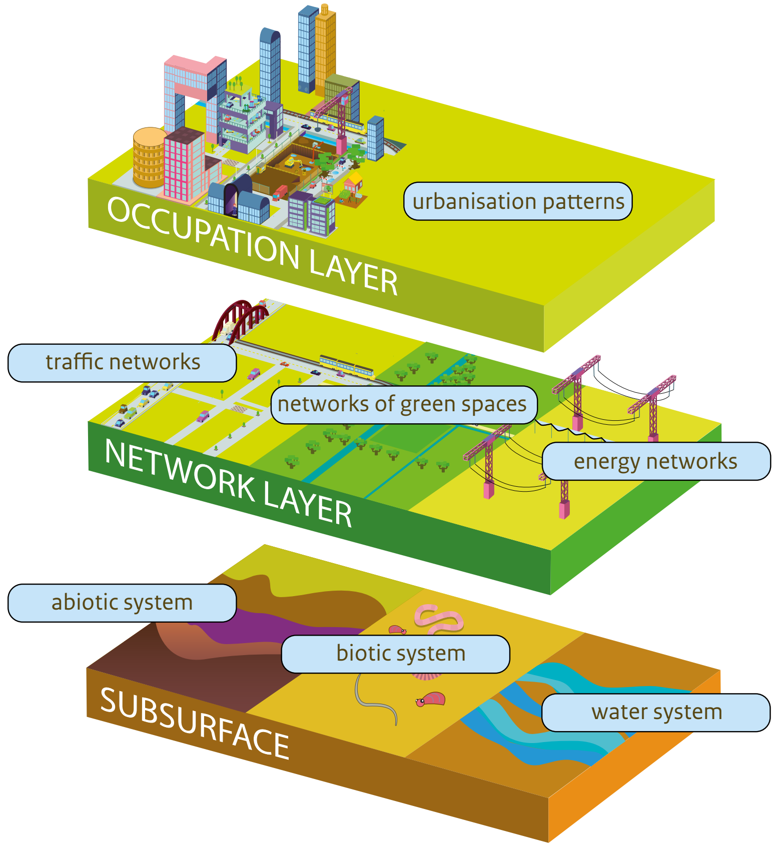
In this chapter, for each theme separately and related to the subsurface, knowledge requirements are explained and discussed.

– Space, the environment and water in relation to the subsurface

The Netherlands is a small country with a high population density and many activities that need space. Space is scarce. Many functions are performed close together and affect each other. How can the various activities be conducted so that the quality of the living environment and green space remain intact, and so that the activities do not interfere with each other or limit future activities?

The layered approach (see figure 4) is an instrument that enables the organisation of the surface space (occupation layer) to also be matched to the infrastructure (network layer) and the subsurface layer. By taking the layered approach to spatial planning, it is possible to lower management costs, reduce the impact of water and subsidence, preserve landscape identity and archaeological values, and prevent seepage from building sites. The layered approach enables advantage to be taken of the opportunities that the subsurface offers as regards energy transition, food production, water management and climate change (see also the other themes).

Figure 4: Layered approach



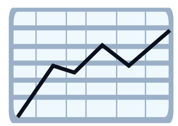
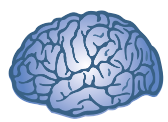
In urban areas, the subsurface can support the quality of the living environment by making it the location for obstructive or dangerous functions (concerning, for example, infrastructure, parking and underground storage) in accordance with the layered approach (combination of the occupation, network and subsurface layers). In rural areas, the structure and quality of the soil both play a key role in optimising the production, nature and recreation functions. Urban and rural functions might be intertwined and affect each other through the natural system.

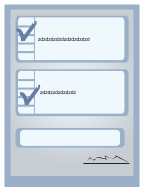
The government advocates the clustering of economic activities around a particular theme (mainports, brainports and greenports). This policy aim requires the focused planning of infrastructure (network layer) in combination with a regional approach to the development of economy and space. For sustainable development, the goal is to optimise the combination of space utilisation by different stakeholders (living, work and recreation). An actual example of this is the relocation and assignment of green functions to areas with a declining population.

The Netherlands' agricultural sector benefits mainly from space elsewhere, especially through imports of cattle feed from developing countries. In the case of raw materials such as gravel and building sand, in addition to manure and ore, the Netherlands also utilises space elsewhere. As the economies in these countries emerge, the space available elsewhere to us becomes more limited, and we have to increasingly look for alternatives within the Netherlands and other European countries. This need is becoming more pressing because of climate change, with the possibility of declining agricultural yields and the use of farmland for the production of biofuels and other applications of biomass in the future (i.e. a biobased economy). The availability of space coupled with the quality of the soil and subsurface are the overriding determinants of the possibilities.

The complexity of the Netherlands' land use is also due to the use of advanced (water engineering) technology, earning the country respect internationally. An improved deployment of natural resources and processes, together with intelligent use of the soil, can result in lower costs for managing this complex infrastructure, higher quality of the living environment, and less damage. In the area of water management, movement is already underway in the form of the 'Room for the River' programme (to allocate space to rivers). Soil management, too, offers the prospect of substantial gains. The suitability of the soil determines construction costs, the potential for generating and storing energy, and the availability of raw materials.

We already use the subsurface intensively in the Netherlands for the extraction of coal, petroleum, natural gas, salt, clay, gravel, etc. The stocks of these materials are both finite and scarce. Sustainable methods for the use of soil and subsurface are still little known and underemployed, apparent, for example, from the lack of a specific policy and a set of legal instruments governing these sustainable services. There is a steadily growing awareness that the soil and subsurface services – by products of natural cycles and other processes – represent significant value. Societal partners have requested the government to participate in defining the rules for the allocation of society's assets that are public to some extent, such as drinking water, buffers and catchment areas for rain, soil fertility, and alternatives for generating and storing energy. Apart from the sustainable management of these different services, their ongoing availability requires instruments for assigning value to them and for balancing the demands to use them.

Knowledge questions concerning space, environment and water in relation to the subsurface	
Creating awareness 	• How do we develop a comprehensive vision for the sustainable use of soil and subsurface, taking into account objective (or target group) and scale? • What opportunities offered by the soil are the best ones to utilise for societal tasks (and what information do we need for this)? • What knowledge do we have to amass in order to improve the transition process (creating awareness, expansion and integration)? • How can risk-based management or use be specified in detail for the sustainable use of the subsurface?
Status assessment 	• How do we develop a comprehensive vision for the sustainable use of soil and subsurface, taking into account objective (or target group) and scale? • Which parts of the subsurface merit explicit protection, i.e. are vulnerable? • How can data (including metadata) be catalogued and interpreted, and how is the quality of the data to be guaranteed?
System knowledge 	• What is the impact of the use of soil and subsurface on spatial tasks, health, welfare and safety? • How can we increase understanding of the relationship between soil functions and their effect on ecosystem services? • What is the impact of area transition on the soil water system and the sustainable use of the subsurface?

Comparative assessment 	• How do utility and soil suitability relate to each other? What uses are different soils suitable for? What requirements does use impose on the soil?
Implementation 	• What knowledge do we require to manage the environmental stressors (pollution and subsidence) and how do we make this knowledge suitable for implementation (by the target groups)? • How do we utilise the opportunities offered by the ecosystem services, for example, to improve the water system or other elements?
Evaluation 	• How do we have to capitalise the subsurface and how do we obtain insight into its value? • What methods do we have to develop for cost-benefit analyses and effectiveness assessments of the sustainable and comprehensive management of soil and subsurface? • What instruments do we need in order to apply the methods for cost-benefit analyses and effectiveness assessments of the sustainable and comprehensive management of soil and subsurface?

Preliminary analysis

When analysing the knowledge needs for the theme space, environment and water management, a possible conclusion is that the knowledge questions within this theme are evenly divided among the different phases of the policy cycle. This might imply a broad need for knowledge about soil and subsurface in relation to the theme space, environment and water management.
Noteworthy, however, is the absence of questions concerning the extraction of raw materials for example.

– Urbanisation of the green delta area and the subsurface

Large parts of the Netherlands are urbanised. The built-up environment will expand even more.[3]

On a relatively small spatial scale, combinations of residential areas, workplaces, agriculture and nature will arise. The boundaries between cities, farmland and nature reserves will become less defined.

In rural areas, the residential zoning is growing faster than the zoning for nature and agriculture. Apart from a different form of land use, this also demands more infrastructure. The infrastructure concept Randstad 2040 outlines the design of an urban area appropriate for a modern metropolis. Such a design uses space efficiently, with high-rise buildings and underground infrastructure, as well as substantial space for green areas and water in close proximity to the residents (DSP 2008).

A possible scenario is that fewer people move to **Vinex** districts (see *Vierde Nota Ruimtelijke Ordening Extra*) in the Randstad conurbation and towns outside the Randstad. Young families move away and the number of children in inner cities shrinks. The peripheral areas of the Netherlands face a population decline as residents relocate to other parts of the country with more employment and facilities.

To improve and maintain the quality of life in the cities, the organisation of space should be tailored to integrate the needs for living, work and recreation (red and green). Nature and green space in cities are both important for a sound living environment where well-being, recreation, biodiversity and economy are all high standard. The approach of “rooting construction in the natural system” and the application of ecological concepts to urban areas open up possibilities for enhancing the quality of life. This is illustrated in a book by TCB (Soil Protection Technical Committee) and Natuurmedia, *Ontdek de stadsbodem* (‘Discovering urban soils’), published in 2010.

In connection with this, it is important to understand the functioning of the natural system within and underneath cities, the key processes, and ways to employ natural resources. How can the sustainable use and management of the subsurface be implemented in relation to economic and social developments? In this context, sustainability

[3] Nederland later, PBL, 2007

also includes preventing the transference of effects in space and time. The pressure on space in the Randstad conurbation demands investment in construction projects in peatland meadows, where the subsurface is unsuitable for the purpose. To this end, it is important to properly understand the feasibility of the soil system for building, and hence set limits for it.

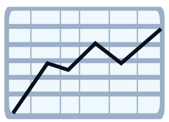
A region-centric approach is key to the harmonisation of surface and subsurface. To cross sector boundaries and support comprehensive regional development, mutual gaining of awareness, knowledge and technology are all-important. The potential for multiple uses of space and land has to be identified. Gaining insight into the balancing of surface and subsurface utilisation – including the costs and benefits, and their allocation – is equally essential.

Knowledge questions concerning urbanisation of the green delta area and the subsurface

Creating awareness

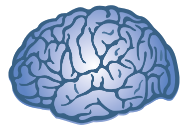
- How can we preserve and/or better utilise the soil and landscape heritage (including the archaeological elements)?
- Which nature objectives are feasible, and which are not, based on soil conditions and spatial tasks?

Status assessment



No questions listed.

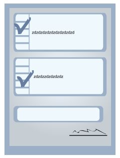
System knowledge



- Which soil processes are key for the soil in urban areas to perform ecosystem services (breakdown of pollutants, water and/or air filtration, local climate buffering, and heat stress resistance)?
- How can we maintain and/or stimulate the biodiver sity (as well as its use) in urban soil?
- What is the impact of subsurface construction, covering and other urban-related modifications on the subsurface itself?
- What are the new threats to the soil in urban areas?

Comparative assessment

- How can we make landscape and subsurface values factors in urban environments?
- How should we treat the costs and benefits relating to the use of the subsurface in urban areas (with the prevention of transference as an aspect of sustainability)?
- What do the design and management have to be for nature reserves where the chemical quality (natural or man-made) can pose a threat?

Knowledge questions concerning urbanisation of the green delta area and the subsurface	
Implementation 	• What is the role of the soil in ecological concepts used for sustainable design? • How can we optimise and control ecosystem services provided by the soil, and assign a monetary value to them? • How can we design or close cycles? • What technology has to be developed for utilising urban soil better?
Evaluation 	No questions listed.

Preliminary analysis

What is striking about the knowledge needs relating to this theme is the absence of knowledge questions concerning the condition of the soil (soil status) or concerning monitoring and evaluation. This might be a consequence of the mindset that soil can be made and, accordingly, no supplementary information on soil condition is needed.

> Within cities, knowledge about the soil is mostly limited to pollution. There is still little known about indicators for biodiversity, ecosystem services, and the functioning of the soil and water system.

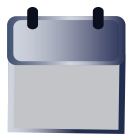
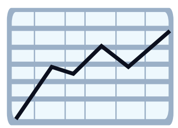
– The environment and health in relation to the subsurface

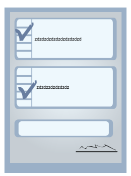
Recent years have seen the soil in the news mainly as posing a risk to public health. This raised many questions! If I buy a new house, is the ground really unpolluted, am I legally liable for any damage, or do I have to bear the decontamination costs myself? Can my children play safely in the sandbox? Is it OK to eat produce from my vegetable garden?

The soil is therefore often seen as a repository for harmful substances originating from industrial and agricultural processes, and from exhaust gases. Antibiotics and pathogens in manure constitute a threat to soil biology, or spread via the soil to humans and animals (causing Q fever or liver flukes). The soil is overloaded with nutrients from manure and other anthropogenic sources, which has adverse effects on both ground water and surface water. Owing to climate change, new threats will also appear (or might do so). New substances, medicines, hormones, nanoparticles and genetically modified organisms form a potential threat whose nature and extent are insufficiently identified, if at all.

> How can the soil be managed to gain the maximum benefit from its potential and minimise the health risks?

The soil also contributes a great deal to public health, though. Thanks to the enormous biodiversity in the subsurface, opportunities exist to develop new medicines such as antibiotics. A healthy soil breaks down pollutants and ensures clean ground and surface water, enabling the use of these raw materials for drinking water and agricultural irrigation. It also provides a natural resistance to agricultural diseases and pests, enabling a reduction in the use of pesticides.

Knowledge questions concerning the environment and health in relation to the subsurface	
Creating awareness 	No questions listed.
Status assessment 	• Which substances (and in which proportions) really represent a problem for public health? • What is the potential for the production of medicines or the breaking down of pollutants? • What are new threats for the quality of soil water and groundwater (and its receptors)?

Knowledge questions concerning the environment and health in relation to the subsurface	
System knowledge 	• What is the significance of the presence of substances alien to the system for quality and disease resistance of the soil?
Comparative assessment 	No questions listed.
Implementation 	• How can the new threats to groundwater and drinking water be mitigated, and how can they be monitored? • How can we improve the method for comprehensive risk assessment of soil pollution?
Evaluation 	• What is the quantitative impact of soil pollution on human health?

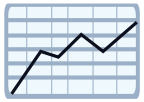
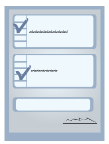
Preliminary analysis
Apart from chemical soil pollution, the link between soil conditions and the subject of public health is fairly new. As a result, the emphasis of the need for knowledge is on obtaining information about the state of the soil and possible steps for enlarging the contribution of the subsurface to public health. Knowledge questions relating to comparative assessment and selection will probably only be posed once more is known about this contribution.

– Climate change and the subsurface

Climate change is a fact. The conclusion of the IPPC (2007) is that the effects of climate change are already visible in many parts of the world, and this conclusion has been confirmed by the Netherlands Environmental Assessment Agency (PBL, 2010). Rainfall is heavier, there will be a greater frequency of high water levels, extreme rainfall, and drought, with heatwaves set to increase. Climate change brings new species to our country and causes existing ones to disappear. Owing to a higher sea level, salt water is encroaching further inland. Extreme rainfall contributes to increased flooding, and greater river outflows lead to a higher risk of overflowing. Summers will become hotter, causing temperatures to rise, especially in the cities. Climate change is attributed to high concentrations of greenhouse gases (CO_2, N_2O and CH_4) in the atmosphere. The soil can be both a sink and source for CO_2 through the storage and release of this gas by organic elements in the soil, and through the formation and breaking down of peatland. The reduction in CO_2 emissions that the use of biofuels can bring is described as part of the global food supply theme.

How can the soil support CO_2 sequestration as a way of mitigating climate change, and how can we use the soil and water system in adapting to climate change so that the quality of the living environment is maintained, or even improved?

Effects of climate change are apparent directly and indirectly in the soil, such as the salinisation in the western part of the Netherlands. At the same time, the soil system can help adapt to this climate change, for example, by storing surplus rainwater and by providing cooling for urban environments through the creation of open soil areas and green spaces in cities. It is easier to maintain the existing stocks of organic elements in the soil, than to bring about an increase in its organic content. Knowledge questions therefore mainly focus on methods for soil management and usage, including water-level management, that result in the maximum retention of peat and organic soil elements.

Knowledge questions concerning climate and subsurface	
Creating awareness 	• How can we make public and private parties aware of the subsurface's potential for combating or mitigating the impact of climate change?
Status assessment 	• How can we monitor and track the impact of climate change on the subsurface?
System knowledge 	• What is the effect of climate change on soil quality, soil characteristics, soil processes and ecosystem services? • How does climate change affect the use of the subsurface? • What part does the subsurface play in climate adaptation (water storage for example)?
Comparative assessment 	• How can the costs and benefits of using the subsurface (in urban areas) be estimated? • How can we factor landscape and subsurface values (ecosystem services) into spatial planning?
Implementation 	No questions listed.
Evaluation 	No questions listed.

Preliminary analysis

A preliminary analysis of the knowledge needs concerning soil and subsurface in relation to the climate highlights that knowledge questions about climate mitigation are present in the policy phase for creating awareness. The need for knowledge concerning the issue of climate adaptation belongs to a later phase of the policy cycle, dealing with assessment and selection. A possible reason for this is that climate adaptation issues are also handled at local and regional levels, whereas mitigating issues are addressed mainly at national and global levels.

– Energy supply and the subsurface

Energy certainty is major prerequisite for the prosperity of the Netherlands. It is a subject with a high priority on the political as well as the social agenda.

The Netherlands satisfies its energy needs partly from its own stocks of fossil fuels (oil, coal and natural gas). These energy sources are finite, however. Using fossil fuels causes an increase in the concentration of CO_2 in the atmosphere, which has consequences for the environment and the climate. Moreover, the dependence on a small number of oil producing countries (some politically instable) is high. Because of the increasing scarcity of fossil fuels, supply certainty is declining. The subsurface offers alternatives in the form of underground thermal storage, geothermal energy, and the extraction of unconventional gas from shale for example.

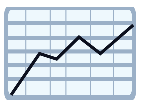
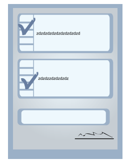
> Soil and subsurface can help support a sustainable energy supply.

By utilising the soil and the subsurface, it is possible to reduce the dependence on energy from other countries and cut back CO_2 emissions. The constant temperature of the upper subsurface makes it suitable for storing heat in hot periods and providing heat in cold periods. A prerequisite for this is that we introduce the heat into the soil by means of thermal storage. The lower subsurface is an inexhaustible source of heat, a form of geothermal energy that can be extracted. Thermal storage and geothermal energy both offer considerable promise.

Geothermal energy and thermal storage are not the only energy sources that the subsurface offers. There are also different types of unconventional gas that can be extracted, with shale gas being a solution for the Netherlands. Since 2010, definite plans have existed for extracting this gas in the province of Noord-Brabant. Gas extraction must always be carried out carefully, and thorough exploration is essential.

The use of the subsurface for supplying energy raises a variety of issues. The Netherlands has a highly developed infrastructure for transporting energy and has the ambition of becoming a European gas hub. What can the subsurface contribute to this?
The issue of using the subsurface for the storage of CO_2 and radioactive waste is also topical. Strikingly, this is not apparent from the list of knowledge questions.

The dilemma surrounding the use of fertile agricultural land for biofuel production is referred to as part of the global food supply theme.

Knowledge questions concerning energy supply and subsurface	
Creating awareness 	• What are the current and future roles of the subsurface in the transition to a sustainable energy supply?
Status assessment 	• How will the knowledge about soil energy be effectively communicated and interpreted?
System knowledge 	• What is the impact of soil energy on the characteristics of the subsurface (amount, chemical quality, and physical, geotechnical and microbiological features)? • What opportunities and risks does polluted ground water present for soil energy?
Comparative assessment 	• What opportunities and risks does the application of soil energy entail for other users of the subsurface (water extraction and water storage)? • Is an energy balance sheet essential for an open thermal storage system?
Implementation 	• How can technology and efficiency be optimised, without sacrificing soil functions?
Evaluation 	• How can the management, maintenance, monitoring and dismantling of soil energy systems be optimised?

Preliminary analysis
Strikingly, the knowledge need relating to energy is in a different phase of the policy cycle than that relating to the climate for example. In the case of energy, the main focus is on technology and implementation. For climate, however, it is largely on creating awareness and system knowledge. The explanation for this might have to be sought in relation to the fact that the soil is increasingly being used for our energy supply. As a result, more research into the contribution of the subsurface to this supply is already underway.
A second noticeable point is the absence of questions concerning CO_2 sequestration, nuclear waste storage and the extraction of unconventional fossil gases.

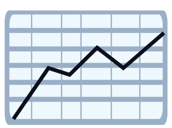
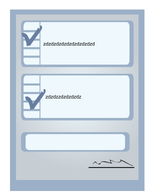
– Global food supply in relation to the subsurface

Because of a growing world population and greater prosperity, there is also an increase in the need for food production. This often results in agriculture being carried out on marginal land, unsuitable for the purpose. In the Netherlands, by contrast, agricultural lands are converted to urban areas (new designations, industrial zones and infrastructure) or nature reserves (including areas for water storage). At the same time, the available agricultural land is used increasingly intensively, with food production carried out more and more under cover (in greenhouses and factory farms).

Another trend, evident globally and certainly in the Netherlands, is the move towards a biobased economy (or green economy). Such an economy centres on the multiple use of biomass for food, fuel, chemicals, raw materials, electricity and heat. The production of biomass for raw materials, energy and chemicals can have implications for soil fertility, if harvest residues are no longer left on the soil, but used instead for energy or other applications. If the demand for biomass for new applications grows, this can suppress the production of food crops, resulting in rising food prices. One consequence is more hunger in the world, resulting in greater pressure to use marginal land, with the associated risks of soil depletion, erosion and land degradation.

The use of marginal land for agriculture has serious implications for crops. Erosion increases, causing flooding downstream, and soil fertility rapidly declines. The essential raw materials and natural resources become ever scarcer. Attention in the Netherlands is mainly on the effects of the intensification and modifications to the production systems. Some examples are the problems of ammonia in nature reserves, nitrate in ground water, and eutrophication of surface water. The current approach to finding solutions is to close more cycles on a variety of scales.

The Netherlands has an economically strong agricultural sector that is also innovative. From both a national and global perspective, how can the country put its farmland to the best possible use? Which spatial considerations come into play and who decides on them? How can the depletion of soil and raw materials be prevented in the face of the growing demand for agricultural products?

Knowledge questions concerning world food production in relation to the subsurface	
Creating awareness 	No questions listed.
Status assessment 	No questions listed.
System knowledge 	• What is the role of soil organisms in the soil's natural resistance and how can this be influenced? (Is less use of pesticides a possibility?) • What is the effect of agricultural use on soil parameters (and quality)? • What is the effect of agricultural production on the emission of fertilisers, pesticides and other pollutants into ground and surface water, and how can the impact be reduced (biologically)? • What are the effects of covering? • What is the impact of soil compaction in agricultural land on the soil itself and above ground?
Comparative assessment 	• How can the suitability for agriculture be factored into spatial and economic choices? • How can agricultural use be optimised with soil parameters as a basis? • How do we set the direction for land use in relation to scale?
Implementation 	• How can we design or close cycles? • How can we find ways to maintain the presence of organic substances in the soil? • Which (new or improved) farming methods can decrease the dependence on external inputs (nutrients and fuels) and reduce the risks of soil degradation? • How can the conversion of agricultural soil to an environment for natural development be optimised?
Evaluation 	• What are the effects of a changing living standard (more consumption of meat, greater need for energy, choice of biological food) on the use of the soil and on the risks of soil degradation?

Preliminary analysis

For the analysis of the knowledge needs relating to the subject of global food supply, it is noticeable that there are no questions about creating awareness or status. There are two possible explanations for this. This stage has already been passed, so that the need for knowledge no longer exists. Alternatively, there is insufficient awareness of the signßifi-cance of the soil and subsurface, resulting in an inability to identify the knowledge needed. It appears that within the soil discipline there is certainly awareness of the contribution by soil and subsurface to the solution of the global food issue. Accordingly, the need for knowledge is mainly in the comparative assessment and action phases.

– Governance

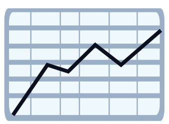
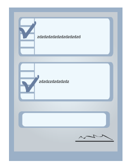
> Governance stands for sound management. In brief, governance concerns supervision, accountability, direction and control. As such, it involves, for example, the allocation of duties, powers and responsibilities. Accordingly, one area that governance influences comprises the rules and procedures for making investment decisions. This is also true of the soil sector.

The knowledge agenda sets out the potential of the subsurface to support the successful completion of societal tasks. The way in which this potential is expressed in policy is a governance issue. Policy has to be focused on the uniting of interests, values and knowledge. It takes the form of processes that link actors to stakeholders and vice versa. The scope of tasks concerning the soil is, of course, extremely wide, ranging from protection and management, to the sustainable utilisation of soil and subsurface. Additionally, soil development policy is being decentralised further, with local and provincial authorities receiving more tasks and powers.
This expansion demands more collaboration with other parties from other fields than was formerly customary and necessary. The regional approach continues to grow in importance. It remains to be seen which different types of spatial use and needs are balanced against the variety of functions desired. Who has control and which parties are involved? How are the costs and benefits shared out?

> The societal tasks, along with the roles and interests of different stakeholders in their successful completion, are leading determinants of the need for knowledge.

The practice of development planning provides an example of the wide gulf that still separates people with training in the hard sciences from those schooled in the social sciences. We have to close this gulf in the next few decades, a prerequisite being a holistic approach to the combination of region and system. We must understand how knowledge of the soil and water system can tie into the societal themes, including in quantitative terms. It concerns not only spatial issues, but also the true significance of soil and subsurface for health, food supply and quality of the living environment. It equally concerns economic and ecological issues that play out on different levels of government. We expect soil and subsurface to become potential factors in the comparative assess-ment process, provided the value of the ecosystem services can be evaluated in economic terms. Briefly, when it comes to defining governance in detail, the key aspects are government, policy instruments, communication and creating awareness, and the changing roles and powers of private as well as public parties. Attention to training and education is also necessary, because new ways of designing, collaborating and consider-ing have to be learnt!

> Governance issues are relevant to all the previous themes in this chapter. When comparing multiple interests on different space and time scales (internationally as well) and allocating public assets, costs and benefits, questions concerning governance are raised explicitly.

Knowledge questions concerning governance	
Creating awareness 	• How do we define creating awareness of sustainable use of soil / value of the soil / ecosystem services / soil functions and processes to the general population, other disciplines, policymakers and government officers? • How can the Dutch central government assist other government authorities to perform new tasks? • How can new policy principles (system-focused, dynamic and European) be formulated and what does this mean for the Dutch government? • What is the level of the group in charge? What is the best level for each task? What are the current and future allocations of roles within the public administration? • How do we strengthen the Netherlands' international position in relation to EU soil policy, and how do we implement the policy nationally? • How can scenarios and models be developed for designing societal tasks that embed a clear allocation of risks (ruling out the subsequent transfer of costs)? • What legal, financial and collaborative instruments are in place or require further development?
Status assessment 	No questions listed.
System knowledge 	No questions listed.
Comparative assessment 	• What governance strategies are in place (or planned for development) applying to subsurface use?
Implementation 	• What knowledge is required about the allocation of roles between public and private parties, and about strategic control? • What instruments can be developed or deployed to encourage the integration of knowledge from different sectors and actors?
Evaluation 	• How can a systematic evaluation of the experiments and the role of governance concerning the soil be organised as part of the knowledge development?

Preliminary analysis

Worthy of note is that the knowledge need concerning "governance" does not include more knowledge about the condition of the soil or the functioning of the soil and water system. The emphasis of the knowledge need is on creating awareness, policy design and monitoring of the resulting policy. Possibly this is because knowledge relating to the soil and water system plays a subordinate role in governance processes. These processes apply specifically to procedures aiming for collaboration and policy formation.

The Research Agenda for Soil and Subsurface has been composed by the joint group of Dutch government bodies, in close cooperation with the Dutch Soil Platform (DSP). DSP was installed by the Ministries of Infrastructure and Environment, and Economic Affairs for coordination of the knowledge questions from various governments and the subsequent activities of the knowledge institutes. One activity is the deliverance and maintain a national agenda for the development of strategic knowledge underpinning policy and societal activities in a framework of sustainable use of soil, groundwater and subsurface.

The agenda lists how soil and subsurface may contribute to solve societal tasks in the next decennia, and what knowledge is required for that purpose. The societal tasks recognized comprise urbanisation in the green delta, climate change, energy supply, spatial planning, human health and (global) food production. These soil-related themes from different spatial scales and dealing with societal issues imply an integrated and system-oriented approach which combines soil, water, atmosphere, people and ecology. See also: Otte et al. 2012 Current Opinion in Environmental Sustainability, 4:565–572.

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