Science of the Total Environment 485–486 (2014) 798–803

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Ecosystem services in sustainable groundwater management

Jaap Tuinstra *, Joke van Wensem

Soil Protection Technical Committee (TCB), P.O. Box 30947, 2500 GX The Hague, The Netherlands

HIGHLIGHTS

- Ecosystem services concept seems to get foothold in environmental policy and management.
- Ecosystem services concept can contribute to sustainable decisions in groundwater management.
- Overview of groundwater related ecosystem services is presented.
- Key elements for sustainable groundwater management are derived and related to the ecosystem services concept.
- Sustainability of groundwater management solutions will increase when more of the key elements of sustainable groundwater management, as defined in this article, are fully used and the guidelines for long term use of ecosystem services are respected.

ARTICLE INFO

Article history:
Received 1 July 2013
Received in revised form 21 March 2014
Accepted 21 March 2014
Available online 13 April 2014

Editor: D. Barcelo

Keywords:
Ecosystem services
Groundwater
Natural resources
Stakeholder
Management
Protection

ABSTRACT

The ecosystem services concept seems to get foothold in environmental policy and management in Europe and, for instance, The Netherlands. With respect to groundwater management there is a challenge to incorporate this concept in such a way that it contributes to the sustainability of decisions. Groundwater is of vital importance to societies, which is reflected in the presented overview of groundwater related ecosystem services. Classifications of these services vary depending on the purpose of the listing (valuation, protection, mapping et cetera). Though the scientific basis is developing, the knowledge-availability still can be a critical factor in decision making based upon ecosystem services. The examples in this article illustrate that awareness of the value of groundwater can result in balanced decisions with respect to the use of ecosystem services. The ecosystem services concept contributes to this awareness and enhances the visibility of the groundwater functions in the decision making process. The success of the ecosystem services concept and its contribution to sustainable groundwater management will, however, largely depend on other aspects than the concept itself. Local and actual circumstances, policy ambitions and knowledge availability will play an important role. Solutions can be considered more sustainable when more of the key elements for sustainable groundwater management, as defined in this article, are fully used and the presented guidelines for long term use of ecosystem services are respected.

1. Introduction

Groundwater is a vulnerable natural resource under increasing pressure. The pressures result from intensive use of the soil and subsoil, such as agriculture, storage of thermal energy in closed and open systems, extraction of groundwater and the use of subsoil space for infrastructure. These pressures may lead to scarcity, unwanted fluctuations in water levels, chemical contamination, nutrient loading, drought and salinization.

In the past, policies for groundwater protection in The Netherlands have been targeted at different threats separately, and disconnected from for instance surface water policies. Lately, it has been recognized that groundwater and surface water, both in qualitative and quantitative aspects, relate to each other, for example when surface water surplus is infiltrated in groundwater or when groundwater is feeding surface waters. A need has been identified for a more integrated policy approach toward groundwater protection, taking into account the different threats, qualitative and quantitative aspects, in connection with other environmental compartments.

The ecosystem services concept might be the key for connecting these different aspects of groundwater protection and management. This is one of the conclusions of a scientific recommendation on groundwater ambitions, prepared by the Soil Protection Technical Committee (TCB, 2012a) for the Dutch government. This paper discusses the use of the ecosystem services concept for sustainable groundwater management, with a focus on the regional or landscape scale and is an elaboration of the recommendation.

* Corresponding author. Tel.: +31 6 52740042, +31 6 27276553.
E-mail addresses: tuinstra@tcbodem.nl (J. Tuinstra), vanwensem@tcbodem.nl (J. van Wensem).

http://dx.doi.org/10.1016/j.scitotenv.2014.03.098
0048-9697/

2. The ecosystem services concept in decision making

Ecosystem services have been defined as the benefits of ecosystems for human well-being (Hassan et al., 2005). The services are generally categorized in: provisioning services (e.g. food, fuel), regulatory services (e.g. climate regulation, water purification), cultural services (e.g. education, recreation) and supporting services (e.g. water cycling, soil formation).

The ecosystem services concept might be used in decision making (policy, spatial planning, management), with the intention to protect and enhance natural resources and thus to maintain healthy ecosystems and biodiversity. The TCB has analyzed the potential use of the ecosystem services concept for environmental decision making in The Netherlands and concluded that the concept has potential to achieve more sustainable use of ecosystems, especially in the Dutch context, characterized by strong competition for space, and consequently the need for multipurpose land use (TCB, 2012b).

For human well-being all ecosystem services are needed, though not all services can be provided at the same time and at the same place. There is spatial and temporal variation. This can be the result of properties of the subsoil that do not support a certain ecosystem service. In addition, users optimize certain uses, for example to extract water, and this may be to the detriment of other services at the location (Van Wensem et al., 2013). Choices have to be made in decision making processes, in which besides environmental, also economical and social aspects are considered (Daily et al., 2009). Sustainable management of ecosystem services needs the balancing of the combined investments and interests of stakeholders at a specific place. Knowledge of the ecosystem processes and increased awareness of the importance of these processes are important prerequisites for such decision making (Otte et al., 2012).

Supporting tools for the decision making process at, for instance, landscape scale are available. A six step approach was proposed (see Box 1). Experience with applying the ecosystem services approaches has increased in recent years, for instance in the context of the project The Economics of Ecosystems and Biodiversity (TEEB, 2012). Awareness of the available natural capital is increasing due to national inventories initiated by the European Union (EU, 2013). High relevance is attributed to the ecosystem services framework for developed countries where it is expected to become one of the leading influences in environmental policy in the coming years (Matzdorf and Meyer, 2014).

An inventory of the use of the ecosystem services concept in landscape management in The Netherlands has indicated that the concept seems to be gaining foothold. In several projects the approach is not only seen as valuable for better decisions with respect to sustainable land management, but also to attract more funding for the plans due to the involvement of broader stakeholder groups (Van Wensem, 2013).

Box 1
Basics for the ecosystem services (ES) concept decision making process.

The basics for the decision making process with the ES concept are for instance described by six steps distinguished in The Economics of Ecosystems and Biodiversity project (TEEB, 2012) for decision making by local and regional authorities:

Step 1: Specify and agree on the problem (including stakeholder inventory).
Step 2: Identify which ES are relevant to the decision.
Step 3: Define the information needs and select appropriate methods.
Step 4: Assess the changes that are expected in the flow of ES.
Step 5: Identify and assess policy options.
Step 6: Assess distributional impacts of policy options.

Box 2
Overview of ecosystem services related to groundwater (not exhaustive) (based on Stuurman and Griffioen, 2003, with additions and regrouping).

Providing services:

- Drinking water
- Water for food and beverage industry
- Water supply for agricultural activities, such as irrigation
- Strategic groundwater resources
- Process water for industry
- Cooling water for industry

Regulating services:

- Groundwater as a storage medium for heat or coolness
- Groundwater as a supplier of coolness and warmth
- Maintain groundwater level and prevent subsidence
- Maintain groundwater level and stability of civil engineering constructions
- Water retention, drainage (water buffering)
- Water supply in groundwater dependent surface water regimes
- Water supply in groundwater dependent seepage areas
- Purifying and filtering effect of groundwater and soil

Cultural services

- Preservation of cultural–historical and archeological values
- Esthetical and ethical values of the groundwater ecosystem

Supporting services:

- Groundwater functions and processes (indirectly) related to ecosystem services
- Role of groundwater in the biogeochemical cycles

Before considering the meaning of the ecosystem services concept for sustainable groundwater management, a closer look is needed on groundwater related ecosystem services, the meaning of groundwater management and the adjective 'sustainable'. These subjects are addressed in the following paragraphs.

3. Groundwater related ecosystem services

The groundwater ecosystem (the ecosystem of the water-saturated soil) provides essential ecosystem services. European Union residents depend for 75% of their water supply on groundwater (EC, 2008). Groundwater is extracted for human consumption like drinking water, use in processing of food and breweries, storage and supply of coolness and warmth, water buffering and moisture supply for crops. Groundwater is of vital importance to groundwater dependent ecosystems, like wetlands, and their ecosystem services (Kløve et al., 2011).

Classifications of groundwater related ecosystem services are presented by Stuurman and Griffioen (2003), and Landers and Nahlik (2013). Box 2 presents a compilation of groundwater related services, ordered in the four classes of the Millennium Ecosystem Assessment (Hassan et al., 2005). This compilation is mainly useful in the context of communication and awareness raising. It can function as an eye-opener for the appreciation of the value and potential uses of groundwater.

Depending on the intended use of the classification, the listing can be shorter or more detailed and the descriptions of the services can vary. CICES lists of ecosystem services (Haynes-Young and Potschin,