# Towards a Comprehensive Framework for the Assessment of Groundwater Drought in Temperate Regions

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**Abstract:** Drought is a recurrent natural hazard affecting arid/semi-arid, as well as temperate regions. Numerous research efforts have been made for all types of drought (e.g. meteorological, hydrological and agricultural) in arid/semi-arid regions, whereas only a small number of studies have been performed in temperate regions. Moreover, in these regions, the type of hydrological drought which is related to groundwater is largely left unstudied. The GRoWaDRISK project is aimed to contribute to covering this gap. This paper summarises the aims, scope and methodology of the project. A large part of the Belgian territory was chosen as the study area. The project encompasses three groups of research tasks. First, knowledge regarding influencing factors of groundwater drought will be increased through using the best available spatial information on related variables (groundwater level, recharge and discharge). Second, the socio-economic and environmental impacts of droughts will be assessed for the current and future conditions through mapping the vulnerability of groundwater resources and assessing the related risk. Third, a methodology and supporting quantitative tools will be developed to assist sustainable groundwater management in Belgium.

**Key words:** Groundwater drought, temperate regions, influencing factors, impacts, vulnerability, risk.

## 1. INTRODUCTION

Drought is usually defined as a temporary decrease in water availability over a significant period of time and for a large area. At a first approach, drought is considered as a direct result of deficient precipitation and as such it is a meteorology related hazard, mainly associated with arid and semiarid regions. Due to the assumed insignificance of drought hazards under temperate climatic conditions this field remains poorly studied.

Three types of drought are conventionally assessed: meteorological, agricultural and hydrological drought. The first is referring to a period without or with little precipitation; the second is referring to a shortage of water in the soil and as such for crops or natural vegetation; the third is describing an impact on water bodies. In case it concerns groundwater bodies the term groundwater drought is used. Although groundwater is a valuable source of freshwater, the groundwater drought remained relatively unstudied. Only since the late nineties there has been a growing interest for this natural hazard.

Groundwater drought is a complex and hard to identify phenomenon (Van Lanen and Peters, 2002). It develops slowly but can have considerable and lasting socio-economic and environmental effects (Vogt and Somma, 2000). A conceptual definition of groundwater drought describes it as "a situation where groundwater sources fail as a direct consequence of drought" (Calow et al., 1999). This rather narrow definition is closely linked to the specific application in an African arid context. Van Lanen and Peters (2000) use a more general definition where groundwater drought occurs when the groundwater heads in an aquifer drop below a certain level. A further extension of the

definition considers groundwater drought as “a special type” of hydrological drought that occurs when groundwater recharge, level or discharge deviate from “normal” (Peters et al., 2005; Tallaksen and Van Lanen, 2004). Van Lanen and Peters (2002) also introduce a differentiation between natural and induced groundwater drought; the latter referring to the groundwater level drop as a result of human activities (e.g. abstraction, drainage, etc.). To describe groundwater drought three main variables are important: groundwater recharge, groundwater level and groundwater discharge (Tate and Gustard, 2000; Van Lanen and Peters, 2002). Groundwater recharge is important as it is the source (inflow) of all groundwater. The level of the groundwater table gives an idea of the storage, while groundwater discharge represents the outflow from the groundwater system.

A thorough knowledge of all three influencing factors and their interaction or combined effect is essential for a reliable estimation of the groundwater budget and a sustainable management. There is also a need for an improved knowledge on climate-related and human-induced effects of groundwater drought. This should form the basis for an integrated approach which allows tackling these negative effects and safeguarding sustainability. Moreover such an approach is essential in meeting the requirements of the EU Water Framework Directive (WFD), which requires a monitoring of their groundwater resources. The development of a drought-related vulnerability and risk assessment strategy for the sustainable management of groundwater resources under temperate conditions is attempted through the GroWaDRISK project, presented in this paper.

## 2. OBJECTIVES AND METHODOLOGY

The project aims at covering the gap created due to the lack of drought studies under temperate conditions by: (1) Increasing policy-relevant understanding of influencing factors determining groundwater drought in a temperate context, (2) obtaining reliable spatially distributed timeseries for groundwater recharge and water table levels, enabling to describe where (space) and when (time) groundwater drought occurred/occurs, (3) assessing the socio-economic and environmental impacts of groundwater drought at a large catchment scale for the present and future situations, (4) mapping the individual and combined vulnerability of groundwater resources, (5) assessing the risk as a monetary loss in order to enable objective evaluation and reduce the groundwater drought risk towards the future, (6) developing a methodology and supporting quantitative tools aimed at supporting decisions with respect to groundwater management, applicable at the level of river basins in Belgium and beyond, and (7) informing the public, consisting of domain specialists and lay persons about the results of the analysis carried out in the case region, by means of an Internet-based indicator atlas.

In order to assess drought-related vulnerability and risk of groundwater resources an integrated water balance and groundwater modelling strategy is applied in combination with a threshold method. The first step is a groundwater drought hazard assessment to increase knowledge and understanding of groundwater drought in a Belgian context. The complex interaction of influencing factors demands a multi-disciplinary modelling approach to generate a reliable estimation of spatially distributed groundwater recharge and water table timeseries using the combined water balance and groundwater modelling strategy. Using the threshold method the “rules” to maintain the groundwater system sustainable are set. A baseline scenario, representing a sustainable groundwater system, forms the basis for the final groundwater drought risk assessment. Based on groundwater simulations the reference and current status of agriculture (crop yield), natural ecosystems and water supply are determined. A next step is to study the impact of changing influencing factors on the total system. Finally, the individual risk related to the socio-economic activities will be assessed as a monetary loss. From individual risks, using the multi-criteria approach, the composite risk will be determined. The statement of the problem of depletion of groundwater resources in Belgium in terms of its influencing factors and impacts thereof is depicted in Figure 1.

The main topics that will be addressed are: (1) Rainfall analysis and drought hazards; (2) impervious surface mapping; (3) land-use change scenario modelling; (4) water budget and

groundwater table simulation; (5) impact on agriculture; (6) impact on natural ecosystems; (7) drought risk assessment.

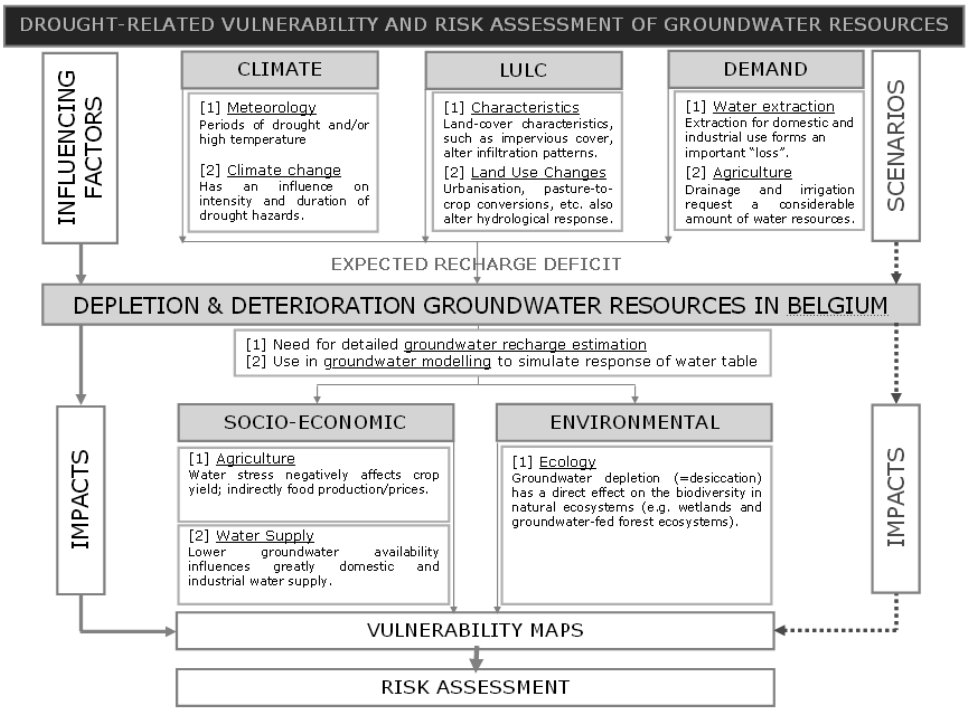


*Figure 1. Influencing factors and impacts thereof with regard to the problem of depletion of groundwater resources in Belgium.*

## 2. CONCLUDING REMARKS

Groundwater drought is a complex phenomenon, hard to identify and assess. Human induced factors play an important role with respect to drought-related depletion and deterioration of groundwater resources and should also be considered in the assessment of groundwater drought, in parallel to the natural meteorological variations, which are customarily examined.

The GRoWaDRISK research project presented in this paper aims at an increased understanding of the influencing factors and the development of a quantitative tool to address drought-related deterioration of groundwater resources. The outcomes of the project will serve concerned authorities and those responsible for operational management in setting priorities for an integrated sustainable management and a reduced risk for groundwater resources in Belgium.

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