Framework for adaptive monitoring of land subsidence

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Abstract

Currently, monitoring of land subsidence mainly focuses on the physical aspects of the problem. In this paper we present a framework that also includes the societal and governance aspects. This framework is currently being tested and applied in case studies within the Netherlands. The first results show that the framework helps to get a clearer picture of what is needed for adaptive monitoring.

Introduction

This paper covers a framework for adaptive monitoring of spatial interventions, which can be applied to land subsidence. Currently during spatial interventions, such as the ones focusing on land subsidence, the main focus is on decision-making supported by *ex-ante* evaluations upfront. However, to be adaptive, monitoring during the process (*ex-durante*) and afterwards (*ex-post*) are also important. To this end we present a framework for adaptive monitoring with a special focus on technology and systemic effects, economic costs and benefits, societal acceptation and support and institutional feasibility. The framework is also suitable for monitoring of other spatial interventions such as the energy transition or climate adaptation.

Methods

Currently, within the monitoring of soil subsidence, there is a heavy focus on the physical aspects of the problem (See also the 6M-method – Erkens & Stouthamer, 2020). However, in this method the public administrative and governance aspects are largely missing whereas in practice these have a large influence on the process. In order to be able to monitor these aspects as well, we have developed our framework (Figure 1).

This framework consist of the following steps:

1. <u>Identifying potential problems cause by the system and a stakeholder-analysis;</u> Establishing what the problem is that needs to be monitored and what the goal of this effort is. Here the focus lies on the physical elements (system data) (what causes land subsidence?) and governance elements (whose problem is it and who carries responsibility?). Additionally, also other (spatial) problems in the region can be identified which can be solved when taking interventions against soil subsidence.
2. <u>Development of a monitoring plan and suitable indicators;</u> Based on the system data and the stakeholder analysis a monitoring-plan can be established. During this process, attention also needs to be given to the responsibilities involved stakeholders carry. Additionally, also consensus needs to be established between the different stakeholders to prevent discussion about the approach or results in later stages of the cycle.

3. Collecting data from practice; During the implementation-phase data is collected according to the way it is described in the monitoring-plan. In this plan potential changes can be made if deemed necessary (see also loop 1)
4. Analyzing and interpreting the collected data; The collected data will be analyzed and then reviewed by an independent person/group in order to prevent bias.
5. Evaluating the data and integrate results in future approaches; As a final step, the results need to be evaluated and integrated within practice. Based on these results choices for new interventions (if necessary) can be made. In this process also attention needs to be given to potential alternative interventions (loop 2) or whether the goal for which these interventions are taken is still 'appropriate' (loop 3).

An important addition that we add to existing methods is the inclusion of the social context in which decision-making is taking place. This is not linear but rather the result of a consensus that is formed between different stakeholders. For this reason, we argue for discussions between these stakeholders to develop plans and products that are supported by all involved partners. This also promotes the support amongst stakeholders for potential results from the monitoring, which in turn eases the discussion for future steps. Additionally, we also observe that made plans in practice don't always match with reality. To this end we support the inclusion of different feedback loops that make this monitoring framework more flexible and adaptive.

In the framework we distinguish the following feedback loops over the course of the monitoring cycle:

- Loop 1: during the data collection it needs to be periodically checked if the indicators provide the correct data. It can occur that the used measurement-methods or indicators in practice do not fit as well as intended. At certain moments in the process (milestone moments) changes can be made to the monitoring-plan if deemed necessary.
- Loop 2: during the evaluation phase it needs to be discussed whether the current measures are providing the expected benefits or if alternatives need to be implemented. The results can show that the taken interventions do not work as intended in practice. In that case, in a next cycle alternatives can be used instead.
- Loop 3: during the evaluation it can be discussed if the effort to solve the problem is still worth it or whether acceptance of the problem might be better. It can happen that the goal for which the measures are taken needs to be adjusted. This can happen when the benefits do not outweigh the costs of reaching this goal

By including these feedback loops, the process of monitoring and adaptation can adjust itself for unforeseen changes when this is deemed necessary.

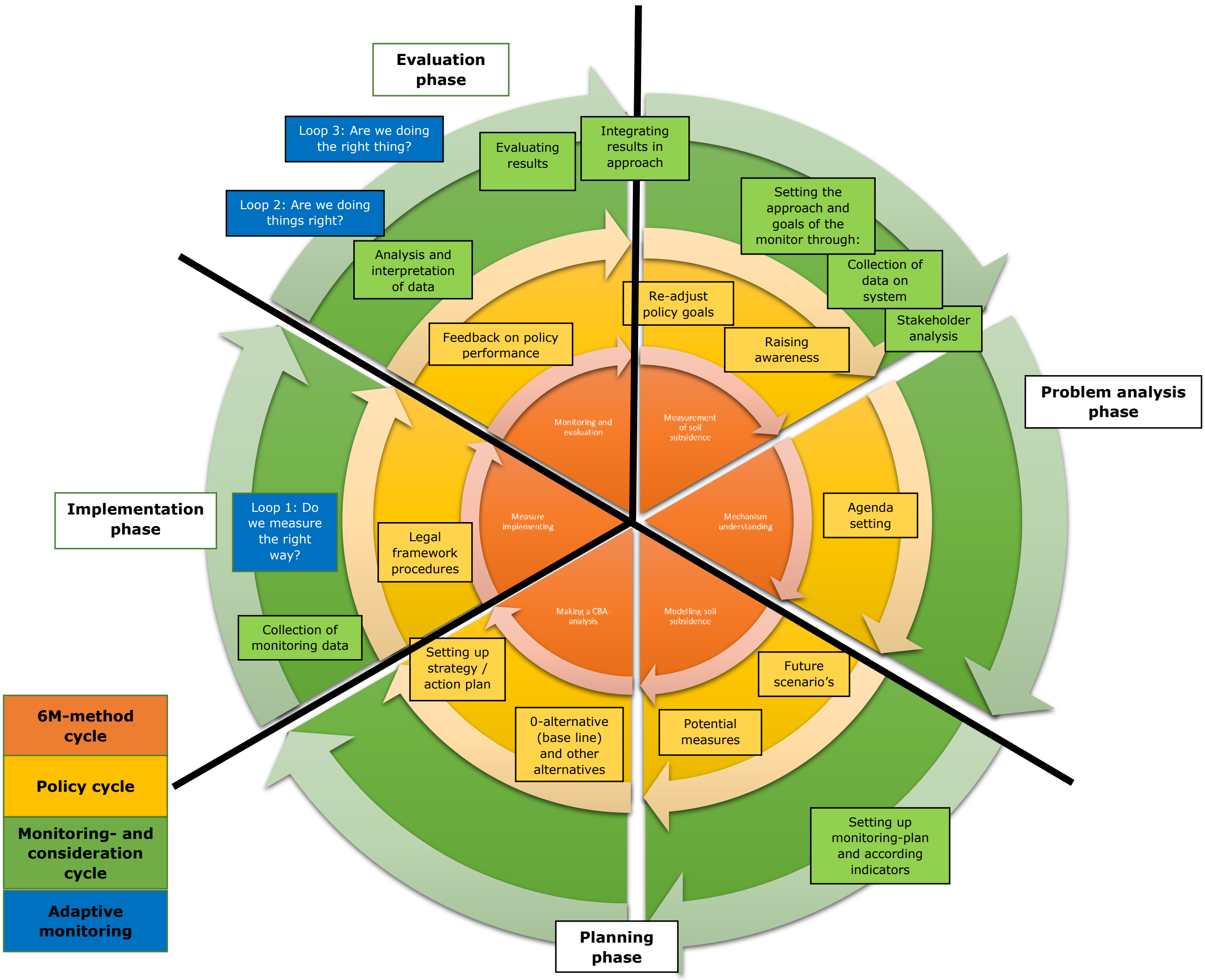

Figure 1 Framework for adaptive monitoring of spatial interventions

Results

The proposed framework for adaptive monitoring is being tested in case studies within the Netherlands: 1) Land subsidence plan for the innercity of Gouda; 2) Climate adaptation plan in Súdwest-Fryslân.

Case study 1: Gouda

The center of Gouda is subsiding with approximately 3–5 mm yr^{-1}. Most likely, the subsidence is caused by a mix of compaction of shallow unconsolidated clay and peat layers as a result of urban loading and peat oxidation (van Laarhoven, 2017). Buildings in Gouda predating 1900 are mostly grounded on shallow (footing) foundations which settle along with the foundation depth (i.e. the upper soil). To prevent groundwater flooding subsequent to subsidence, the groundwater level has been artificially lowered a few times in the past by lowering the city canal water level. However, from 1900 onwards, building on timber pile foundations became common practice in the region – to be replaced around 1950 by concrete piles. Further lowering of the groundwater level, though desirable from the perspective of pluvial flood risk reduction, is expected to cause significant damage to timber pile constructions due to fungal degradation, which initiates after the normally inundated timber is exposed to oxygen.

Since 2014, the municipality of Gouda has been conducting research into subsidence together with the Rijnland Water Board and other partners like Deltares. In the autumn of 2020, the city council of Gouda and the joint meeting of the Rijnland Water Board adopted the Soil Subsidence Inner City Framework Plan (Gemeente Gouda & Hoogheemraadschap Rijnland, 2020). The implementation of this plan started in January 2021 with the aim of gradually lowering the level by 25 centimeters from 2024. Monitoring is also part of this implementation. In this research we tested the framework and reflected upon the first draft of the monitoring plan.

Case study 2: Súdwest-Fryslân

The municipality of Súdwest-Fryslân (SWF) is active in creating a climate robust and attractive environment for its citizens and companies. For this aim a roadmap to a climate-proof Súdwest-Fryslân is developed to further explore a supported approach and implementation of climate adaptation (Omgevingsprogramma Klimaatadaptatie Súdwest-Fryslân, 2022). The roadmap consists of the cyclical recurring steps necessary to boost climate adaptation and to monitor and direct the implementation of climate adaptation until 2050. The framework presented in this paper will be used to formulate the monitoring plan for SWF.

Conclusion

This paper presents a framework for adaptive monitoring of spatial interventions, such as land subsidence. This framework is currently being tested in two case studies in the Netherlands. First results show that the framework is helpful in setting up adaptive monitoring for a spatial intervention such as dealing with subsidence.

References

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