

This policy brief describes briefly the challenges and the actionable approaches to counteract subsidence. Recommendations are made on policy and governance, technology, capacity building and financing aspects.

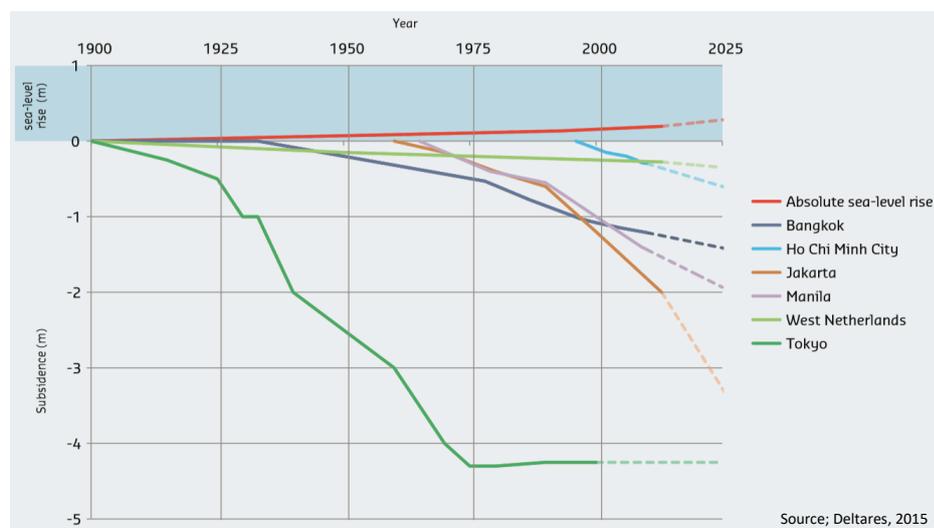
Subsidence is a huge challenge

Key messages:

- There is abundant evidence that subsidence is a big challenge worldwide, especially in urbanizing deltas and coastal zones;
- Without proper measures many cities will sink below sea level resulting in increased flooding, loss of lives and huge damage
- The impacts of subsidence are further exacerbated by extreme weather events (short term) and rising sea levels (long term)
- Subsidence is a versatile, interlinked issue: multi-sectoral, multi-level and multi-stakeholder; a major rethink is needed to deal with the often ‘hidden’ but urgent threat of subsidence

IPCC and OECD identified coastal cities and the larger deltas around the world as most vulnerable environments threatened by climate and human-induced changes, resulting in increased hazards and displacement risks for 0.5 billion people. In many delta cities land subsidence exceeds absolute sea level rise up to a factor of ten by excessive groundwater extraction related to rapid urbanization and population growth. Without change, parts of Jakarta, Ho Chi Minh City, Bangkok and numerous other delta (and coastal) cities will sink below sea level. Increased flooding and also other widespread impacts of land subsidence result already in damage of billions of dollars per year.

Current global mean absolute sea level rise is around 3 mm/year. However current observed subsidence rates in coastal megacities are in the range of 6-100 mm/year and projections till 2025 expect similar subsidence rates, depending on future measures.



Subsidence for several coastal cities compared to absolute sea level rise in the same time period (please note that average subsidence values are presented as subsidence can differ considerably at local scale, depending on groundwater level and subsurface characteristics)

Policy and governance aspects of subsidence

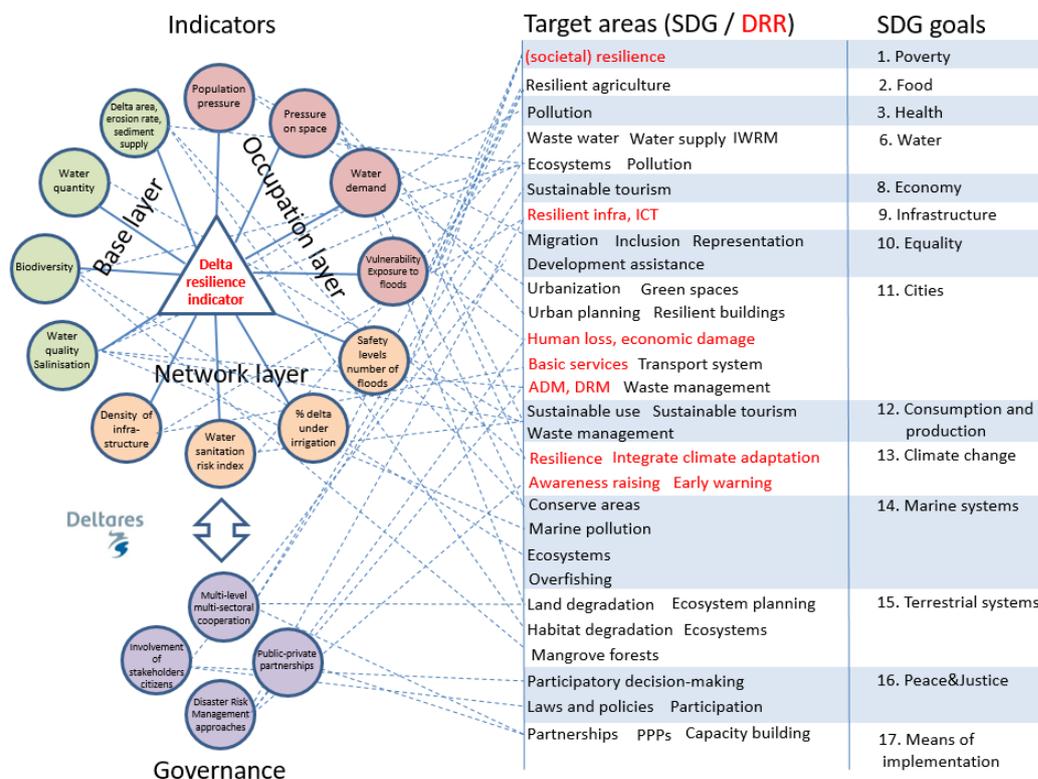
Key messages:

- Subsidence is not mentioned in the global agendas (such as Agenda 2030, Sendai Framework for DRR) and often also not addressed in national or local policy agendas
- Subsidence is often a 'hidden' policy issue, not fully recognized or acknowledged
- In many cases there is a lack of a comprehensive subsidence strategy and approach, no multi-sectoral cooperation, no legal framework nor specific instruments, which hampers setting of clear policy targets and implementation of measures to mitigate subsidence
- An organizational structure with clear roles and responsibilities regarding subsidence issues is often non-existent or not sufficient, thus undermining planning and action

Subsidence is not directly mentioned in the global agendas (such as Agenda 2030, Sendai Framework for DRR), however there are many clear linkages with those policy agendas and targets, see figure below. The Delta Coalition and Delta Alliance are taking up the challenge to address subsidence in a broader context.

The Delta Coalition is world's first international coalition of governments that have formed a partnership to deal with the challenges in deltas and to make deltas more resilient. Fast, informal, and flexible, the coalition facilitates discussion, exchange, innovation and creativity between the participating members and observers. This government lead and multi-stakeholder initiative aims to get things done to improve and protect lives in urbanising deltas (see also www.deltacoalition.net)

The Delta Alliance is an international knowledge-driven network organisation with the mission of improving the resilience of the world's deltas, instrumental to the Delta Coalition. The Delta Alliance addresses this by collecting and updating the knowledge base on the state, risk and future scenarios of these dynamic and socio economically critical coastal areas and their cities (see also www.delta-alliance.org).



Main linkages between target areas of SDGs and delta challenges (including subsidence), elaborated into specific 'delta resilience sub-indicators' for several spatial layers (occupation, network and base layer) and governance aspects (Source: Deltares, 2018)

Comprehensive approach towards solutions

Key messages:

- An integrated framework is needed to address all aspects of subsidence, incorporating technical as well as governance aspects, multi-sectoral cooperation and stakeholder involvement at all scale levels
- Actionable and sustainable interventions should be based on an integrated (stepwise) approach and built on sound delta system knowledge, understanding of the complexity and dynamics
- Good case examples are available with lessons learned (good and bad) to be built on (see also Sinking Cities II brochure)
- The Delta Alliance can be instrumental in knowledge exchange and addressing knowledge gaps regarding subsidence in a broader perspective of delta management (see also Delta Alliance toolbox <http://www.delta-alliance.org/toolbox>)

In ever more densely populated and subsiding deltas, the close interconnections between groundwater management, surface water quality, climate change, river basin management, coastal zone management and integrated landscape management are key in long term integrated planning, addressing subsidence in a much needed broader perspective.

The (policy) development path that cities could follow, from problem identification to planning and implementation of solutions and their evaluation, will be much supported by an integrated approach. This is elaborated in the figure below, through a stepwise approach based on Measuring, Mechanisms, Modelling, Measures (incl. cost/benefit analysis, decision support, implementation), Monitoring and evaluation.

The Sinking Cities II brochure features several specific case study examples illustrating actionable and sustainable interventions based on an integrated approach.

Policy cycle	Questions to address	Step-wise approach		Products
		Technical aspects	Governance aspects	
Problem analysis	<ul style="list-style-type: none"> • How much subsidence is there? Are people aware of this? • What is impact of subsidence • What are the causes? • Who is involved and responsible? 	1. Measuring <ul style="list-style-type: none"> • Measurement data collection • Impact assessment 2. Mechanisms <ul style="list-style-type: none"> • Data analyses to disentangle subsidence causes 	<ul style="list-style-type: none"> • Awareness raising • Stakeholder analysis • identification of problem owners 	<ul style="list-style-type: none"> • Subsidence map with current subsidence rates (+ sum) and impacts • Communication plan • Measuring plan and set-up • Subsidence database with publically available data • Subsidence map with causes of subsidence • Stakeholder mapping
Planning	<ul style="list-style-type: none"> • How much future subsidence is predicted? • What are most vulnerable areas? • What are possible measures? • What are the current and future impacts (quantified and monetised)? 	3. Modelling <ul style="list-style-type: none"> • (Inverse) modelling to make predictions • Scenario constructions / analyses • Modelling / forecasting • Vulnerability assessment • Damage assessment 4. Measures - Cost-benefit analysis and decision support <ul style="list-style-type: none"> • Cost-benefit analyses / multi-criteria analysis of possible measures • Decision support system • Selection of (innovative) measures in an integrated multi-sectoral perspective 	<ul style="list-style-type: none"> • Capacity building / education • Multi-sectoral planning, participation, stakeholder engagement and commitment • Political action, development of policy, strategy and legal instruments • Planning and design of buildings and infra-structure, incl. building codes • Decision-making on implementation 	<ul style="list-style-type: none"> • Subsidence map with future subsidence rates (+ sum) • Vulnerability map • Capacity building plan • Overview of possible measures • Subsidence impact map (current + future) • Decision support tools • Strategy and action plan (including selection of measures)
Implementation	<ul style="list-style-type: none"> • What will be done, how and when and by whom? 	5. Measures - implementation <ul style="list-style-type: none"> • Implementation of measures • Setup monitoring plan • Setting up pilot projects 	<ul style="list-style-type: none"> • Multi-sectoral cooperation / organisational structure • Legal framework / operational procedures / guidelines • Enforcement of laws and regulations • Financing mechanisms / asset management 	<ul style="list-style-type: none"> • Implementation plan (incl. organisation, operational procedures, legal aspects, financing, asset management) • Monitoring plan • Pilot sites
Evaluation	<ul style="list-style-type: none"> • Is the problem under control? 	6. Monitoring and evaluation <ul style="list-style-type: none"> • Monitoring, remodelling • Setup evaluation plan • Compliance checking • Assessment and outlook • Exchange of knowledge and best practices 	<ul style="list-style-type: none"> • Stakeholder evaluations • Public hearing 	<ul style="list-style-type: none"> • Evaluation plan (technical and socio-economic) • Best practices • Knowledge exchange plan

Integrated framework and stepwise approach addressing all aspects of subsidence, incorporating technical as well as governance aspects (Source: Deltares, 2018)

Recommendations

Technology

- Knowledge agendas and collaborative research on subsidence, should be jointly developed with all stakeholders involved, supported by international network organizations such as the Delta Alliance
- In-depth knowledge about subsidence is needed to further develop models and tools in order to assess and forecast subsidence and their impacts, and the effects of proposed mitigative measures
- Systematic monitoring should be well organized and data should be reliable and easily accessible
- During underground construction activities (those for deep parking lots or metro-stations or involving tunneling), the effects of de-watering should be minimized, well monitored and mitigated if needed
- Artificial groundwater recharge should be further developed and implemented

Policy and governance

- A clear policy framework and appropriate legislation on subsidence issues will support the agenda setting, planning and implementation of actions (and enforcement) at national and local level. Network organisations like the Delta Coalition can help to set and develop the political agenda.
- Multi-sectoral cooperation, joint policy development, coordination and participation of all relevant stakeholders is needed for good governance and institutional arrangements on subsidence
- Responses and solutions should be identified in a (policy) context of sustainable natural resources management, climate change scenarios, and socio-economic developments, and based on an integrated (multi-sectoral) approach addressing also the SDGs and DRR targets
- Making good (future proof) decisions will be enabled by decision support models and tools for selecting the most appropriate adaptive measures (best practices), including their costs and benefits
- Restriction of groundwater extraction is vital for counteracting human-induced subsidence through several policy instruments such as zoning and charges for groundwater use; moreover reduction of water use should be promoted while increasing waste water use and rain harvesting
- In the planning and design of (heavy) buildings and road infrastructure, geotechnical research and modelling of the subsoil should be taken into account in order to avoid subsidence problems

Capacity building

- Awareness raising (as part of a communication plan) and need assessments on subsidence issues are needed for policymakers, decisionmakers and experts from national to local level
- Capacity building on subsidence issues can be strengthened by training programs, workshops, seminars and conferences, supported by international network organizations such as Delta Alliance
- Exchange of knowledge and best practices is important to avoid repetitive problems and duplication of (research) activities, supported by international network organizations such as the Delta Alliance
- Setting up a 'community of practice on subsidence' may deliver added value for all stakeholders

Finance

- Main financial risks and costs/benefits associated with investments and maintenance of assets (buildings, infrastructure) in subsidence-prone areas should be assessed; this can lead to improved design options, programming and prioritization of investments, feeding into asset management
- Financing mechanisms and innovative financial instruments for several types of measures to mitigate subsidence should be further explored and implemented
- There is a need for an integrated economic assessment framework for land subsidence to facilitate damage estimates which in turn will provide input for cost-benefit analysis of solutions

Colofon and references

This policy brief is made by Deltares (T. Bucx, G. Erkens, S. Hommes, S. Kok, G.J. Ellen, C. v.d. Guchte) in cooperation with and supported by the Delta Alliance and its affiliated institutes. The Delta Alliance Wings have provided input through a brief questionnaire (autumn 2018).
References: Sinking Cities brochure, Deltares, 2015, Sinking Cities II brochure, Deltares, 2019; S. Kok, Literature review on economic impact analysis of land subsidence, 2019 (in prep).

Websites: Delta Alliance: www.delta-alliance.org; Deltares: www.deltares.nl