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A game theory based analysis

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On the nature based flood defence dilemma and its Resolution: A game theory based analysis

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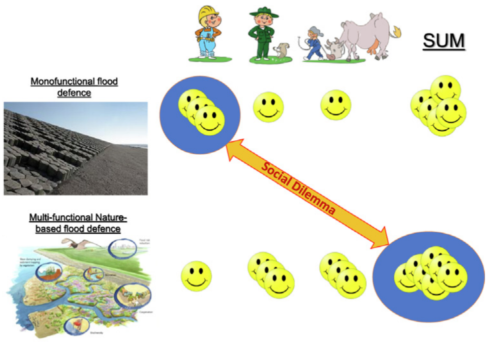
HIGHLIGHTS

- Social dilemma encountered by nature-based flood defences prevents implementation.
- Water authorities gain insufficient benefits from nature-based flood defences.
- Underlying problem of the social dilemma is a fragmented policy landscape.
- Removing flood risk objectives enables nature-based flood defences.
- Interwoven policy domains set a favourable context for nature-based flood defence.

GRAPHICAL ABSTRACT



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ABSTRACT

Nature-based flood defence is an innovative design alternative for achieving protection against flooding. Despite significant advancements in science, models and concepts, routine implementation beyond pilot projects remains limited. To better understand why, we have looked into the complexities of nature-based flood defence implementation and its resolutions, modelling decision-making situations using game theory in three nature-based flood defence cases: The Markermeer Dikes, the Afsluitdijk Dam and the Sand Engine. We observe that nature-based flood defence games are of a multi-level and nested nature. While the decision of whether to employ a nature-based flood defence is seemingly made at the project level, this can only happen when it is coherent with the institutional context that is determined at the policy level. A social dilemma is apparent: while a multi-functional nature-based solution is attractive to a coalition of actors, it is not the most beneficial option for individual actors. Hence, they are faced with the dilemma of opting for their maximum benefit or opting for the greater societal benefit which is less favorable to them. This social dilemma can be tackled by making 'smart moves', as inspired by the Sand Engine case. The nested nature of the problem requires structural change in the institutional context to enable favourable conditions for nature-based flood defence implementations.

1. Introduction

Nature-based flood defence is an innovative design alternative for achieving protection against coastal or fluvial flooding. Instead of conventional flood protection approaches, such as dike

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reinforcement, dike heightening or dike enlargement, flood protection levels are improved by using natural dynamics and materials (Waterman, 2010, de Vriend et al., 2015). The idea is that such an approach not only enhances flood defence levels, but also that other functions such as nature, economy and recreation can benefit. Nature-based flood defence falls under the umbrella of nature-based solutions as put forward by the IUCN. Nature based solutions are 'actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits' (IUCN, 2016). Nature-based flood defences can take many different forms; examples include oyster reefs, mussel beds, vegetated foreshores and sand nourishments, cyclic floodplain rejuvenation, managed realignment and mangrove restoration (Baptist et al., 2004; Borsje et al., 2011; French, 2006; Vreugdenhil et al., 2010; Van Wesenbeeck et al., 2014). Vegetated foreshores often function as flood defences in combination with existing hard structures such as dikes, where the vegetation on foreshores can absorb wave energy, counteract erosion and facilitate sedimentation processes (Moller et al., 2014; Gedan et al., 2011). Under suitable hydrodynamic and sediment supply conditions, a foreshore may be able to adapt to rising sea levels.

Nature-based flood defences and similar ecosystem based management approaches have been attracting increasing global attention over the last decade and the scientific field has progressed significantly. For example modelling tools and nature-based flood defence concepts for different coastal systems have been developed (e.g. Temmerman et al., 2013; Bridges et al., 2015) and educational material is now widely available (Slinger, 2015, 2016). Government authorities in many countries including USA, Indonesia and Europe are interested in furthering possibilities for implementation and several large scale pilot projects have been implemented (Van Thiel der Vries et al., 2012). Examples include the Hondsbossche and Pettemer Zeewering in The Netherlands and mangrove restoration in Demak, Java.

Despite the recent advancements, routine implementation beyond pilot projects remains limited. Decision making is complicated for at least two reasons. First, nature-based flood defences are a new type of solution. Experiences with real-life examples and thus the 'proof of concept' are limited, particularly at a large scale (Temmerman et al., 2013). Furthermore, nature-based flood defences are often associated with significant uncertainties as the designs are dynamic and not static as in conventional flood protection solutions. Second, nature-based flood defences explicitly aim to combine multiple use functions, including nature restoration, recreation and flood defence. Other services like carbon sequestration could also be relevant (Nedkov & Burkhard 2012; Derkzen et al. 2017). While this enables the creation of win–win situations, the actor playing field is also broadened to include a range of actors from flood protection authorities to conservation organizations, agriculture, recreational interests and others (Korbee et al., 2014).

The combination of different types of uncertainties with multiple functions and actors means that nature-based flood defences can be viewed as 'wicked problems' (Rittel and Webber, 1973). Wicked problems, also known as untamed or ill-structured problems (Enserink et al., 2010), are situations where knowledge is uncertain and there is contestation (Douglas and Wildavsky 1982). Science and research cannot be relied upon to arbitrate the conflicts arising within society about the importance of differing objectives and interests. Decision-making around such wicked problems is notoriously difficult and social dilemmas arise (Bisaro and Hinkel, 2016). Such complexities in decision making have been observed for nature-based flood defences (Bontje et al., 2019, Van den Hoek et al., 2012, Oudenhoven et al., 2018). For example, cooperation is not self-evident because both conservation organizations as water authorities have possibilities to achieve their own goals. However, without cooperation both will have a suboptimal result.

In these situations, it is relatively easy to recognise the win/win-potential at an abstract system level, and it is also relatively easy to recognise the complexities involved in the joint decision-making required to implement win–win solutions. In this paper, we aim to move beyond this recognition, to identifying some of the conditions and patterns that support the societal interactions in the successful realization of nature-based flood defences. We focus on the interactions between actors in three recent cases in the Netherlands, which, at the early stages of their development, were expected to support nature-based flood defences: The Markermeer Dikes, the Afsluitdijk Dam and the Sand Engine. The analyses of these three cases centers around the question of how actor interactions took shape to deal with the uncertainties and conflicting values, to help uncover some of the mechanisms and conditions underlying potential solutions to such difficult nature-based flood defence decision situations.

2. Materials and methods

2.1. Decision making for nature-based flood defences: Uncertainties and multiple functions involved

Decision-making around the implementation of nature-based flood defences is complicated by their associated uncertainties and the combination of multiple functions. They differ from standard infrastructure in that they are not finished after construction but continue to develop (De Vriend et al., 2015). Uncertainties derive both from their dynamic nature and the fact that this new type of solution still embodies many unknowns (Bouma et al., 2014). Even if some of the knowledge gaps were filled, others would remain owing to the dependency of nature-based solutions on local environmental and hydrodynamic circumstances. There is no such thing as a 'standard' design. For example, vegetation types on foreshores in the Netherlands range from willows and reeds in fresh water environments, to grass weed in brackish environments and cord grass in saline environments (Borsje et al., 2014). In more tropical coastal environments mangroves form an important vegetation type. In addition to the diversity of vegetation types that can be used, uncertainties can arise during all phases of the life cycle, not only in the design, but also in the construction and maintenance phases. Acknowledging the different uncertainties is essential for successfully implementing and managing vegetated foreshores (Bontje et al., 2019).

The multifunctional nature of nature-based flood defences is one of their unique selling-points. However, combining nature and flood protection in one design is not self-evident. A nature-based solution for flood protection does not maximise nature value alone nor does it maximize flood protection values alone, rather it is an 'optimal' solution that combines both. To achieve such a solution, actors are faced with making trade-offs between different functions (Van Loon-Steensma and Vellinga, 2013). A classic example is the trade-off between vegetation heterogeneity (preferred by nature parties) and vegetation homogeneity (preferred by flood protection parties, for stability and predictability reasons). A second example of a trade-off is whether to allow natural dynamics or not. From an ecological perspective, the cyclic development of erosion and sedimentation of salt marshes is preferred (van Loon-Steensma and Slim 2012) whereas from a flood protection perspective a stable and predictable area of salt marshes is ideal.

2.2. Multi-actor decision-making in nature-based flood defences: Institutions and actor-interactions

Institutions are social constructs that enable decision-making processes in which multiple actors interact to deal with partially conflicting interests and to resolve social dilemmas (Bisaro and Hinkel, 2016). Institutions function as "the prescriptions that humans use to organize all forms of repetitive and structured interaction" (Ostrom 2005, p.3). The institutional setting does not just affect interactions among actors, institutions also "constitute [s] composite actors, create and constrain options, and shape perceptions and preferences" (Scharpf 1997, p.42). The institutional setting refers to the set of formal and informal rules that are in use, including legislation, agreements, official project objectives and evaluation criteria, contracts and tacit rules such as cultural conventions and norms. Therefore, studying actor interactions around nature-based flood defences is helped by using an institutional lens.

Actors interact within institutional settings. An often-used metaphor for such interactions is that of games (Scharpf, 1997; Ostrom, 2005; Hermans and Cunningham, 2018). Within an institutional setting, different actors or players are involved, with different resources, different values and preferences, and different world views and perceptions. Resources relate to the means an actor has to enforce a particular strategy and can include legal, financial, human or other resources. Values translate into more specific actor preferences and are reflected in the actors' objectives beyond a particular problem situation. The perception refers to the problem formulation of actors but also to their beliefs about cause-and-effects related to more technical matters. Guided by the institutional rules of the game, these actors can then be seen to engage in cooperative or non-cooperative games, to try to achieve satisfactory outcomes (Scharpf, 1997; Ostrom, 2005; Hermans and Cunningham, 2018). Fig. 1 below illustrates this view of multi-actor decision-making within institutional settings, based on the work of Scharpf (1997).

Fig. 1 depicts institutional settings as external to the games of actors, which in turn result in outcomes that affect a biophysical and material environment. However, these institutional settings themselves are also the result of actor interactions and 'games'. Institutions change over time, either as result of a conscious new design, or through a process of emergence. This means that multiple institutional levels exist, within which actor interactions take place. For instance, if actors see that certain flood protection norms are no longer sufficient to deal with sea level rise, they will try to change the norms to guide future decisions. The result is a multi-level institutional system where lower level games are nested in higher level structures (Ostrom, 2005). We thus expand the actor-centered conceptualization of Scharpf (1997) with the notion of multi-level institutions of Ostrom (2005) and others. For nature-based flood defences, this means that games take place both at the project level around their design and construction, and at the policy level that shapes the institutional context for these projects.

2.3. Case study research

Case study research is a suitable approach for studying real-life and complex phenomena (Yin 2009) such as nature-based flood defence projects. We have conducted an ex-post analysis of three Dutch flood defence projects with the potential for the implementation of nature-based solutions: the Markermeer Dikes, the Afluitdijk Dam and the Sand Engine (see Fig. 2).

The Markermeer Dikes, concerns 33 km of dikes along Lake Markermeer that required reinforcement. Instead of heightening the existing dikes, the waterboard HHNK proposed a foreshore consisting of soft sandy material located within the lake in front of the existing dike in 2009 (Van der Linde et al., 2012).

The Afsluitdijk, is a 32 km long closure dam constructed in the north of the Netherlands in 1932 to close off the Zuidersea, forming Lake Ijsselmeer. More than 80 years later, the closure dam needs a serious make-over to ensure future protection against flooding. A project was initiated in 2007 with the ambition to not just renovate the dam for flood protection purposes, but to do 'more' (Rijkswaterstaat et al., 2009). Here the 'more' referred to integrating across nature, sustainable energy, mobility, economy and landscape values.

The Sand Engine is a mega-nourishment along the Dutch North Sea coast. Instead of multiple nourishments at different locations along the coast to combat erosion processes, an innovative approach involving placing a large volume of sand in one location was agreed in 2008: the 'Sand Engine'. A mega-nourishment at one location and the subsequent natural dispersion of sand to adjacent areas along the coast would reduce ecological disturbance, stimulate natural processes such as dune growth, and could benefit recreation. In contrast to the Markermeer Dikes and Afsluitdijk Dam, the Sand Engine was initiated as a pilot project.

In the three cases studies recurring players are identified: 'the Ministry of Infrastructure and Water' (hereafter referred to as the ministry), with overall responsibility for flood risk management[1]; the national operational water authority Rijkswaterstaat and the regional water authorities (water boards) who share the responsibility to maintain dikes and coastlines to meet predetermined flood risk levels; and the Provinces who are responsible for spatial planning and development at the regional level. Furthermore, in the Afsluitdijk project, private companies play a role in determining the design solutions considered.

Data on the three projects were collected in earlier work through in-depth examination of documents, participant observation and interviews (Janssen et al., 2014a; Janssen et al., 2014b; Janssen 2015). The interviews yielded data on who was involved, their resources, perceptions and preferences regarding different flood defence alternatives. The analysis of these data sources supplied the information needed for the modelling of actor-interactions (e.g. stakeholder-based rankings, payoffs). The information was cross-checked with the stakeholders and was enriched during discussions with participants in various meetings related to the "BE SAFE" project. This provided the basis for the game models as presented in this paper.

2.4. Modelling and analysing actor-interactions

Following Scharpf (1997) and Ostrom (2005), game theory models offer an appropriate modelling tool to analyse actor interactions for such strategic situations. In our analysis, we opted for a detailed representation of the games being played, using non-cooperative game theory. Game models represent the players, the set of possible moves for each player, possible outcomes and the payoffs each player receives for a certain outcome (Straffin, 1993; Scharpf, 1997; Rasmusen, 2007; Hermans and Cunningham, 2018). For each case study we identify essential stakeholder dynamics affecting whether or not NBFD solutions are selected. This involves identification of the players, their possible moves, and the possible outcomes of the situation. The next step is identification of the values, or payoffs, that stakeholders assign to the different outcomes. This is done by first identifying the evaluation criteria used by that player and the relative weight of the criteria, second scoring the outcomes for each criterion, third averaging the outcomes for all

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[1] Ministry of Infrastructure and Water: note that the name of this Ministry has changed several times over the last two decades.

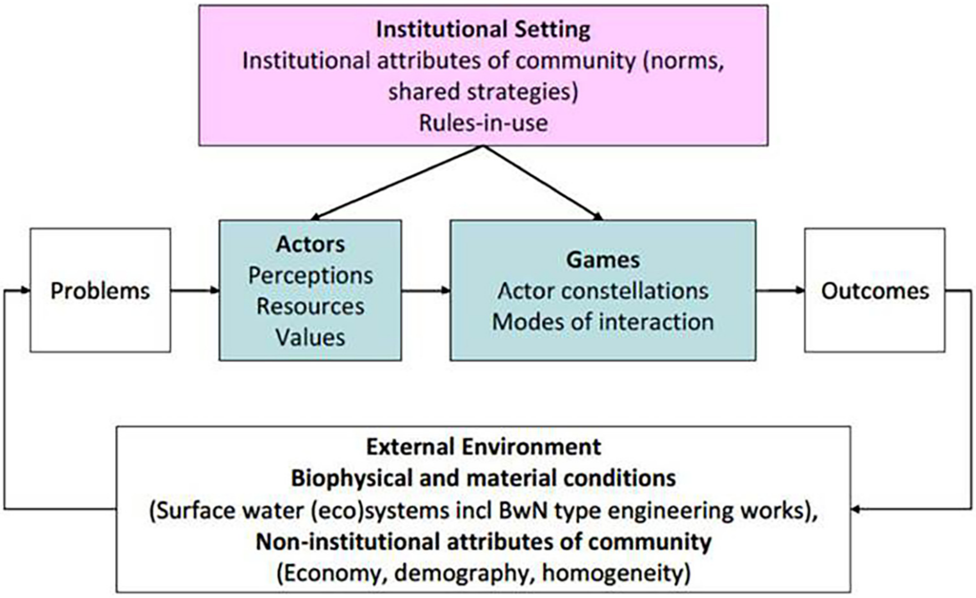

Fig. 1. Multi-actor decision-making in nature-based flood defences (adapted from Scharpf, 1997.

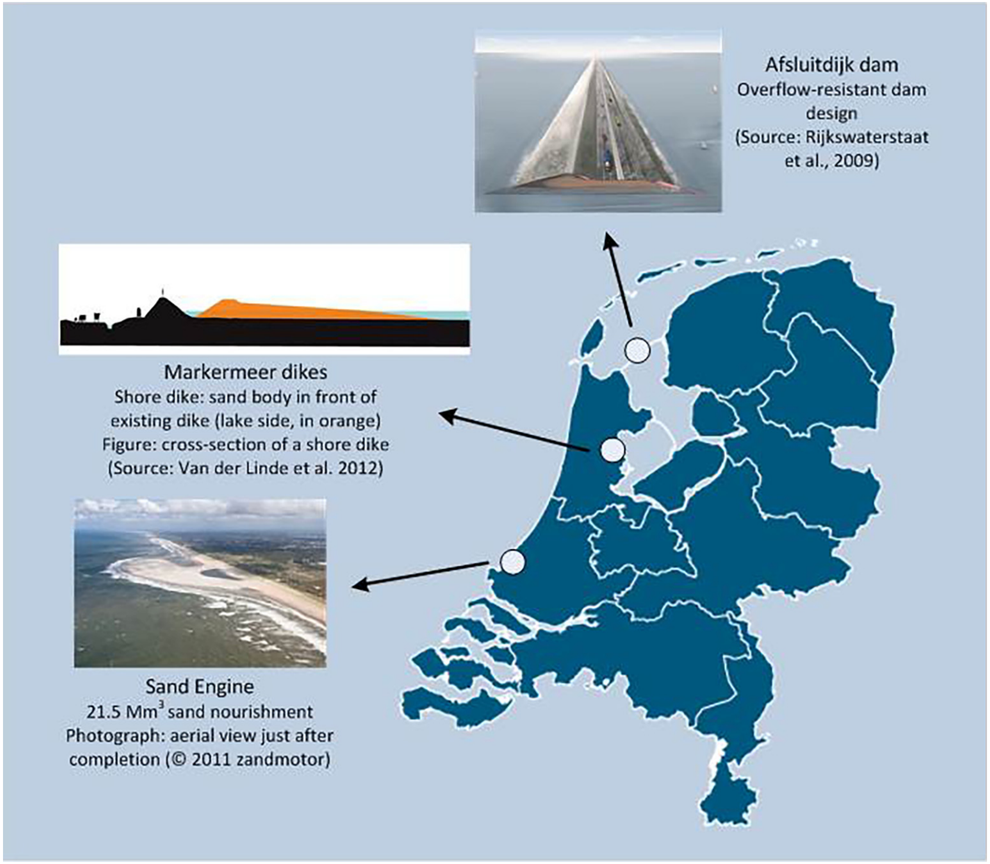

Fig. 2. The locations of the three case studies in the Netherlands.

criteria, and lastly ordering the outcomes from most '1' to least '4' preferable outcome for that player (Janssen and Hermans 2017). The games are represented in a game matrix. A game matrix provides an overview of the players and their options, for example the players can choose between a single or multiple objective infrastructure. Each cell represents a move. In the cells the payoffs to each player can be found. For example (1,4) in a cell means that the option is preferred by the first player (payoff is ranked 1) and has a low preference value for the second player. A player's strategy is the rationale by which the player selects their moves given certain circumstances in the game (e.g. when the other player chooses outcome A, then I choose outcome B, and when the other player chooses outcome B then I choose outcome A).“

When the game model is completed, the game is analysed using the game concepts of dominance and social optimum (Straffin, 1993; Rasmusen, 2007). A player has a dominant strategy when, regardless of the action of other players, the strategy yields the highest payoff to the player (i.e. always choose outcome A). When both players have a dominant strategy, the game has an equilibrium outcome. The second analysis step involves looking at the desirability of the outcomes, for that we look into the social optimum, which is the maximum utility for all players. When the equilibrium outcome is different from the social optimum, a social dilemma exists.

Central assumptions in game theory models are that players strive to maximise their individual utility, behave in a rational manner, and do not enter into binding agreements. These assumptions do not necessarily reflect reality and are debated at length in literature on game theory. Empirically oriented political scientists, economists and institutional scholars conclude that, despite these obvious simplifications, game theory models still offer a powerful means of understanding strategic decision making situations (e.g. Scharpf, 1997; Ostrom, 2005; Schelling, 2010). In this sense, game theory models are no different from other models in providing simplifications of reality. This also means that the limitations of game theory models should be realized and observed (Hermans and Cunningham, 2018).

This results in arguments of game theory models as ‘exemplifying theory’, which can help us reason about situations that might be true, and the conditions under which they might be true (Rasmusen, 2007). We use game theory models in this way: not claiming precise predictive value, but to structure information we have about past events, in a way that helps us to understand the conditions under which certain nature-based solutions might be expected as the outcome, and the conditions under which this outcome is implausible.

3. Results from the case studies

3.1. Policy level games

3.1.1. Markermeer policy level game

The Markermeer policy level game determined the institutional context for the Markermeer Dikes project. A critical decision at this level was whether the dike reinforcement project should have a single objective (flood protection) or a double objective (flood protection combined with improving the ecological quality of the lake). The Markermeer game model (Fig. 3) reveals a dominant strategy for the regional water authority to prefer a single-objective project (as noted in Fig. 3, matrix 1 cells B and D), regardless of any move by the ministry. The regional water authority was concerned with providing timely flood protection as well as acquiring budget for this from the national dike reinforcement programme (“HWBP” is the Dutch acronym). For the water authority, introducing a double objective would increase the risk of project delay. Moreover, functions other than flood protection are not subsidised by the national programme. The Ministry preferred a double objective if the regional water authority would agree. They could propose a double-objective project to the regional water authority or alternatively initiate a parallel nature-based project. Anticipating the dominant strategy of the regional water authority, the ministry’s best move was to opt for a parallel nature-based project and so possibly still to influence the flood protection project positively. Following the dominant strategies, the game leads to the equilibrium outcome ‘D’, which is also a social optimum: a “single-objective flood protection project, with a parallel nature-based flood defence project”.

In reality, the Ministry first proposed a double project objective, which was rejected by the regional water authority. Later in the process, the players agreed to cooperate in parallel trajectories: outcome D.

3.1.2. Afsluitdijk policy level game

Similar to the Markermeer policy level game, the critical decision in the Afsluitdijk policy level game was whether the project should have multiple objectives or a single objective for flood protection. Rijkswaterstaat could adopt a single- or multi-objective project, while the Provinces could participate in the project or run a separate project to realise their ambitions. The game model (Fig. 3) shows that Rijkswaterstaat has a clear dominant strategy to always prefer a single-objective flood protection project over a multi-objective project (Fig. 3, second matrix, cell B or D). The Provinces value an integrated multi-objective Afsluitdijk project, in which they could also achieve their regional development aims (Fig. 3, second matrix, cell A). So, in response to the dominant strategy, the provinces do best to opt for a separate project on regional development, in parallel with the flood protection project. The equilibrium outcome of this game is Outcome D: a ‘single-objective project, with a parallel provincial project’. Outcome ‘A’ is the social optimum in this game: a ‘multi-objective project’ provided maximum utility for all players, however, this outcome was not achievable.

In reality, Rijkswaterstaat promoted an integrated multi-objective approach at the start, but when budget, time-planning and other implications became apparent, Rijkswaterstaat chose for their mandated task of flood risk management. They then stated that they would not want to include other aims, unless a detailed plan and associated budget were available. The provinces left the project, initiating alternative trajectories to achieve their ambitions for regional development.

3.1.3. Sand Engine policy level game

The Sand Engine policy game was about joining forces in a multi-objective project or alternatively realizing separate goals through separate project trajectories. The Ministry could invest in a multi-objective Sand Engine or alternatively, conduct innovative experiments in long-term coastal management using a single-objective approach. Similarly, the Province could participate by investing in a multi-objective Sand Engine, or alternatively look for separate ways or locations to improve the coastal quality.

The Sand Engine policy level game model (Fig. 3) shows that the dominant strategy for the Province was to participate in a multi-objective Sand Engine (Fig. 3, third matrix, cell C). The Province was concerned with the provision of a high-quality living environment with flood protection and space for nature and recreation. Coastal quality would benefit from a multi-objective Sand Engine, given that the opportunities to realise nature and recreation area elsewhere were limited. To the Ministry, a single-objective approach to testing the Sand Engine concept was most attractive, because such a Sand Engine innovation could be designed to contribute optimally to coastline management (Fig. 3, third matrix, cell B or D). However, the Ministry also valued an integrated multi-objective approach, but only on the condition that others co-financed functions other than flood defence. So, in response to the move of the province, the Ministry participated in the multi-objective Sand Engine. This results in equilibrium outcome A which is also the social optimum.

In reality, the Ministry and Province agreed to cooperate on the Sand Engine in 2008 by means of an ambition agreement. The formal financial commitment was not made by the Ministry until the Province formally committed finances.

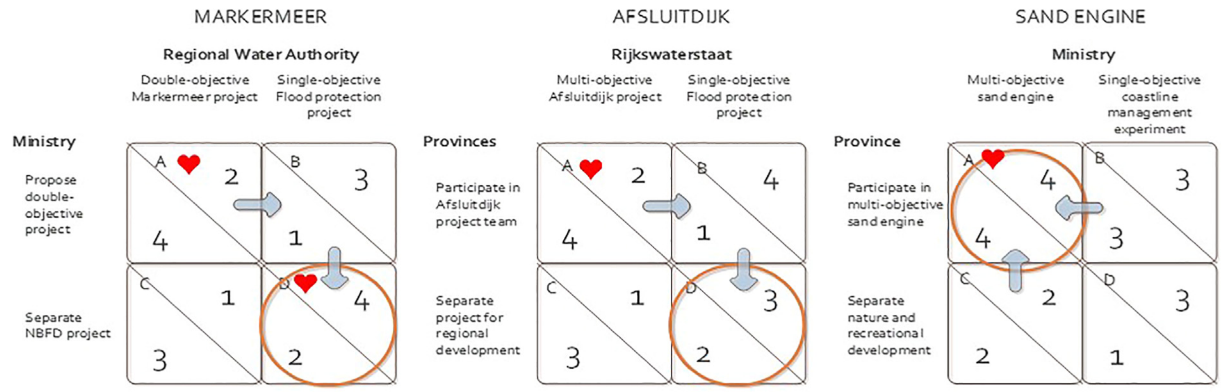

Fig. 3. Three policy level games. The arrows represent the moves taken in reality. The circles indicate the outcome in reality whereas the hearts represent sociall optima.

3.2. Project level games

3.2.1. Markermeer project level game

The Markermeer project level game concerns the design rationale applied to the innovative foreshore dike. In designing this concept the regional water authority could apply conventional flood protection principles that emphasize stability and predictability, resulting in a design of a shore dike without vegetation cover, or select a 'nature-based' approach, which incorporates natural dynamics and vegetation cover. The Markermeer project level game model (Fig. 4) shows that the dominant strategy for the regional water authority was to apply a conventional design rationale as it was expected that this was the most reliable way to achieve flood protection (Fig. 4, first matrix, cell B or D). The Ministry, in a parallel nature-based project, could promote a nature-based foreshore design (Fig. 4, first matrix, cell A) or, second best, focus on additional ecological benefits of a conventional design (Fig. 4, first matrix, cell C). The Ministry opted for additional ecological value to improve the quality of the lake. A conventional dike making no contribution to the natural quality of the lake was of limited value for the Ministry. This leads to the equilibrium outcome in the game: 'D'. The social optimum however, is outcome 'A', where both parties focus on a nature-based design.

In reality the regional water authority designed a conventional and non-dynamic foreshore, while the Ministry mainly looked into ecological benefits while neglecting interaction with flood protection.

3.2.2. Afsluitdijk project level game

The Afsluitdijk project level game concerns the design assessment rationale applied to evaluate the different designs developed by private consortia. The project level game was played while the policy level game was not yet concluded.

Consortia, composed of contractors, consultants and architects, were invited to develop 'an integrated vision for the Afsluitdijk'. Each consortium aimed at delivering the most attractive design to the project team. However, this 'attractiveness' was as yet undefined. They could focus on 'feasibility' or alternatively on 'innovativeness'. In assessing the different designs the project team could evaluate the visions from an integrated perspective, considering the Afsluitdijk as an important location for innovation with potential worldwide exposure as a national icon, or go 'small' and consider the Afsluitdijk merely as a flood protection barrier, using conventional approaches to evaluate the visions in terms of flood protection, costs, and environmental impacts separately. The Afsluitdijk project level game model (Fig. 4) shows that the project team has a dominant strategy to evaluate designs using a conventional approach (Fig. 4, second matrix, cell B or D). Since the consortia 'move first', and they do not have a dominant strategy, the game does not have an equilibrium outcome. The social optimum outcome in the game is 'D', where consortia aim at feasibility and the project team evaluates conventionally.

In reality, the consortia opted for an integrated and innovative vision, since the project team had communicated their desire for an integrated approach. However, the visions were judged on separate components using more conventional assessment methods: outcome B.

3.2.3. Sand Engine project level game

The Sand Engine project level game concerns selecting the preferred design: a multi-functional design serving flood risk management as well as nature and recreation goals, or an underwater nourishment as a single-function design only relevant for flood safety and coastline management. This game was played when the policy level game was unfinished. Rijkswaterstaat, responsible for the operational part of the Sand Engine on behalf of the Ministry, could either support the peninsula or the underwater nourishment. The Province could opt for a multi-functional peninsula or alternatively withdraw from the project since an underwater nourishment did not serve any functions of interest to the province.

The Sand Engine project level game model (Fig. 4) displays a dominant strategy for Rijkswaterstaat: the underwater nourishment was most attractive as risks are lowest and the cost-benefit ration highest (Fig. 4, third matrix, cell B or D). However, Rijkswaterstaat depends on the Province to withdraw from the project. The Province was concerned with visibility of the nourishment and its value for nature and recreation. A withdrawal would be unattractive. Outcome 'A' a 'multi-functional peninsula' was the outcome of this game.

In reality, Rijkswaterstaat was unable to opt for an underwater nourishment as the Ministry had made agreements with the Province in the higher level policy game which obliged Rijkswaterstaat to participate in a design the Ministry had selected. The game has two social optima: outcome 'A' and outcome 'D'.

4. Discussion

We identified games at two levels in three cases, with the policy level games providing the institutional context for the project level games. Nature-based solutions typically require actors to pool resources in larger multi-objective initiatives, which bring most benefits to society. However, in two out of three games, the decision fell upon single objective projects and the actors concerned proceeded to develop separate projects.

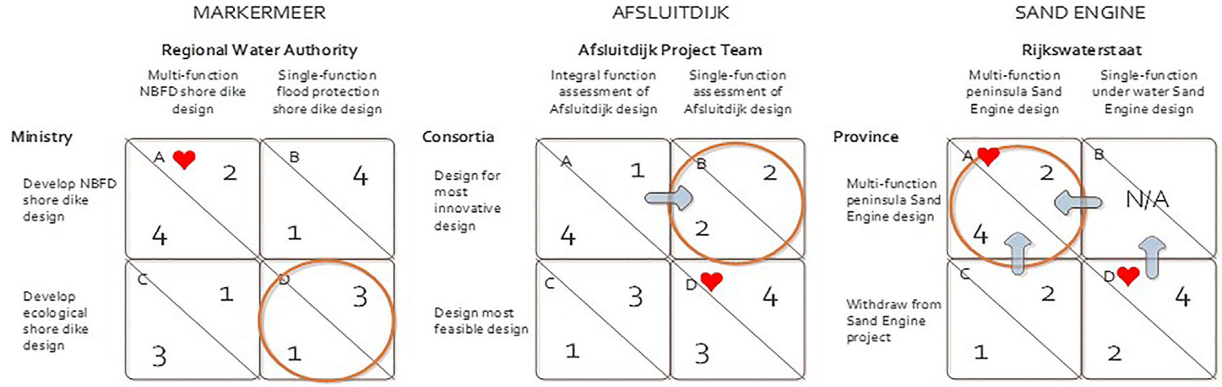

Fig. 4. Three project level games. The blue arrows represent the moves taken in reality. The circles indicate the outcomes; the hearts represent the social optima in the games. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4.1. Nature-based flood defences as a multi-level problem in a fragmented policy landscape

The policy games are about the decisions of actors for multiple or single objective projects and whether to participate in such a project or to develop separate parallel projects to meet individual objectives. In addition, at the policy level decisions were made about whether the project would be initiated as a regular project or as a pilot project enjoying a greater degree of freedom. These decisions have not been discussed separately in our game models, but the Sand Engine was initiated as a pilot project, while the other two were initiated as regular projects within the existing policy frameworks and programmes.

In contrast to the policy level games, the project level games focused on the specific flood defence designs. In two out of our three cases, the outcomes of these games were mono-functional rather than the multi-functional nature-based flood defence alternatives. These outcomes to the project level games reflect the struggle embodied in the policy level games: How to accommodate multi-functionality within a fragmented policy landscape?

The nature-based flood defence games are recognized as multi-level and nested. Although the decision of whether to employ a nature-based flood defence is seemingly made at the project level, this can only happen when it is coherent with the institutional context that is determined at the policy level.

Combining the above dimensions, results in four different possible games at project level, as shown in Fig. 5.

A serious challenge for integrated solutions is the fragmentation in the policy landscape (Gaglio et al. 2019). Policy domains are characterized by particular actors, rules, discourse, resources and represent particular knowledge and knowledge processes (Janssen 2015; Van Buuren 2009). The marine and coastal environment in particular is characterized by compartmentalisation that 'has resulted in a patchwork of EU legislation and resultant national legislation' - the 'horrendogram' of Boyes and Elliott (2014). While the divides between spatial planning, environmental protection, coastal defence, mining, fisheries and many other sectors can have benefits in implementing issue-specific policies for which relevant and adequate knowledge and practices are developed, their disadvantages are that actors each develop their own priorities and prefer single objective approaches that their organisations can achieve by themselves (see Taljaard et al., 2012). Budgets are fragmented accordingly and often have limited time frames. This exerts a major influence on the outcomes of policy level games, which set the boundaries for the games by the operational authorities who have to achieve certain targets (e.g. flood defence levels) within a prescribed budget. This fragmented policy landscape hinders the implementation of nature-based flood defences.

4.2. The nature-based flood defence dilemma

This brings us back to the social dilemma of nature-based flood defences. Apart from the Afsluitdijk project level game, the games analysed in this paper show a similar pattern: multi-functional design provides maximum utility for the players, and at the same time this is not attractive for the water authorities. They prefer a mono-objective project as this represents their best chance of meeting their responsibilities in flood risk management. A mono-functional design reduces uncertainties and current financial structures effectively support achieving the single objective. This gives rise to a social dilemma: a multi-functional nature-based solution is attractive to a coalition of actors, but not to the water authority as individual actor. Since water authorities are often the most powerful actor, nature-based flood defences will not be realized as they will prefer the solution that best fits their individual objectives.

Based on pilot project theory (Vreugdenhil et al., 2010, 2012) and our case study observations, both 'smart' moves and structural changes in the institutional context can contribute to resolving the social dilemma.

4.2.1. Smart moves

The Sand Engine case study was the only case study where the social dilemma was effectively overcome. According to our analysis, this happened because the favourable outcome in the policy level game was able to condition the project level game to such an extent that Rijkswaterstaat was overruled by the outcomes agreed to by the Ministry in the policy level game. Three important 'smart moves' were involved: (i) the policy level actors reached an agreement to truly develop a joint initiative (ii) policy level actors decoupled policy-level objectives from operational level responsibilities (i.e. divert from the flood risk objectives), and (iii) the project was implemented as a pilot project.

First, the project was a joint initiative because other parties could contribute financially as well. Joint initiatives are a practical way of bridging boundaries and may serve to enable nature based flood defence. At the same time players need to account for each other's interests, values and working styles to avoid a break up (Vreugdenhil et al., 2009; D'Hont et al., 2014). Second, in the Sand Engine game, the Ministry persuaded the Rijkswaterstaat to cooperate in the project by decoupling the project from their main concern of achieving flood risk standards. Meeting flood risk standards could still be achieved in the regular manner, whereas the Sand Engine was an additional contribution. So in this case, taking

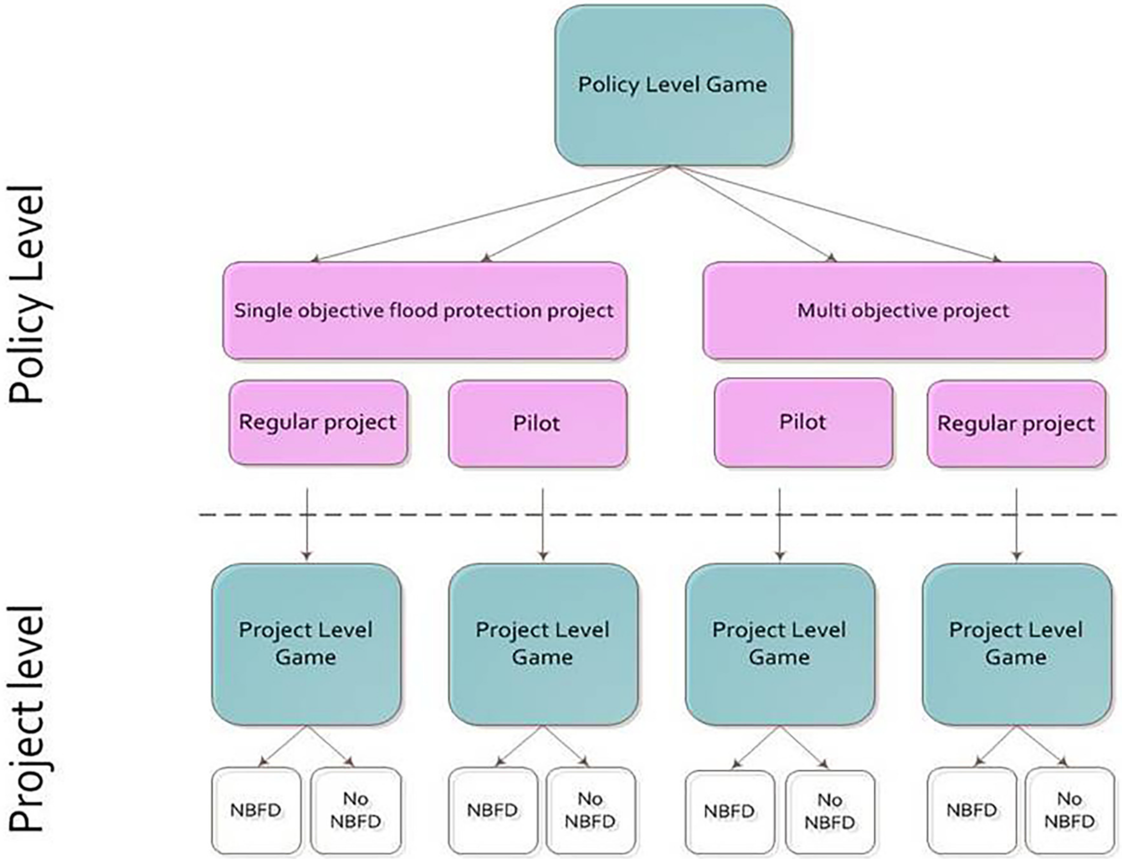

Fig. 5. Refined conceptual model of multi-actor decision making in nature based flood defence (based on Scharpf 1997). Games are played at the policy level and at the project level. The policy level games determine the institutional context for the project level games, in which the specific project solutions are designed (NBFD or not).

standard flood risk management objectives out of the debate paradoxically contributed to the implementation of nature-based flood defences. Third, pilot projects were an important means to enable nature-based flood defence implementation. Pilot projects have more freedom to 'fail' and allow more flexibility for innovations that are difficult to fit within existing institutional structures (Vreugdenhil et al., 2010). Thus, even if nature-based flood defences eventually will need to move beyond the pilot stage, the pilot stage may very well be a necessary interim step before further mainstreaming of nature-based flood defences becomes possible. Pilot projects contribute to knowledge development by testing nature-based flood defences in the real world and can reduce risks for actors enabling them to participate.

4.2.2. Structural changes in the institutional context

Nature based flood defence implementation is a nested problem, so favourable conditions are needed at all institutional levels. At the higher institutional levels this involves interweaving of objectives or crossing boundaries between policy domains, facilitating the movement between a single-objective focus and a multi-objective focus. Accompanying financial structures also need to be aligned to support a multiple objective focus and a longer time span. As such, in the decision making on nature-based flood defence projects, the recognition of multiple objectives, and merging of policy domains is required (Janssen 2015). In water management in the Netherlands, this occurred in the "Room for the River" programme, where both flood protection and landscape values were officially recognized as dual objectives (Rijke, et al., 2012). This programme includes examples where nature based flood defence is implemented (de Vriend et al., 2015). Indeed, both objectives were reflected in the criteria used in decision making, moving nature-based flood defence from an incidental choice to a structural possibility.

5. Conclusions

Choosing for nature based flood defence solutions is not self-evident as it often leads to a social dilemma: nature based flood defence is multi-functional by nature which is attractive for the coalition of actors, however, for individual actors and particularly the water authority it is not. Particularly when the water authority responsible for achieving specific targets in flood risk management is more powerful than others, implementation of nature based flood defence paradoxically becomes highly unlikely. They will opt for the solution that is best for them: the mono-functional solution. Decision making for nature based flood defence implementation is a nested problem. The 'green light' for nature based flood defence at the project level is conditional upon the 'green light' at the policy level, i.e. the institutional context needs to be favourable. De-coupling routine major concerns, such as achieving specific flood protection targets, and (temporarily) tackling uncertainties with the help of pilot projects further encourages nature based flood defence implementation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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