Land Use Policy 113 (2022) 105886

Contents lists available at ScienceDirect

Land Use Policy

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

Modelling choices and social interactions with a threshold public good: Investment decisions in a polder in Bangladesh

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ARTICLE INFO

Keywords:
Voluntary contribution
Threshold public good
Social influence
Agent-based model
Bangladesh

ABSTRACT

Farmers in South-West Bangladesh face excess precipitation in monsoon season, which cannot be discharged to the silted-up rivers. In low lying polders, this leads to waterlogging. Consequently, the water level in the polder remains too high for reliable rice production during the monsoon and the following season, and therefore rice is often grown in the dry season (Rabi) only, which leads to reduced yearly yield and income. The objective is to model the decision-making process of buying a pump collectively to discharge water to the river and reduce waterlogging. Hypotheses on this decision making process will be tested. We present a theoretical model that introduces farmers' decision making in the context of a threshold public good. We develop an extension of the Consumat approach that includes farmer's prosocial behaviour characteristics in the decision of cooperation towards investing in the pump. The model is applied in an agent-based model (ABM) and hypothesis are tested with respect to (i) the farmers' income, (ii) the effect of different climate scenarios that affect the probability of waterlogging (iii) the role of social preferences in achieving cooperation towards investment in the pump. We find that farmers' income is significantly higher when the pump is present and income variability between years is reduced considerably compared with a situation without a pump. Farmers capture higher benefits from an investment if the probability of waterlogging is higher, also during a dry scenario income is higher than in a situation without a pump. Farmers seek cooperation faster if the probability of waterlogging increases. We find that the distribution of social preferences plays a role in the time till investment in the pump. Our research shows the complexity of promoting collective investments with public good characteristics. At the same time, it highlights the long term benefits that collective investments have on farmers livelihoods, especially under climate variability.

1. Introduction

In South-West Bangladesh, polders were developed 40 years ago. Since then, the adjacent rivers have silted-up, and the polders subsided (Awal, 2014; Islam et al., 2018). Discharging the excess water with gravity is not sufficient anymore to drain the polders properly. In the Netherlands, polders face comparable situations, and Dutch polders are drained with pumps. This paper analyses whether pumped drainage can be transplanted to Bangladesh. Farmers face excess precipitation in monsoon season from June to September (Kharif 1), which in the low-lying polders cannot be discharged quickly to the river, leading to waterlogging. In areas where waterlogging is severe, yields are low in two out of the three seasons (Kharif 1 and Kharif 2), and the total annual crop production and income are lower than in areas which can be drained (Datta and de Jong, 2002; Mohamedin et al., 2010; Awal, 2014; Shaibur et al., 2019). The basic idea is that if farmers invest themselves collectively in a pump and repay for the pump with part of the additional income (compared with the current situation without pumped drainage), they will have a higher income. Pumped drainage in severely waterlogged polders has the potential to increase food production (Datta et al., 2004; Shekhawat, 2007) in Bangladesh, as it did in the Netherlands (Hoeksema, 2007).

Our research aims to provide insights necessary to increase food production in Bangladesh polders reducing the adverse effects of waterlogging by stimulating the investment in pumps. The objective of this paper is, to model the farmers' decision-making process of investing in a pump collectively, and to test three hypotheses which potentially effect cooperative investment behaviour among farmers in a polder.

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https://doi.org/10.1016/j.landusepol.2021.105886
Received 30 March 2021; Received in revised form 7 November 2021; Accepted 15 November 2021
Available online 3 December 2021

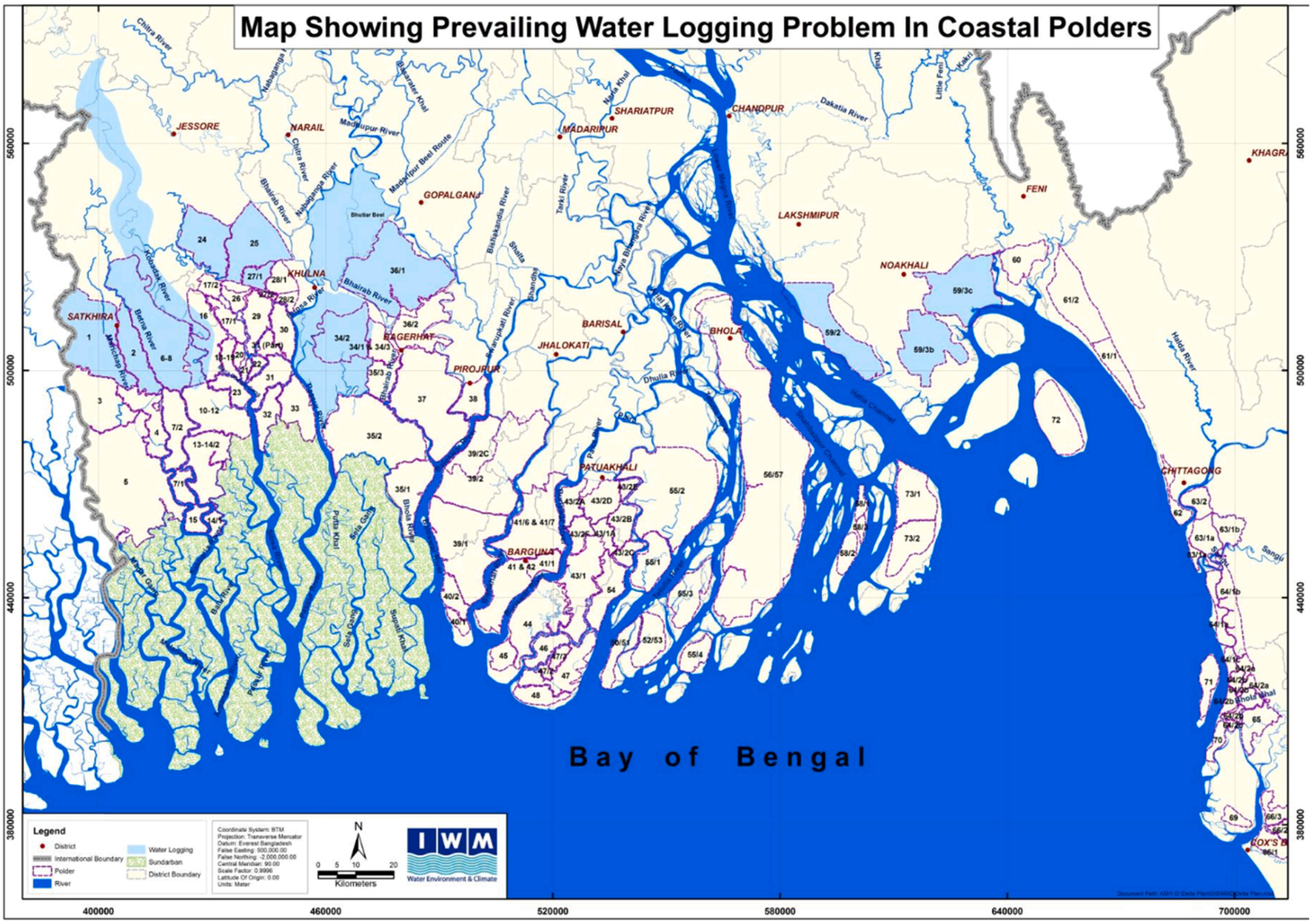

Fig. 1. Water logging problems in South-West Bangladesh.
Source: BDP (2015).

Famers inside the polder cannot be excluded from the benefits of the pump once it is introduced (non-excludable) which makes the pump a public good (the lower water level is non-rivalrous). We present an investment behaviour model that introduces the pump as a threshold public good. We assume that the internal drainage system of the polder allows all farmers to benefit from the reduced water level. Farmers decide whether or not to contribute to investment in a pump (collectively). When the threshold is reached (i.e. enough farmers are willing to invest to cover the pump costs), water variability and income expectations will change for the next seasons.

We apply the investment behaviour model in an agent-based model (ABM) and compare two polders. Both polders are identical in terms of heterogeneous characteristics, in one polder (polder A) cooperation to invest in a pump is possible and in the other one (polder B) the possibility of investing in a pump is not an option. We compare differences in the average income between the polders and time required to reach the threshold when testing our hypotheses with respect to: (i) the average income in the polder (ii) the effect of an increase in the probability of waterlogging (iii) the role of social preferences.

We follow the Consumat approach (Jager et al., 2001) to define cognitive behaviour rules under uncertainty (individual maximisers vs heuristic-based agents) (van Duinen et al., 2016). We present an extension of the Consumat approach that includes farmer's prosocial behaviour characteristics in the choice of cooperation towards investing in a pump. We model farmers' interactions using an ABM to simulate information exchanges with other farmers in the same polder before making the decision whether to investing in a pump or not.

The remainder of the paper is divided as follows: next section introduces the problem of waterlogging in polders in SW Bangladesh. Then, we summarise the relevant literature on the implementation of a threshold public good. The second section describes our methodology; thereafter the we elaborate on the implementation of our hypotheses in the ABM and present the data and results including a sensitivity analysis and the final section contains the conclusions and discussion.

1.1. The problem of waterlogging

Waterlogging is an acute problem in the southwestern region of Bangladesh, especially Jessore, Khulna and Satkhira districts Fig. 1, causing severe damage to people's livelihoods (Lázár et al., 2015, BDP, 2015, Bernier et al., 2016, Alam, 2017). Waterlogging in this part of the country stems from reduced upstream flow from the river Padma, which contributed to siltation in the rivers and elevation of riverbeds. Hence, the tidal rivers in SW Bangladesh cannot effectively drain the nearby lands (BDP, 2015). Construction of polders' embankments in the 1960s and 1970s cut off this natural sediment accretion within polders. (Brammer, 2014). The combination of the rivers' siltation and lack of sedimentation within the polder reduced drainage capacity, together with land subsidence (Brammer, 2014), sea level rise and increased precipitation in the changing climate, is causing waterlogging (BDP, 2015). Waterlogging has affected millions of people, especially poor and marginal (landless) farmers, as well as sharecroppers (Alam, 2017). Waterlogging has drastically reduced agricultural productivity across the region (Awal, 2014), and it has adversely affected homestead vegetable production, which is important for food security (Rahman et al., 2008). Although water is present everywhere, scarcity of clean

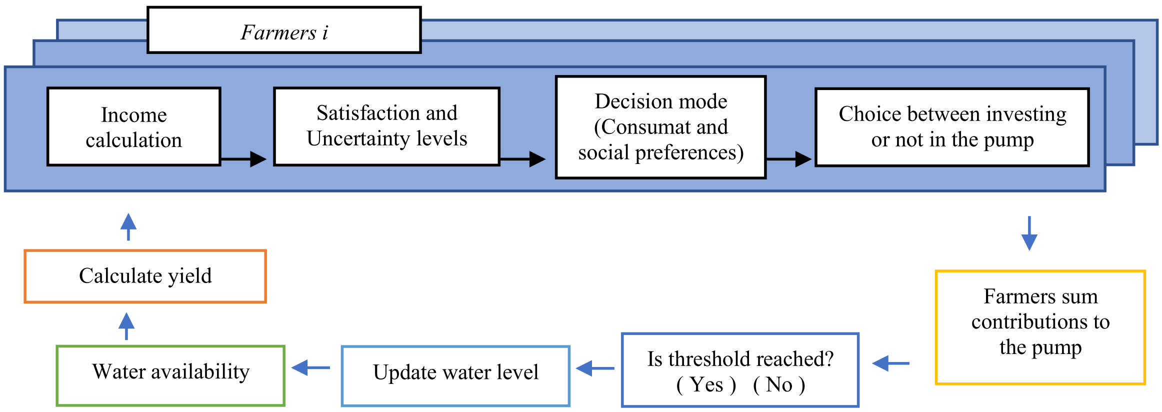

Fig. 2. Model overview: the farmer decision-making model of investment in a pump.
(Adapted from Malawska and Topping (2016)).

drinking water causes diseases, malnutrition and environmental degradation in the region (Abedin et al., 2019). Although the primary goals of polder construction during the early 1960s were to decrease flood risk and salinity intrusion for increasing agricultural productivity, polders started to affect people's livelihoods after the 1980 s adversely (Nath et al., 2019). Bangladesh has a typical monsoon climate with a hot and dry season from March to May, followed by a rainy season from June to October and a cold period from November to February. Mean annual rainfall in the area is about 2000 mm of which approximately 70% occurs during the monsoon season (Shahid, 2010; Dewan et al., 2014).

Boro rice production is dominant in Rabi (dry season) in the region followed by fallow land in Karif-1 (wet monsoon season) and if waterlogging is not severe T.Aman rice (transplanted Aman) in Kharif-2 (directly after monsoon season) (IWM, 2014). Private pumps are sometimes used to drain water for rice production at plot level at start of Rabi (Awal, 2014). A pump drained system will facilitate cultivation of crops in all three seasons (Brammer, 2010). This system includes power supply, pump house and in-field drainage system and the community must be prepared to make clear choices on the set-up and boundaries of their drainage system. Participatory water management is organized at different levels (De Silva, 2012). At the smaller level (<1000 ha) the water management groups (WMGs) operate at the grass-roots and are meant to be directly involved in water management. The next level are the water management associations (WMAs), they are the point of formal interface between a water sector agency and a WMO (water management organisation). The WMAs collect beneficiary contribution towards scheme investment and operation costs (De Silva, 2012; Dewan et al., 2014). Currently the financial contribution of stakeholder to operation and maintenance of the infrastructure is small. As the channels and dikes are public (state) property, operation and maintenance is accomplished with support from projects, government agencies or NGOs (Bernier et al., 2016).

1.2. Cooperation with threshold public goods

Literature has emphasised the importance of studying cooperation mechanisms in the formation of institutions dealing with social dilemma situations, especially in developing countries (Ostrom, 1990). Socio-economic heterogeneity and composition of the group are structural factors that play an essential role in reaching large-scale cooperation (Rustagi et al., 2010). However, cooperation is difficult to maintain, especially in situations where a collective risk is part of the social dilemma (Wang et al., 2009).

By tradition, cooperation with respect to public goods has been studied by the implementation of public goods games. Traditional public good games capture the value of moving one unit of resources from an individual's private consumption to the public good. Hence, each individual has an incentive to free ride, and the dominant-strategy equilibrium involves zero provision of the public good. Still, the community as a whole would be better off if all contributed to providing the public good. (Croson and Marks, 2000). Frequently in social dilemmas, the collective contributions must meet a certain threshold to provide the public good. This threshold level is implicitly used as the focal point for coordination. In other words, there is a strategic behaviour such that group members have to coordinate and that this may explain why people are often willing to support the collective interest (van Dijk et al., 2009).

For example, in a traditional public goods game, an individual is invariably better off if this person contributes less. However, when a threshold is present, and the total contributions are near or at the threshold, it is no longer necessarily the case that an individual is better off not contributing or reducing the contribution. If the person's contribution results in satisfying the threshold, this person is often better off contributing than not. If the sum of the players' contributions is precisely the threshold, there is no incentive for anyone of them to reduce (or to increase) their contribution (Abele et al., 2010).

Empirical studies have studied the role of social influence in threshold public goods. For example, Carlsson et al. (2015) used field experiment designed as a threshold public good, where the subjects (i.e. household heads of all households in the village), were asked to make voluntary contributions for the construction of a bridge in their village. If the village members contributed enough money, the bridge would be built. If, on the other hand, the total contributions fall below the threshold, the public good is not provided.[1]

In situations where the number of subjects deciding whether or not to contribute is large, the probability that the individual contribution decision will be decisive for whether the bridge will be built or not is small (Carlsson et al., 2015). There might be different conditions for an individual's choice having the potential to be decisive. For example, if the contribution of others is sufficiently low, the individual contribution does not matter at all. On the other hand, when the contribution of others is sufficiently large, the public good can be reached regardless of how much the individual contributes and then the best response of the individual is to contribute nothing. However, situations based on conventional self-interested preferences are more likely, and it is reasonable to interpret individual contribution as a measure of the strength of social preferences, or cooperative behaviour (Carlsson et al., 2015).

Literature has highlighted the importance of considering social behaviours, such as conditional cooperation (Fehr and Fischbacher, 2003; Rustagi et al., 2010). If individuals are conditional co-operators, their cooperation is conditional on the cooperation of others. In other words,

[1] In the case of not reaching the threshold, contributions are returned to the subjects (Carlsson et al., 2015).

they are willing to cooperate more, the more others contribute to a public good. Other social preferences also play an essential role. Altruistic individuals place a positive value on resources allocated to others (Fehr and Fischbacher, 2002; Putterman, 2006). In contrast, selfish individuals (non-cooperators) are considered free riders and cannot be excluded from the benefits delivered by public goods (Fehr and Fischbacher, 2002).

For example, a study by Rustagi et al. (2010) shows the extent to which variation in the distribution of social preferences among groups explains the success of forest management. Their study shows that success of forest patrols in Ethiopia vary significantly in the proportion of those classified as conditional co-operators. Patrols with larger amount of conditional co-operators in the group are more successful in forest management.

In this paper, we present the decision of investing or not in a pump as a threshold public good in the context of collective risk, where, in case of not reaching the threshold, contributions are returned to the subjects. Given the pool of farmers in the polder, we reflect on social preferences theory to characterize the strategic behaviour of individual farmers. Furthermore, we assume farmers have distinct cognitive behaviours (individual maximisers vs heuristic-based agents) which define whether or not farmers seek for information and copying their peers' behaviour (van Duinen et al., 2016). The next section presents the methodology to explore the investment behaviour by describing the behavioural rules based on personal satisfaction and uncertainty.

2. Methodology

We study cooperation behaviour towards investing in a pump using a conceptual framework (Fig. 2), in which farmers decision making is modelled in the context of a threshold public good and individual behaviour follows the Consumat approach (Jager et al., 2001; Janssen and Jager, 2001). We simulate the Consumat's interactions between farmers using an ABM.

2.1. Threshold public good under collective risk

All farmers within the polder are exposed to rainfall variability that raises the water level in the polder with a probability, p. If the water level in the polder is too high, farmers cannot plant rice (or the rice planting period is shortened) and rice yields are low. If the water level in the polder remains low, farmers can extend the rice planting period and increase the yield. In other words, farmers are exposed together to the risk of waterlogging and the decision of investing in a pump echoes a public good threshold (Brekke et al., 2017; Carlsson et al., 2014; Wang et al., 2009).

We define p as the probability of high-water levels, where $(0 \leq p \leq 1)$. Then, without investment in a pump, in situations in which the water level in the polder is high, farmers cannot plant rice optimally, resulting in low yield $(Y^L_{i,t})$, all farmers indexed with a subscript, i, and all seasons indexed with a subscript, t. If the water level in the polder remains low $(1-p)$, farmers can extend the rice planting period and increase the yield $(Y^H_{i,t})$. Each of the three cropping seasons in a year is associated with a different probability of high levels of rainfall based historic data. [2] Hence, yields are stochastic (over the years).

At the end of every season, the farmer must decide to cooperate by investing in the pump or not, given the income from the previous season and their expectations for the next season. In the case when no pump is bought collectively, farmers income $\pi_{i,t}$, is calculated as yield $(Y_{i,t})$, on their land (A_i) in season t multiplied by the related crop price according to the season (cp_t) in BDT/kg, minus their production costs. We added a stochastic component to farmer's yield to reflect differences in agricultural practices and to add variability. Farmers' initial income is given by the income in the previous season $\pi_{i,t-1}$. as following:

$$\pi_{it-1} = (A_i \bullet \mathrm{Y}_{\mathrm{it-1}} \bullet \mathrm{cp}_{\mathrm{t-1}}) - \mathrm{C}_{\mathrm{it-1}} \tag{1}$$

Where the individual costs are the sum of variable costs that include labour cost (LC) per hectare, input costs (IC) per hectare and the fixed costs (FC). We assume there are no additional costs for the increased yield.

$$\mathrm{C}_{\mathrm{i}} \quad = A_i \bullet (\mathrm{LC} + \mathrm{IC} \quad) + \mathrm{FC} \tag{2}$$

Under the uncertainty of rainfall scenarios, farmers can use credit to invest in a water pump. which allows all farmers in the polder to extend the period in which they grow rice. It allows for discharging water out of the polder if water levels inside the polder are too high. Nonetheless, the realisation of the public good, depends on reaching a threshold of enough loan to buy the pump. Therefore, all farmers collectively need to gather the total amount of money needed to repay the loan (R), which depends on the price of the pump (PI), a given interest rate (r), and the period of repayment (γ).

$$R = \frac{(1+r) \bullet PI}{\gamma} \tag{3}$$

The period of repayment (γ) is equal to the life expectancy of the pump and set equal to 10 years (30 seasons).[3] We assume farmers who are willing to cooperate, contribute relatively to their acreage because benefit depends also on the acreage. Their contribution per ha, x, is a percentage of R. The larger the x, the smaller the number of farmers needed to invest in the pump.

We define n as the number of farmers willing to invest in the pump, $\sum_i^N H_i = n$, where $\mathrm{H_i}$ is a binary variable taking the value of $H_i = 1$ if farmer participates and $H_i = 0$ if not. Finally, the threshold is reached when the sum of the contributions reach the repayment of the loan: $\sum_i^N A_i x H_i$.

Those who contribute have to bear additional seasonal costs of the pump such as the energy costs $(\mathrm{EC_t})$,[4] and maintenance and operational costs and insurance costs $(\mathrm{MC_t})$, which are also distributed relative to the acreage. Hence, the pump costs for each farmer is a share in proportion to the initial contribution and relative to the total contributions (Carlsson et al., 2015) as follows:

$$\mathrm{PC}_{\mathrm{i,t}} = A_i H_i \frac{\mathrm{R}}{\sum_i^N A_i \quad H_i} + (\mathrm{EC_t} + \mathrm{MC_t}) \quad A_i \quad H_i \tag{4}$$

Since all farmers who cooperate are contributing to the same proportion, there is no excess of contributions. Furthermore, if threshold is reached and the public good is provided, all farmers enjoy the additional gains independently from who contributes. The additional gains (G_i), are defined as the difference between high yield and low yield scenarios, as the pump will allow high yield in unfavourable rainfall conditions.

The farmer's expected income $(E\pi_{i,t})$ depends on the farmer's acreage, the probability of high water levels, the associated yield, the individual contribution to the pump, the benefits of pumping depending on reaching the threshold or not,. Eq. (5) describes the situation when the farmer cooperates and the threshold is reached to invest in a pump. Eq. (6) describes the case if the farmer does not cooperate and there is a pump in place. Eq. (7) describes a situation for all farmers when there is no pump:

[2] Probability of high water levels depending on the season: Rabi (dry season), Karif-1 (wet monsoon season) and Kharif-2 (directly after monsoon season). Probabilities are described in the ODD protocol (Appendix A supplementary material).

[3] All variables and values are defined in detail on the ODD protocol.

[4] Energy costs are relative to the water level. Hence, when water levels are low, pump is not used and energy costs are zero.

Expected income for cooperators (c) and non-cooperators (nc) with pump

$$E\pi_{i}^{c,}{}_{t}^{p} = A_i \left\{ p \left[\left(Y_{it}^{L} + G_i \right) \bullet \mathrm{cp_t} \right] + (1-\mathrm{p}) \left[\mathrm{Y_{it}^{H}} \bullet \mathrm{cp_t} \right] - \mathrm{C_{it}} - \mathrm{PC_{it}} \right\}$$

$$if \sum_{i}^{N} A_i x H_i \geq R \tag{5}$$

$$E\pi_{i,t}^{nc,\ p} = A_i \left\{ p \left[\left(Y_{it}^{L} + G_i \right) \bullet \mathrm{cp_t} \right] + (1-\mathrm{p}) \left[\mathrm{Y_{it}^{H}} \bullet \mathrm{cp_t} \right] - \mathrm{C_{i,t}} \right\}$$

$$if \sum_{i}^{N} A_i x H_i \geq R \tag{6}$$

Expected income in situation without pump

$$E\pi_{i}^{np}{}_{,t} = A_i \left\{ p \left[Y_{it}^{L} \bullet \mathrm{cp_t} \right] + (1-\mathrm{p}) \left[\mathrm{Y_{it}^{H}} \bullet \mathrm{cp_t} \right] - \mathrm{C_{i,t}} \right\}$$

$$\text{if} \sum_{i}^{N} A_i x H_i < R \tag{7}$$

Farm costs and income (Eqs. 1 and 2) are updated accordingly when the farmer invests in the pump and we assume farmers consider investing in a pump a profitable decision if the expected income of investing in the pump over the last year (3 seasons) (Eq. 5) is 10% higher than a scenario without a pump (Eq. 7):

$$\sum_{t}^{t-2} E\pi_{i,t}^{c,\ p} > 1.1 * \sum_{t}^{t-2} E\pi_{it}^{nc,np}$$

Free riders always have a higher expected income when the pump is in place than those who cooperate (Eq. 6): $E\pi_{it}^{nc,p} > E\pi_{it}^{c,p}$, and their decision is not to invest in the pump (see Section 2.4).

Furthermore, situations can exist in which the farmer's expected income is negative. Most probably, farmers could face negative incomes during the Karif-1 monsoon season in a no pump situation, because risk of high water level is very high. Our model takes into account that if expected income is negative farmers will not plant rice. In that case, we assumed the income (Eq. 1) and costs (Eq. 2) are adjusted for no yield and no variable costs, only the fixed costs remain.

2.2. Modelling social interactions: consumat approach

The Consumat approach (Jager et al., 2001; Janssen and Jager, 2001), developed to guide the decision-making process and implements concepts of satisfaction and uncertainty to determine four possible strategies in decision making (imitation, repetition, optimisation and social comparison). Each strategy defines an individual cognitive process. Depending on the farmers' level of income satisfaction and uncertainty, they interact and learn from other farmers in the polder, or not (Pacilly et al., 2019). Farmers can make decisions in isolation (i.e. individual maximisers), or decide to look at their neighbours and learn from them (i.e. heuristic-based agents) (van Duinen et al., 2016).

Initially, Janssen and Jager (2001b) introduced this approach as a multi-agent simulation model where artificial consumers choose each period between products. The Consumat approach has been implemented in diverse agricultural settings (Mialhe et al., 2012; van Duinen et al., 2016; Malawska and Topping, 2016. Van Oel et al., 2019; Pacilly et al., 2019).

2.2.1. Level of satisfaction

The level of satisfaction determines farmers' effort to take into account their neighbouring farmers (peers) when making a decision. For example, a satisfied farmer does not put much effort comparing his choice to that of his peers, and either continues with the same choice (repetition) or seeks information only from the adjacent farmers with whom strong links exist (imitation). On the contrary, unsatisfied farmers are motivated to search for better future situations and put more effort reflecting on their farm optimisation process without comparing themselves to others (optimization), or seek information and compare themselves in an extended network (social comparison) (van Duinen et al., 2016). Some studies take the behaviour of others (i.e. peers) into account in determining individual satisfaction (Jager et al., 2001; Van Oel et al., 2019). Others use expectations in comparison with the current utility via satisfaction (Jager and Janssen, 2012; Malawska and Topping, 2016). van Duinen et al. (2016), provide a definition of satisfaction based on the agronomical meaning of potential income and a description of uncertainty based on the predicted income. Satisfaction can also be based on the accomplishment of objectives (Mialhe et al., 2012). The definition of satisfaction can include personal and social satisfaction (Jager and Janssen, 2012). It may include different aspiration or ambition levels (Jager et al., 2001; Jager and Janssen, 2012; van Duinen et al., 2016) or a minimum level of satisfaction (Malawska and Topping, 2016).

We apply a dual definition of satisfaction to include individual satisfaction (Jager et al., 2001; Van Oel et al., 2019) and social satisfaction (Jager and Janssen, 2012) in a two-step approach. To define individual satisfaction, we follow the definition by van Duinen et al. (2016), in which satisfaction is based on the agronomic definition of potential income. In our case, the maximum possible income under optimal weather conditions (without pump). Social satisfaction is included as a reference to the average income of other farmers in the polder.

First, the model considers the farmer's individual satisfaction. which in a given period t ($\mathrm{ISAT_{it}}$), is defined as the ratio of the farmer's realised income and the potential income in the same season the year before.

$$\mathrm{ISAT_{it}} = \frac{\pi_{i\ \ t-3}}{\widehat{\pi_{i,t-3}}} \tag{8}$$

Where the potential income is calculated as the highest income possible in a scenario without a pump and favourable weather conditions as follows:

$$\pi_{i}\widehat{\ \ }_{t-3} = \left(Ai \bullet \mathrm{Y_{it-3}^{H}} \bullet \mathrm{cp_{t-3}} \right) - \mathrm{C_{it-3}} \tag{9}$$

Individual satisfaction is modelled with a personal aspiration level. This is the level of income that agents aspire in order to be satisfied, which is set to be relative to the farmer's yield. Farmers with larger acreage are expected to have more income and vice versa. The aspiration level is randomly distributed and we assume that the personal aspiration level is normally distributed across the agents, with N(0.5, 0.17) (van Duinen et al., 2016). If farmer's individual satisfaction is above the aspiration level, the farmer is satisfied and vice versa.

If farmers are not satisfied individually, than the model considers the farmer's social satisfaction. Social satisfaction in each period t ($\mathrm{SSAT_{it}}$), is defined as the ratio of farmer's realized income and a reference income in the previous season as follows:

$$\mathrm{SSAT_{it}} = \frac{\pi_{i,t-1}}{\overline{\pi_{it-1}}} \tag{10}$$

The farmer's reference income is calculated as the average income per capita in the previous season of the eight nearest neighbours[5] (queen continuity), (Getis and Aldstadt, 2004), as follows:

$$\overline{\pi_{it-1}} = \frac{\sum_{i}^{8} \pi_{i,t-1}}{8} \tag{11}$$

We define a social aspiration level equal to the reference income. If the farmer's income is above the average of its neighbours, the farmer is satisfied and if the farmer's income is below that, than the farmer is

[5] For farmers situated at the edge or corner of a polder, the reference income is calculated with a smaller number of neighbors.

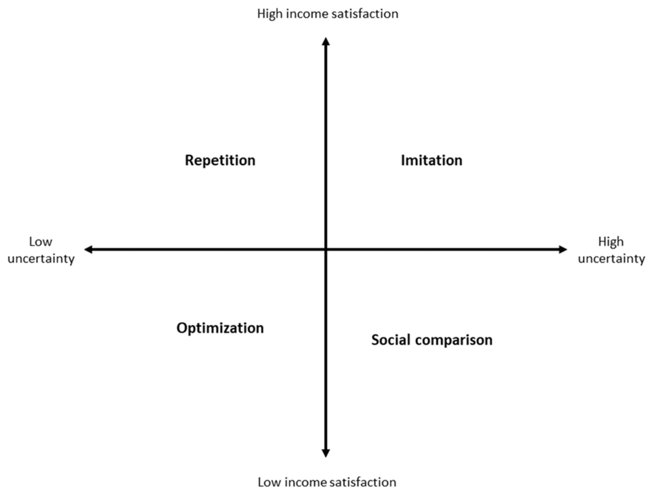

Fig. 3. Possible strategies farmers: repetition, imitation, social comparison, optimization.
Adapted from Jager (2000) and van Duinen et al. (2016).

overall dissatisfied.

2.3. Level of uncertainty

Similarly, the level of uncertainty helps to define whether the farmer gathers information. Some studies take the behaviour of others (i.e. peers) into account in determining uncertainty (Jager and Janssen, 2012; Kangur et al., 2017; Van Oel et al., 2019). Others use expectations in comparison with the current utility to determine uncertainty (Jager, 2000; Janssen and Jager, 2001; Kangur et al., 2017), or base uncertainty on the average performance of the previous years (Malawska and Topping, 2016).

On the one hand, farmers with low uncertainty rely on their own experience (repetition or optimization). On the other hand, farmers with higher uncertainty seek out for information in their network and engage in activities that require social interaction (imitation or social comparison) (van Duinen et al., 2016).

To define the level of uncertainty, we implement the utility concept defined by (Jager et al., 2001), (Janssen and Jager, 2001) and (Kangur et al., 2017), where utility is an individual comparison of current utility and expectations. We use income as a proxy for utility and define the level of uncertainty (UNC_{it}) in a period t, as the ratio of the farmer's realized income and expected income in the same season in the previous year (the income per season varies throughout the year).

$$UNC_{it} = \frac{E\pi_{it-3}}{\pi_{it-3}} \quad (12)$$

If the realized income is larger than the expected income farmers perceive less uncertainty ($UNC_{i,t} \leq 1$). If the realized income is smaller than the expected income, farmers uncertainty increases ($UNC_{i,t} > 1$). A level of uncertainty tolerance is distributed across farmers relative to the farm size. Evidence exists that larger farmers are more risk tolerance than smaller ones, and therefore, more likely to invest (Binswanger and Sillers, 1983). Our model considers farmers with less acreage experience uncertainty faster than farmers with larger areas of land. Therefore, we implement a cut-off point depending on the area, where smaller farmers

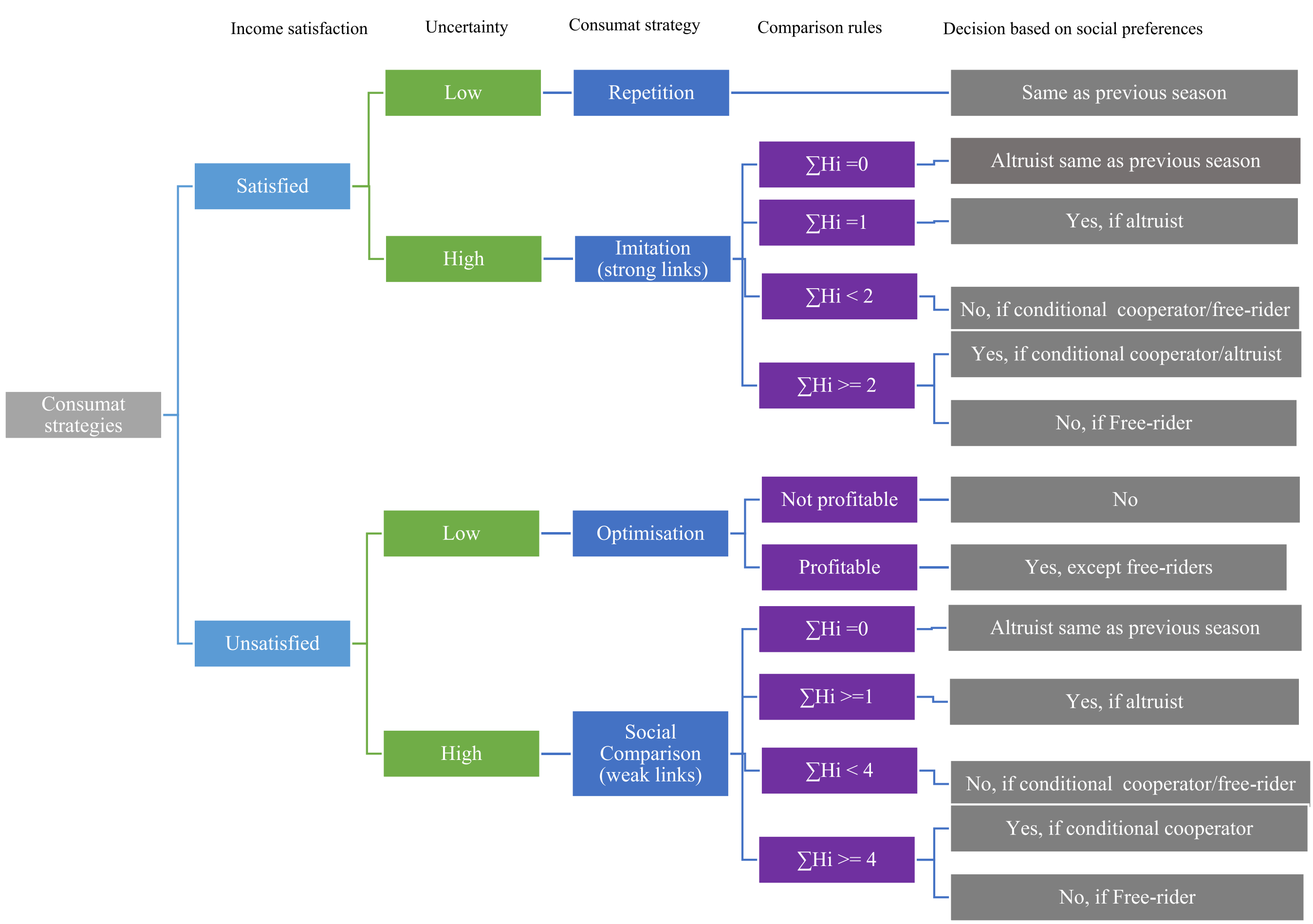

Fig. 4. Extension to the Consumat approach adding farmer's type of social preferences.

experience uncertainty faster and larger farmers are more risk tolerant with a higher cut-off point defined as $1 - 0.25 * (\overline{A} - A_i)$. Where $\overline{A}$ is the average area of all farmers in the polder.

Following an Jager (2000) and van Duinen et al. (2016), if the farmer experiences high-income satisfaction and a low level of uncertainty, the behavioural approach is to continue with the same strategy as the previous season and choose for “repetition” (see Fig. 3). On the other hand, when the farmer has high-income satisfaction but experiences positive levels of uncertainty, the farmer will seek for information in the nearby network (adjacent farmers) and choose for “imitation” of the majority decision of the adjacent farmers with strong links. In circumstances where the farmer experiences both high uncertainty and low-income satisfaction, the farmer is encouraged to seek for information from a more extensive network of peers and to have chosen for “social comparison”, which intake a broader reference of farmers to imitate their decision. Finally, a combination of a low level of uncertainty and low-income satisfaction triggers the farmer’s individual “optimisation” process at the farm level without considering decisions of other farmers (van Duinen et al., 2016). We consider a simple optimisation process where the farmer considers investing in a pump a profitable decision if the expected income of investing in the is at least 10% higher than a scenario without a pump as defined above.

2.4. Modelling interactions in an agent-based model

Agent-based modelling (ABM) represents a process-based "bottom-up" approach that attempts to represent the behaviours and interactions among autonomous agents through which agricultural systems are evolving and thus to simulate emergent phenomena without having to make a priori assumptions regarding the aggregate system properties (Huber et al., 2018). ABMs distinguish from traditional farm level models to include, for example, considerations of the interactions between farms, market simulation, bounded rationality and behavioural heterogeneity (Kremmydas et al., 2018). Agent-based modelling is a suitable tool for improving the understanding of farmers’ behaviour in response to changing environmental, economic, or institutional conditions, particularly on the local level (An, 2012; Huber et al., 2018). For example, in the context of climate change adaptation in agriculture (Troost and Berger, 2015; van Duinen et al., 2016). Our paper uses an ABM to simulate farmers decisions based on the Consumat approach and social preferences theory. To describe more in detail our assumptions and procedures, we use the “Overview, Design concepts, and Details” protocol for ABM (ODD protocol) (Grimm et al., 2020). A standard revised protocol for describing ABMs in literature (see supplementary material).

A grid-based ABM is applied to simulate farmers decisions. The model is spatially explicit and uses a matrix to simulate how individual choices are influenced by neighbours. Adjacent farmers with strong links are modelled by rook continuity (i.e. the four neighbours of each cell in the cardinal directions) (Getis and Aldstadt, 2004). Adjacent farmers with weak links are modelled by queen continuity. The former definition is used when farmers follow an imitation strategy and the latter is implemented when farmer choose a social comparison strategy. The next section, describes the interaction between the different behavioural strategies and farmers’ social preferences.

This ABM model links the probability of reaching or not the threshold to the distribution of farmers’ social preferences in the population of farmers in the polder (i.e. the distribution of conditional co-operators, altruistic farmers and free riders) (Fischbacher et al., 2001). In the model, individual characteristics for social preferences are randomly distributed based on literature as described in Table 3. References in the literature have found that conditional co-operators account for between 50% and 80% of the population (Martinsson et al., 2013; Fischbacher et al., 2001; Fehr and Fischbacher, 2002; Kocher et al., 2008).

Table 1
Probability of high water levels in each season.

Scenario		Baseline	Dry	Rainy
Season	Rabi (dry season)	0.01	0.00	0.05
	Kharif-1 (rainy/monsoon season)	0.95	0.90	1.00
	Kharif-2 (directly after monsoon season)	0.35	0.10	0.60

2.5. Adding social preferences to the Consumat approach

We extend the four Consumat behaviour strategies with social preferences, to reflect farmers heterogeneity on these preferences (altruists, conditional co-operators, free-riders) (see Fig. 4). The final decision is conditional on farmers’ type where he could switch his strategy. In each season first the farmer’s Consumat strategy is determined, then this strategy is linked to the social preference of each farmer to obtain his position in the cooperative investment. Farmers can either cooperate with the group that is willing to buy the pump or not (per season). The options for each Consumat strategy are elaborated in Fig. 4.

Repetition implies that the decision to invest or not is identical to that of the previous season.

When imitation and social comparison strategies are taken, altruists will invest in the pump if one or more of their peers has already contributed, or if the farmer was already willing to invest in the previous season. Conditional co-operators follow peers’ behaviour to invest in the pump if half or more of their peers have already decided to invest. In the case of optimisation, the farmer will check if investing in the pump is profitable or not (as defined in Section 2.1) without considering decisions of others. The free-riders behave in a purely selfish manner and will not contribute to the pump’s investment in any of the Consumat strategies.

3. Hypotheses

We test whether the model behaves according to the underlying assumptions. First test criterion is whether the farmers in polder A will decide to invest in a collective pump or not. We use the number of seasons prior to the collective investment decision as an indicator. The average income in the polder with the pump should be higher than the average income in polder B, from the moment the pump is introduced. To test this hypothesis, we simply compare the income in both polders, which should be identical till the moment polder A reaches the threshold of investment in the pump.

Second, we analyse the effect of uncertainty regarding climate change scenarios. The theoretical model presented by Wang et al. (2009) focuses on the effect of risk on the emergence of social cooperation. Based on their conclusions, the hypothesis is that the threshold is faster reached under high-risk situations. If the probability of high-water levels is low, farmers have fewer incentives to cooperate, given that cooperation is costly. If the probability of high-water levels is high, risk-averse farmers look for cooperation to secure lower costs (Alpízar et al., 2011), higher yields and stable incomes (Pacheco et al., 2014). We test this hypothesis by changing the probabilities of high-water levels. Corresponding probabilities for the baseline, dry and rainy scenarios are described in Table 1.

Third, we explore the role of social preferences in achieving cooperation towards investment in the pump. Social preferences are important in the formation of institutions in developing countries, playing an essential role in reaching large-scale cooperation (Rustagi et al., 2010). We test whether the distribution of social preferences, within the population of farmers in the polder, has a significant effect on reaching the public good threshold. The number of periods needed to achieve the pump should be reduced if free riders are substituted by those classified as conditional cooperators, and vice versa if the proportion of free riders is raised. We compare the “high cooperation” and “selfish” scenarios next to the baseline. The distribution of the farmer’s social preferences

Table 2
Distribution of social preferences in each scenario.

Scenario		Baseline	High cooperation	Selfish
Social preferences	Altruists	0.25	0.25	0.00
	Conditional cooperators	0.70	0.75	0.70
	Selfish/Free riders	0.05	0.00	0.30

Table 3
Uncertainty of climate change scenarios.

Scenario	Time to reach the threshold	Average income in polder		
		Polder A (with pump)	Polder B (without pump)	*t*-test
	No. Seasons	Mean (BDT)	Mean (BDT)	Difference
Baseline	5.44 (1.94)	198,699 (5255)	146,804 (72,560)	51,895 * **
Dry	7.11 (1.75)	189,498 (5173)	176,267 (43,977)	13,231 * *
Rainy	4.27 (1.63)	195,060 (5416)	107,181 (75,388)	87,878 * **

Note: Monte Carlo simulation over 1000 runs of 60 seasons. Difference between the observed means in two t samples. Standard deviation in parenthesis. Significant differences from the two tail *t*-test: *** $p < 0.001$, ** $p = 0.0032$. Probability of high water levels in each season is in Table 1.

in these scenarios is presented in Table 2.

4. Data and results

The polder is modelled as a 10 * 10 matrix where every cell represents one farmer, with an average acreage of 2 ha. As polders in SW Bangladesh are much larger, this is a hydrologically isolated part of a polder, to reduce the complexity of applying larger pumps and more coordination required for applying pumped drainage in larger areas. The farm-size is allocated to each cell stochastically in the model set-up, to represent the variation in the polder. Information on the yield, costs and prices is obtained from a household survey (IWM, 2014). The pump price is based upon the estimated required capacity of the pump (1 m3/s) to drain the polder during monsoon. More information on the data, parameters and their source is in Appendix A1.

We run with the ABM a Monte Carlo simulation over 1000 runs (for practical reasons), of 60 seasons each, to test the hypotheses. Each run starts with a new random set of farms, and the average results of these 1000 simulations are presented. The initial value of the variables and parameters is set according to the values presented in Appendix A1. Hypotheses are tested by analysing the deviations from the baseline scenario of the three indicators in the three scenarios: time to reach the threshold and income in both polder.

4.1. Differences in income with or without a pump

The income in both polders (with an identical distribution of farmer's characteristics and farm layout) is identical until the moment polder A reaches the threshold and invests in the pump. It takes the farmers on average 5.44 (sd=1.94) seasons to reach the threshold, and cooperation is reached in 100% of the simulations (baseline results in Table 3). The difference in income between the two polders is significant ($p < 0.0001$) with an average income of 195,942 BDT (sd = 5063) for the simulation period over all 1000 runs in the polder with the pump, compared to 142,350 BDT (sd = 72,699) in the polder without the pump. Hence the average seasonal income for the entire polder is 53,592 BDT higher (632 USD) with a pump. Variability in income between seasons is smaller in the polder with the pump, as the water level will be

Fig. 5. Differences in average income of the polder over all (previous) seasons (upper panel), and water level (lower panel) between the two polders.

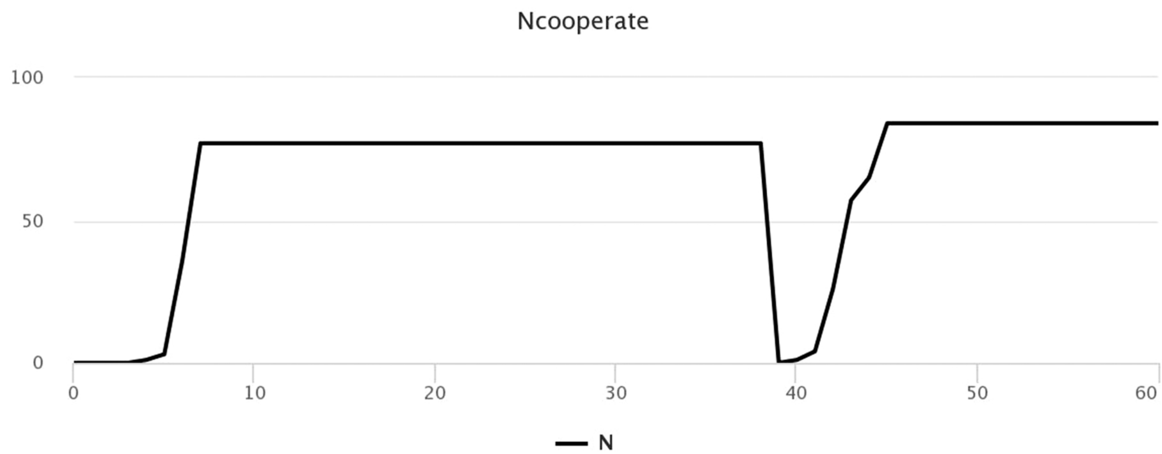

Fig. 6. Number of farmers willing to invest in the pump over time (X-axis). (Total number of farmers is 100).

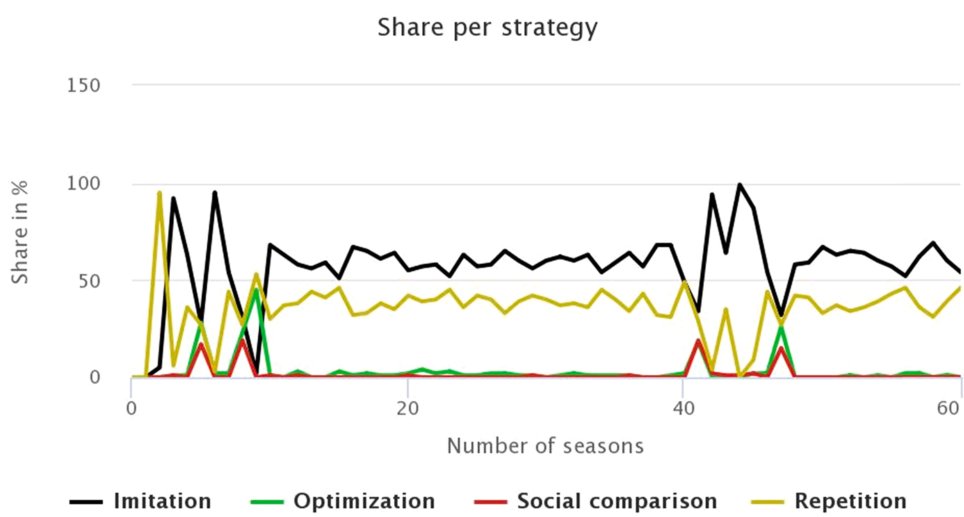

Fig. 7. Share of the consumat strategies in polder A over time.

low, and the yield high, in seasons with unfavourable weather conditions as well (see Fig. 5 lower panel).

For illustration proposes, we run the model for one iteration and graph the differences in water level and income (Fig. 5). The upper panel shows the average income (in BDT) of all (previous) seasons of all farmers in each polder. Hence, from the moment polder A reaches the threshold, the average income in polder A is higher than in polder B. After polder A has invested in the pump, the water-level stays at the minimum level (see lower panel Fig. 5). After the pump reaches its life expectancy (30 seasons), the share of cooperation drops again (Fig. 6). Then, farmers have to coordinate again to reach the threshold for a second investment in a pump.

Farmer's strategies of polder A, derived from the satisfaction and uncertainty levels are presented in Fig. 7. We observe variation between the selected strategies before the threshold is reached. Once the threshold is reached, imitation and repetition are persistent, given farmers' higher-income satisfaction once the pump is implemented. A peak in uncertainty can also be observed when the pump reached its life expectancy, triggering variation between the Consumat strategies again.

4.2. Uncertainty regarding climate change scenarios

We test two different climate change scenarios (Table 3). We again present the average results out of 1000 simulations (of 60 seasons each). In the dry scenario, where the likelihood of high water levels is smaller, farmers take significantly longer to reach the threshold. On average 7.11 (sd =1.75) seasons ($P < 0.0001$). Differences in the average income between polders is less compared to the baseline scenario but still significantly higher for the polder with the pump ($P = 0.0032$). In the rainy scenario, increased likelihood of high water levels, farmers take on average significantly less time to reach the threshold, 4.27 seasons (sd =1.63) ($P < 0.0001$) compared to the baseline scenario. Furthermore, differences in the average income between the two polders increase significantly, because the income in polder B is reduced compared to the baseline.

Results indicate that farmers could benefit considerably from an investment in a pump during the rainy scenario, but the pump is also a profitable investment under drier conditions. Differences in the time to reach the threshold confirm our hypothesis. On the one hand, when the risk of high-water levels is low, farmers have fewer incentives to cooperate, and cooperation takes longer. On the other hand, when the probability of high-water levels increases, farmers look for cooperation faster to secure higher yields and stable incomes.

4.3. Role of social preferences

We vary the distribution of farmers between the altruist, conditional co-operators, and free-riders to analyse cooperation changes. Evidence indicates that, by changing the selfish types' incentives, reciprocity can affect interaction patterns and individual behaviour (Fehr and

Table 4
The role of social preferences.

Scenario	Time to reach the threshold	Average income in polder: Polder A (with pump)	Polder B (without pump)	*t*-test
	No. Seasons	Mean(BDT)	Mean(BDT)	Difference
Baseline	5.44 (1.94)	198,699 (5255)	146,804 (72,560)	51,895 * **
Higher Cooperation	5.02 (1.64)	194,154 (5145)	143,058 (72,121)	51,095 * **
Selfish	11.07 (6.27)	195,714 (18,830)	145,632 (72,431)	50,0823 * **

Note: difference between the observed means in two independent samples. Standard deviation in parenthesis.
Significant differences: *** p < 0.0001. Distribution of social preferences is in Table 2.

Fischbacher, 2002). In other words, the promotion of cooperation might reduce free-riding behaviour, and cooperation is reached faster. We test this hypothesis by comparing two different scenarios with the baseline: a high cooperation scenario and a selfish scenario.

In the high cooperation scenario, it takes farmers less time to reach the threshold. On average 5.02 (sd =1.64) season, but with a less significant p value ($P = 0.0998$). In the selfish scenario farmers take significantly longer to reach the threshold, on average 11.07 seasons (sd = 6.27) ($p < 0.0001$), and the threshold is reached only in 95% of the simulations. Hence, we confirm our hypothesis that promoting cooperation affects the time it takes for farmers to invest in the pump collectively. Both scenarios also show a higher significant average income for the polder with the pump than the other polder ($P < 0.0001$). Table 4.

The results indicate that the distribution of social preferences does play a role in the time of investment in the pump. Under the selfish scenario, farmers take significantly longer to reach the threshold. In the other two scenarios, the number of altruists and cooperators types in the polder is possibly already high, and sufficient to achieve cooperation promptly (Kocher et al., 2008; Martinsson et al., 2013).

4.4. Sensitivity analysis

We apply a one-at-a-time (OAT) approach sensitivity analysis (Fig. 8). In this approach, each variable/parameter is varied one after the other, while all other variables/parameters are kept at their baseline values (Schouten et al., 2014). OAT is commonly selected because it is easy to understand and relatively simple to implement. The method directly assesses sensitivity without transforming the relationship between model input and model output (Schouten et al., 2014; ten Broeke et al., 2016). We evaluate the impact of variables/parameters on the income in Polder A and Polder B and the time to reach the threshold. The input variables/parameters are varied by a 20% decrease and increase as defined in Table A2 (Annex). The results of the sensitivity analysis show (Fig. 8) that the variables that affect the income directly (price of Boro rice and High yield), have the expected large impact on income in both polders. The impact of a change in the price of the pump or a change in the interest rate is small. The contribution (per hectare) to the pump (variable Pct_control in Fig. 8) affects the time to reach the threshold considerably. If the contribution per hectare is larger (pct_control max), the number of farmers required to invest is smaller and the threshold is reached sooner (and vice versa).

5. Conclusions and discussion

Farmers' decision-making process in SW Bangladesh is analysed on whether to buy a pump collectively (a threshold public good) to reduce the impact of waterlogging in a polder. An extension of the Consumat approach is presented that incorporates farmer's prosocial behaviour characteristics in the decision to cooperate (or not). By considering farmer's social preferences, our paper is one of the first to consider individual cognitive behaviour in agricultural land and water management where individuals care not only about themselves but also about outcomes affecting others (Fehr and Fischbacher, 2002). Based upon the extended Consumat approach, an ABM of farmers' interactions is applied, to learn about information exchanges with other farmers in the polder before deciding whether to invest in the pump or not. Hence, our paper highlights the importance of including behavioural traits from human decision-making to microeconomic models.

We estimate the differences in the average income in two polders,

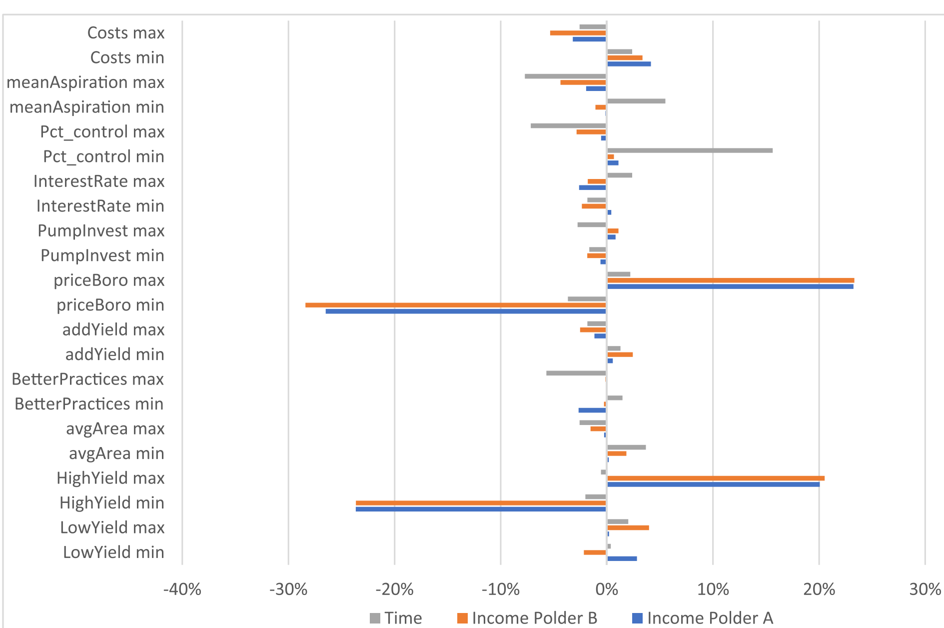

Fig. 8. One-at-a-time (OAT) approach sensitivity analysis. The impact of a 20% decrease (min) and 20% increase (max) is shown on the time to reach the threshold, and the income in Polder A and B. The variables are described in Table A2.

one with and the other one without the possibility to buy a pump. We model the effect of uncertainty regarding different climate change scenarios and test whether an increasing probability of waterlogging would spur cooperation towards investment in a pump. Finally, we explore the role of social preferences in achieving cooperation for investment in the pump, by applying a Monte Carlo simulation with the ABM.

It takes farmers, on average, 5.44 seasons (1.81 years) to reach the threshold of investment in a pump in the baseline scenario. Income is significantly higher, if a pump is present compared to a situation without a pump. Furthermore, the pump reduces variability in income considerably, as the water level will be low, and the yield high in seasons with unfavourable weather conditions as well.

Changes in the probability of waterlogging can significantly impact farmers income. Farmers capture higher benefits from a pump during a rainy scenario (with higher probability of water logging). In that case farmers seek cooperation faster, securing higher yields and income stability. A pump also enables a higher income under a dry scenario compared to a situation without a pump. The time to reach investment takes longer when the risk of high-water levels is small (dry scenario) since farmers have less incentives to cooperate. A larger proportion of selfish farmers increases the time till cooperative investment. Our research highlights the long term benefits that collective investments in agricultural water management may have on farmers livelihoods. It also shows the complexity of promoting collective investments with public good characteristics since many factors play a role. The factors that affect the outcome are applied in the sensitivity analysis.

Previous studies have shown that the composition of the local population plays a critical role in reaching cooperation (Rustagi et al., 2010). We show that in a selfish scenario farmers take significantly longer to reach the threshold, while in a higher cooperation scenario, it takes farmers less time to reach the threshold. Evidence has shown that in developing countries a higher presence of altruists and cooperators exists (Kocher et al., 2008; Martinsson et al., 2013). Hence, policies can support beliefs for the cooperation of their members to maintain cooperation (Gächter, 2006; Martinsson et al., 2009). Nudges are particularly important, because they can change people's behaviour without forbidding any options or significantly changing their economic incentives. Moral nudges can be used effectively to increase pro-social behaviour (Capraro et al., 2019). Also economic incentives such as subsidies (e.g. from the national government or a NGO) that reduce the pump costs can trigger more farmers to cooperate (depending on their impact on the profitability of the pump). A pumped drainage pilot can generate experience on the impact of pumped drainage in SW Bangladesh. This experience in one polder can then be used to facilitate adoption in other polders as learning from influences outside an polder can be applied to stimulate cooperative behaviour in buying a pump. For the farmers buying a pump collectively is a way to improve their farm environment themselves, independently from the planning of the national government.

Our model uses a matrix spatial distribution to simulate how neighbouring farmers influence individual choices in the polder. Another empirical application using actual plots can help to understand spatial dynamics that we cannot observe. Further empirical evidence on the distribution of social preferences will allow calibrating the model to the population's specific characteristics. Other assumptions can also be explored, for example the presence of strong and weak links. Finally, ways to promote cooperation can be further explored; e.g. how decisions can be influenced by the media and politics.

In the Netherlands the first water boards consisting of elected representatives from agricultural communities, were created in the 13th century. They resulted from the desire both to use technology (e.g. windmills) more effectively in a collective way and to resolve conflicts over water management and use (Reuss, 2002; Kuks, 2009). For more effective and efficient water management in the SW Bangladesh polder system (inspired by Dutch polders), the current water management institutions (e.g. water management groups) could benefit from a system which contains more incentives for collaboration, alike the experience in Dutch water boards (TeBrake, 2002; Kuks, 2009).

In SW Bangladesh a long-lasting discussion exists over the sustainability of shrimp cultivation over rice production in salinity prone regions. The profits of shrimp cultivation were higher, but it also increased soil degradation affecting crop yield, and vulnerability of livelihoods (Ali, 2006, Swapan and Gavin, 2011). More recent research finds that after recent widespread adoption of a suite of technical changes shrimp/rice farming shows a higher productivity and less negative environmental impact (Kabir et al., 2016). Although pumped drainage is now considered for polders without salinity issues, the model described in this paper can also be tested in a future step to simulate the rice farming - shrimp cultivation controversy. The public good will in that case be for instance soil fertility or water quality.

Funding

The authors gratefully acknowledge the financial support from the funds from "Deltas under pressure" (KB-35-001-001) and "Prospects for action in a nature-inclusive" (KB-36-005-003).

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.

Acknowledgements

The authors want to express gratitude to John Helming, Robert Huber, the editor and two anonymous Land Use Policy reviewers for their valuable comments on an earlier version.

Annexes

See Table A1 here.

Table A1
Basic model variables.

Variable	Reference in paper	Description	Source	Value
$Y^L_{i,t}$	Low yield for expected income	Low yield (high water level) (kg) per hectare	Empirical data (IWM, 2014)	2000
$Y^H_{i,t}$	High yield for expected income	High yield (low water level) (kg) per hectare	Empirical data (IWM, 2014)	6000
$Y_{i,t}$	Yield (variation)	Include stochastic component to reflect differences in agricultural practices (kg)	Endogenous	Random value. Normal distribution (0,1000)
cp_t	crop price	Crop price BDT per kg	Empirical data (IWM, 2014)	20
PI	Price of the pump	Investment need to buy the pump (BDT)	Empirical data	1780,000
r	Interest rate	Interest rate (5)	(World Bank, 2021)	9.556 in 2019

(*continued on next page*)

Table A1 (*continued*)

Variable	Reference in paper	Description	Source	Value
LC	Labour cost	Individual labour cost BDT per ha per year (model /3 to make seasonal)	Empirical data (IWM, 2014)	40000
IC	Input costs	Individual input costs BDT per ha per year (model /3 to make seasonal)	Empirical data (IWM, 2014)	10000
FC	Fixed costs	Individual fixed costs BDT per year (model /3 to make seasonal)	Empirical data (IWM, 2014)	10000
EC_t	Energy costs	Collective relative to water level energy costs BDT per ha per year	Empirical data (IWM, 2014)	50 if water level high and zero when water level low
MC_t	Maintenance and operational costs and insurance costs	Collective maintenance and insurance costs BDT per ha per year (model /3 to make seasonal)	Empirical data (IWM, 2014)	100
γ	Expectancy of the pump in seasons	Period of repayment of the loan / life expectancy of the pump in seasons	Empirical data	30 seasons (10 years)
n	Number of farmers willing to invest	Farmers willing to cooperate with the investment	Empirical data	Endogenous
N	Number of farmers in polder	Number of farmers in polder 1	Empirical data	100
A_i	Area in hectare	Mean and standard deviation (ha)	Empirical data (IWM, 2014)	Normal distribution (2,0.5)
x	contribution per ha, *x*, is a percentage of R.	Percentage of contribution (relative to acreage)	Parameter	0.75%
H_i	Cooperation	Binary variable of cooperation	Attribute of agent (farmer)	$H_i = 1$ if farmer participates and $H_i = 0$ if not

Table A2
Model parameters and range for sensitivity analysis.

Name in code	Description	Nominal value	Value range for SA	
			min	max
lowYield	Low yield (high water level) (kg) per hectare	2000	1600	2400
highYield	High yield (low water level) (kg) per hectare	6000	4800	7200
avgArea	Mean and standard deviation (ha)	Normal distribution (2,0.5)	Normal distribution (2,0.4)	Normal distribution (2,0.6)
PtcFarmBetterPractices	Include stochastic component to reflect differences in agricultural practices (kg)	20	16	24
addYield	add yield for better practices	1000	800	1200
priceBoro	Crop price BDT per kg	20	16	24
pumpInvest	Investment per farm needed to buying the pump (BDT)	1,780,000	1,424,000	2,136,000
interestRate	Interest rate	9.556	7.6448	11.4672
Pct_control	Percentage of contribution (relative to acreage)	0.75	0.6	0.9
meanAspiration	Level of income that agents aspire in order to be satisfied. Relative to the farmer's yield	0.5	0.4	0.6
labourCostHa	Individual labour cost BDT per ha per year (model /3 to make seasonal)	40,000	32,000	48,000
inputCostsHa	Individual input costs BDT per ha per year (model /3 to make seasonal)	10,000	8000	12,000
fixedCosts	Individual fixed costs BDT per year (model /3 to make seasonal)	10,000	8000	12,000
energyCosts	Collective relative to water level energy costs BDT per ha per year	50 if water level high and zero when water level low	40	60
maintInsurCosts	Collective maintenance and insurance costs BDT per ha per year (model /3 to make seasonal)	100	80	120

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2021.105886.

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