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Understanding farmers' drought risk adaptation in the Netherlands

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Abstract

Even though the Netherlands has a maritime climate, it sometimes has to deal with drought events. Considering the agricultural sector, temporary precipitation shortages cause decreased soil moisture levels and increased salt concentrations. Drought events bring about economic costs by directly affecting crop production and farm income. Future climate change will increase agricultural drought risk in the Netherlands.

The vulnerability of the agricultural sector to drought depends substantially on its adaptive capacity. This is the ability of agents to influence the propensity of the sector to suffer from harm form exposure to drought through adaptation. Public and private adaptation should work together in order to enhance the sector's resilience. Due to the complexity of socio-environmental systems caused by non-linearity and feedback mechanisms, the emergent outcomes of many individual actions do not always go in

line with policy goals. Understanding the factors affecting private adaptation that lowers the vulnerability of the agricultural sector helps to design effective climate change adaptation policies. In this study, we will develop a conceptual model to investigate the factors that affect a farmer's adaptation decision-making under drought risk. In a later phase of the project, we will test the conceptual framework using survey data analysis. These insights will form the basis to investigate the emergent outcomes of farm-level adaptation on the vulnerability of the agricultural sector, using Agent-Based Modeling.

Keywords
Drought, agriculture, adaptation, protection motivation theory (PMT), survey

1. Introduction

In the Netherlands, climate change projections show it is likely that periods of droughts will become more frequent and intense in the future causing decreased water availability. Water is an important production factor for the agricultural sector, since crop production is sensitive to water quality and quantity. The agricultural sector of the Netherlands creates jobs equal to 187,000 years of employment and it accounts for 1,5% of GDP. Decreased water availability due to climate change might cause income losses to farmers. A farmer's drought vulnerability is the state of susceptibility to harm form exposure to drought and from the absence of capacity to adapt (Adger, 2006).

Adaptive capacity is the ability of a farmer to influence his vulnerability through adaptation. Adaptation is the action taken by a farmer to moderate the impacts of future droughts or to better cope with the consequences (Adger, 2006). A farmer's adaptive capacity depends on the available resources and the ability to use the resources effectively in the pursuit of adaptation, for example the use of financial resources. Besides socioeconomic and institutional factors, adaptive capacity also depends on psychological processes such as risk perception and efficacy beliefs (Kuruppu and Liverman, 2011). Sufficient adaptive capacity at the farm level is a prerequisite for adaptation and therefore for the vulnerability of the agricultural sector.

Most studies to the vulnerability of the agricultural sector to climate-induced droughts use traditional neoclassical economic models. The assumption underlying these models allow to evaluate different adaptation strategies, which are exogenous to the model (Crane, Roncoli et al., 2011). This is sometimes referred to as the "dumb farmers approach", since these models neglect endogenous adaptation behavior of farmers and the complexity of the agrarian system (Reidsma, Ewert et al., 2010).

In reality, farmers adapt in response to a changing environment. They operate in a changing natural and social system by taking individual adaptive actions. It is extremely important to understand farm level adaptation behavior since it determines the performance of the agricultural sector and the vulnerability of the sector to droughts (Reidsma, Ewert et al., 2010;Crane, Roncoli et al., 2011) . This is not only a technical process but also a social process. The way adaptation measures are implemented depends on a farmer's personality and on the social network in which he operates.

The objective of this study is to develop a conceptual framework to assess the factors that determine a farmer's adaptive behavior with regard to increasing climate induced drought risk in the Netherlands. In order to develop a conceptual framework we will first describe the specific characteristics of drought in the Netherlands. Then, we will give a description of the agricultural production process, the decisions a farmer faces, the influence of droughts on the production process and some possible adaptation strategies. Since a farmer's adaptation decision can be characterized as a decision under risk, we will continue with a review of theories that explain an individual's decision-making under risk. Eventually, the conceptual model will be tested using empirical data from a survey. Therefore, we review empirical studies that use surveys to assess the determinants of a farmer's decision to adapt to climate-induced drought. Based on this information we will develop a conceptual framework to analyze a farmer's adaptation decision-making under drought risk in the Netherlands. Finally, we will conclude with a section on future research.

2. Drought in the Netherlands

The Netherlands has a maritime climate, with in most of the years a precipitation surplus and a water discharge surplus. In an average year, the precipitation surplus and water discharge are transported to the sea via the new Waterway and Rhine Delta. This does not mean that the water does not serve any function; a certain amount of water transport to sea is needed to prevent salt intrusion via the New Waterway.

Nevertheless, droughts during summer time occur frequently. A drought is a period with lower than average precipitation deficiency, causing a reduction of the water availability (Paulo and Pereira, 2006). Precipitation deficiency is the difference between precipitation and evaporation. In the case of droughts, precipitation is lower than on average. Periods of drought go often accompanied with high temperatures and sunshine; both factors that increase the evaporation. Increased evaporation exacerbates drought. The Royal Dutch Meteorological Institute uses precipitation deficiency as an indicator for drought severity.

Droughts affects the fresh water availability in three ways, see Figure 2.1:

1. Ground water levels go down
2. Due to decreasing groundwater levels, surface water levels go down. River discharges and water levels in lakes decrease for example
3. Low river discharges causes salt intrusion. In periods of droughts, insufficient water can be transported to the sea via the New Waterway to resist the intrusion of seawater. As a result, salt water intrudes the river up to points where water is taken in for supply to water users.

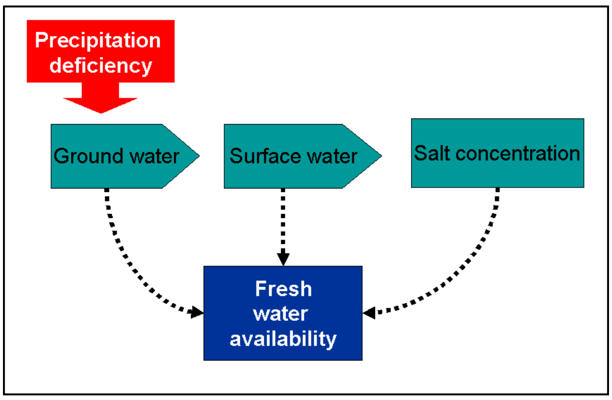

Figure 2.1 Droughts and water availability

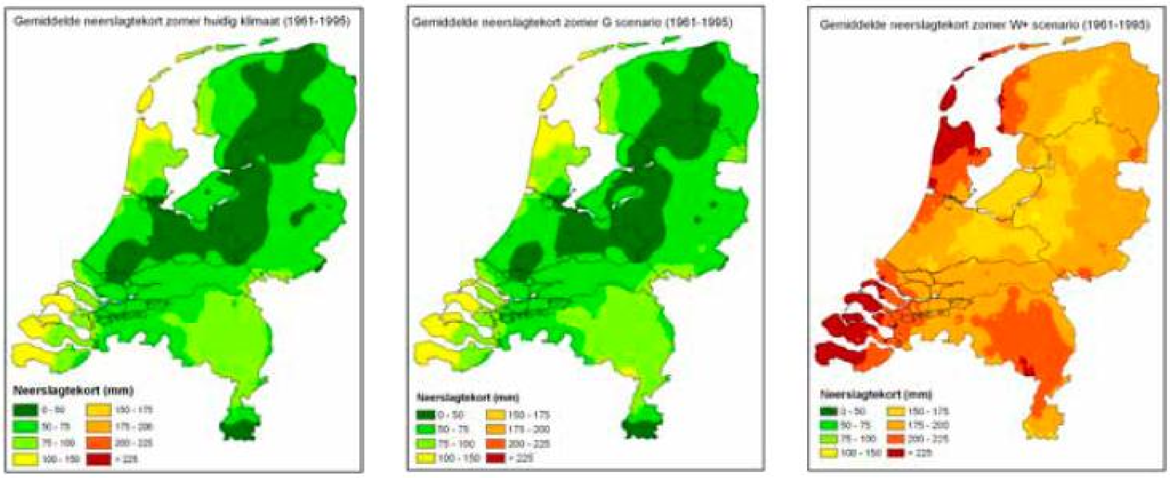

Figure 2.2 Average precipitation shortage under current climate and under two climate scenarios (G and W+) in 2050, more yellow and red indicate larger precipitation shortages (Deltaprogramma Deelprogramma Zoetwater, 2011)

It is likely that summers will become warmer and dryer, and periods of drought will become more frequent and intense due to climate change (Ministerie van Infrastructuur en Milieu, 2009). This puts future water availability and quality in summer time even more under pressure. Figure 2.2 shows the average precipitation shortage under two climate scenarios developed by the Dutch Meteorological Institute (KNMI). It shows that in the most severe climate change scenarios precipitation shortages go up significantly. Figure 2.3 shows the average monthly discharges of the two most important rivers in the Netherlands, the Rhine and the Meuse. In the most severe climate scenario, the average monthly discharge drops significantly during summer time.

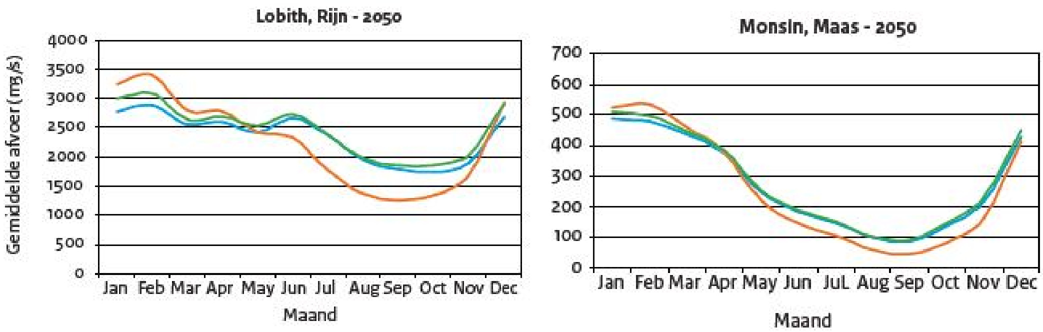

Figure 2.3 Average monthly discharges of Rhine and Meuse under current climate (blue line), climate scenario G (green line) and climate scenario W+ (red line) in 2050 (Deltaprogramma Deelprogramma Zoetwater, 2011)

3. The decision-making process of farmers under climate induced drought

To understand a farmer's behavior regarding climate induced drought adaptation it is first necessary to know the agricultural production process and the management decisions a farmer has to make during a growing season, section 3.1. The next step is to understand how climate induced droughts affect the production process and which decisions a farmer can take to adapt to the changing circumstances, section 3.2 addresses these issues.

3.1 Farm management

Figure 3.1 shows the yearly agricultural production process and the farm management decisions a farmer has to take during the season. Agricultural activities are divided in four subsequent activities; these are preparation, cultivation, harvest and post-harvest.

The *preparation* period concerns the period after harvesting and before planting. Farmers' activities mainly focus on the preparation of land for the coming season, for example plowing.

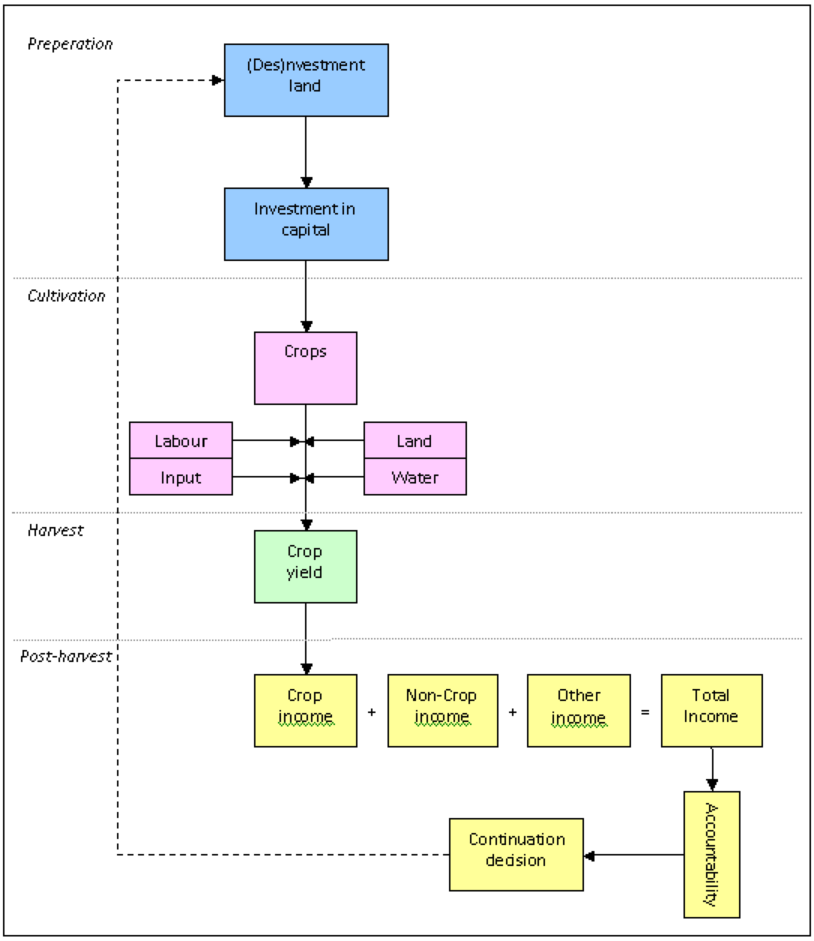

Figure 3.1: The agricultural production process and farm management decisions (adapted from Balmann, (1997) and Nhemachena and Hassan, (2007))

In this period a farmer makes two important decisions, whether to (dis)invest in land, and whether to (dis)invest in capital. He bases these decisions mainly on the results of last years, his current assets, the financial constraints and his expectation about the future (Balmann, 1997). Considering the land decision, there exist two types of markets; a market to buy or sell land and a market to rent or let land. Transactions on these markets may cause changes in land use. The supply on the land market depends on the land that becomes available for sale from farmers that exit the sector or from farmers that do not renew their renting contracts. Demand for land depends on the credit worthiness of farmers, their expectation about the future of their farm, the price of the location and quality of the land. The capital investment decision concerns the purchase of machinery and equipment required for crop production. There are two categories of investments in farm capital: 1) investments in replacement of existing capital and 2) investments in additional capital. Investments in replacement capital depend on the economic depreciation of the existing capital. Investments in additional capital depend on the saved profits of previous years and the expectation about the future of their farm. There is a special type of investment, the investment in innovations. In agriculture, technical improvements are largely process innovations such as irrigation technology, fertilizer, tractors and pesticides, but product innovations also exist such as new crop varieties.

The *cultivation* period consists of the planting of crops and the cultivation activities like weed control and irrigation. During this period, a farmer has to make five decisions.

I. A farmer has to decide which crop he is going to grow on which land, when he is going to sow or plant the crop and how he is going to produce it. A farmer does not always have to take a decision on which crop he will grow the coming period, some crops have a more permanent character and are not removed during the harvest, for example crops from which only the fruit is harvested. The crop decision depends on many factors:

    1. Crop choice is constrained by the soil type and quality.
    2. The crop rotation scheme. Farmers frequently use crop rotation, to prevent soil decreasing soil fertility and to avoid pests. However, not all farmers use rotation schemes.
    3. A farmer’s expectations on for example the weather and crop margins.
    4. A farmer’s knowledge.
    5. The availability of technology, like irrigation. Some crops need specific treatment that requires the possession of particular technology.

II. After deciding which crop they are going to grow, they have to decide when they are going to sow or plant the crop. Crops need to be planted in a specific period, but within this period, there is some flexibility. This decision mainly depends on the weather, to wet or dry conditions can affect the crop during the first phase of the growth-stage.

III. Finally, a farmer has to decide how he is going to grow/cultivate the crop. This decision concerns a farmer’s activities during the crop growth-stage. These activities concern weed control, soil treatment, the use of pesticides and fertilizer and irrigation. The choice of inputs depends on the crop characteristics and on the growing conditions that affect the productivity. Growing conditions concern the weather and the outbreak of pests and diseases.

During the *harvest* period, the crop is harvested. In some cases the crop is completely removed from the land like in the case of potatoes. In other cases, only the fruit is harvested. An important decision a farmer has to take in this period is when to harvest; the weather and the crop maturity are two important determinants of this decision. The weather forecast as well as a farmer’s expectations plays an important role in making this decision. The harvest results in a crop yield expressed in kg/ha.

In the *post-harvest* period, the crop yield is sold on the market. The farmer does not have much influence on this process because there are many buyers and sellers. Important sale determinants are the access to markets and the market prices. This results in the crop income of a farmer. Besides income of crop production, a farmer can create income from other agricultural or non-agricultural activities and he can have income from other sources such as subsidies. Based on the total income and the fixed and variable production costs a farmer is facing profits or losses. At the end of the year, a farmer makes up his balance sheet. Insolvency forces the farmer to exit the sector. Negative cash flows will reduce a farmer's future credit availability. Another aspect in the continuation decision is the farmer's age together with the presence of a successor.

3.2 Droughts and farm management

Water is an important production factor for agricultural production; there should be enough water from the right quality to optimize crop growth. Droughts put pressure on crop production due water quantity and quality problems Figure 3.2.

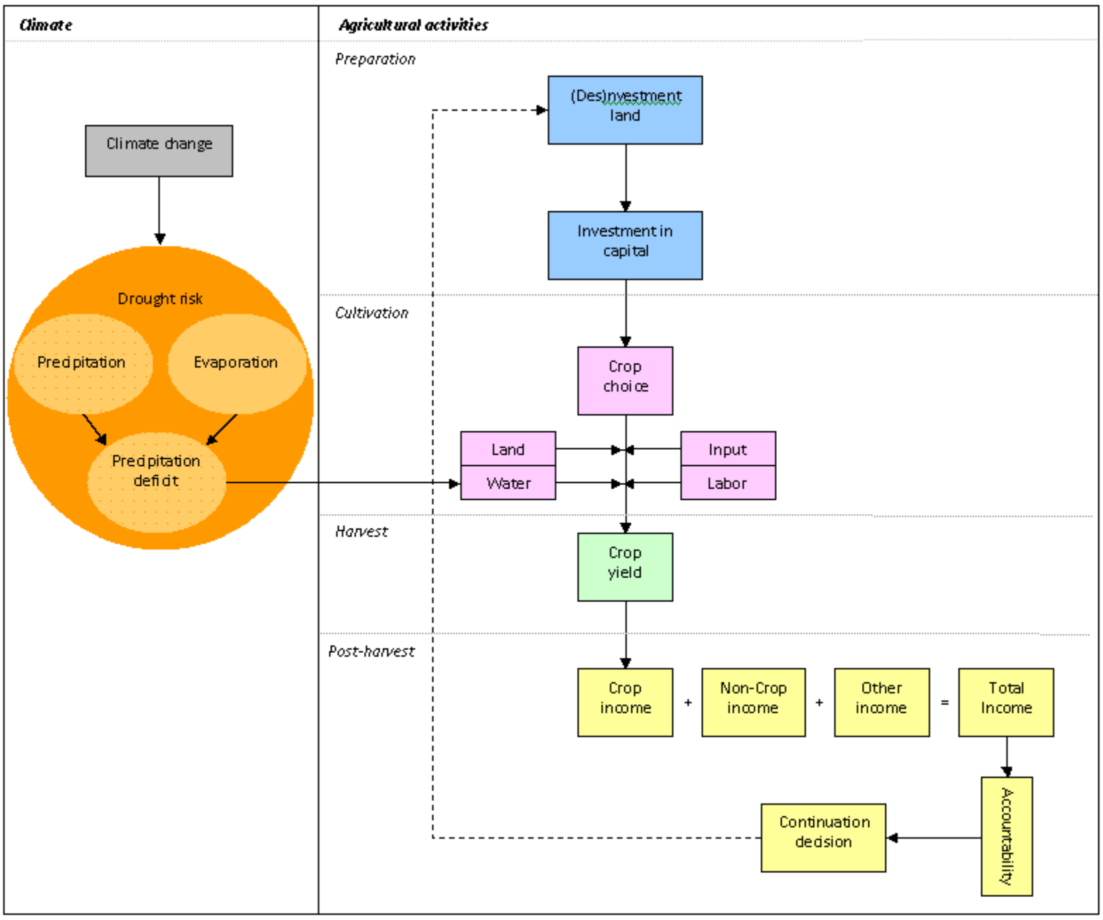

Figure 3.2 Droughts and agricultural production

The amount of crop damage depends on the drought or salt tolerance of a crop, the growth stage and the soil-type. Crop models show that insufficient water or water with too high salt concentrations reduce crop production significantly (Reidsma, Ewert *et al.*, 2010). Depending on the location in the Netherlands, drought can affect crop production in four ways:

1. A decrease in precipitation causes soil moisture levels to go down, affecting dry land crop production.
2. A decrease in precipitation causes surface water levels to go down, causing decreased water availability for irrigated crop production.

3. Low river discharges causes salt intrusion from seawater, salt concentrations in surface waters will go up. Irrigation with increased salt concentration causes damage to the crop production depending on the salt tolerance of a specific crop.
4. Decreasing ground water levels increase seepage with salt water causing decreased crop production.

So, droughts affect both dry land and irrigated agriculture due to water quantity and quality problems.

In the current situation, damage to the agricultural sector in the Netherlands due to drought is estimated at 700 million Euros in the case of a drought that occurs every ten years, and 1800 million Euros in the case of a drought that occurs every one hundred years (Deltaprogramma, 2011). It is expected that under the most severe socioeconomic and climate change scenarios, the frequencies might go up with a factor a five in 2050. This indicates that a damage of 700 million Euros can be expected with a probability of occurrence of every second year in 2050.

Droughts affect a farmer's financial income due to reduced crop production. A farmer's crop income is equal to:

$$Income_j = \sum_i \left(\left(p_i \cdot q_i \right) - C_i \right)$$

Where *j* refers to a specific farmer, *i* is a specific crop, *p* is the price of crop *i*, *q* is the production of crop *i* and *C* are the costs involved in producing crop *i*. Farmers are not able to influence the price assuming a perfectly competitive market. The production *q* is dependent on many factors including the weather. Droughts decrease the production causing a decrease in farm income.

Farmers will respond to this decline in income by adaptation. Adaptation is a strategy to better resist and cope with droughts that induce losses to farmers. Besides adaptation at the micro level or farm management level, adaptation can also take place at the macro level, this is concerned with adaptation at the national or regional scale as a response to domestic and international policy and climate change (Nhemachena and Hassan, 2007). In this study, we will focus on a farmer's drought adaptation at the micro level.

There exist several strategies for farmers to adapt to drought (Blom, Paulissen *et al.*, 2008). Figure 3.3 shows which adaptation options are available at each of the agricultural activities. In the preparation stage, a farmer decides whether to (dis)invest in land and capital. Due to drought a farmer might adapt by acquiring land that is suitable for irrigation or that is located in an area where droughts have less impact on crop production due to local conditions. A farmer can also decide to sell or let land that is has bad local conditions and that is unsuitable for irrigation. A farmer can also adapt through the investment in capital, for example by investing in irrigation equipment or in rain basins. This could also be the investment in innovations like new reverse osmosis technology to desalinate water or new crop varieties.

In the cultivation stage, a farmer has to decide which crops he is going to grow, when he is going to sow or plant and how he is going to cultivate these crops. As a response to drought, a farmer can choose to use crops that are less water demanding or that are more salt tolerant. Furthermore, he has the choice to delay or move up the sowing or planting. Finally, he has the chance to respond to drought during the growth-stage. In the case of drought, a farmer has the choice to irrigate or to use water with increased salt concentrations. In the harvest stage a farmer does not have so many options to adapt. The only thing he can decide upon is to move up the harvest date.

At the end of the season, in the post-harvest stage, when the farmer makes up the balance of last year, he has several options to adapt his production to future droughts. He has the choice to voluntary exit the sector or he can decide to diversify his income for the coming year. This has consequences for the (dis)investment in land or capital at the preparation stage of the season.

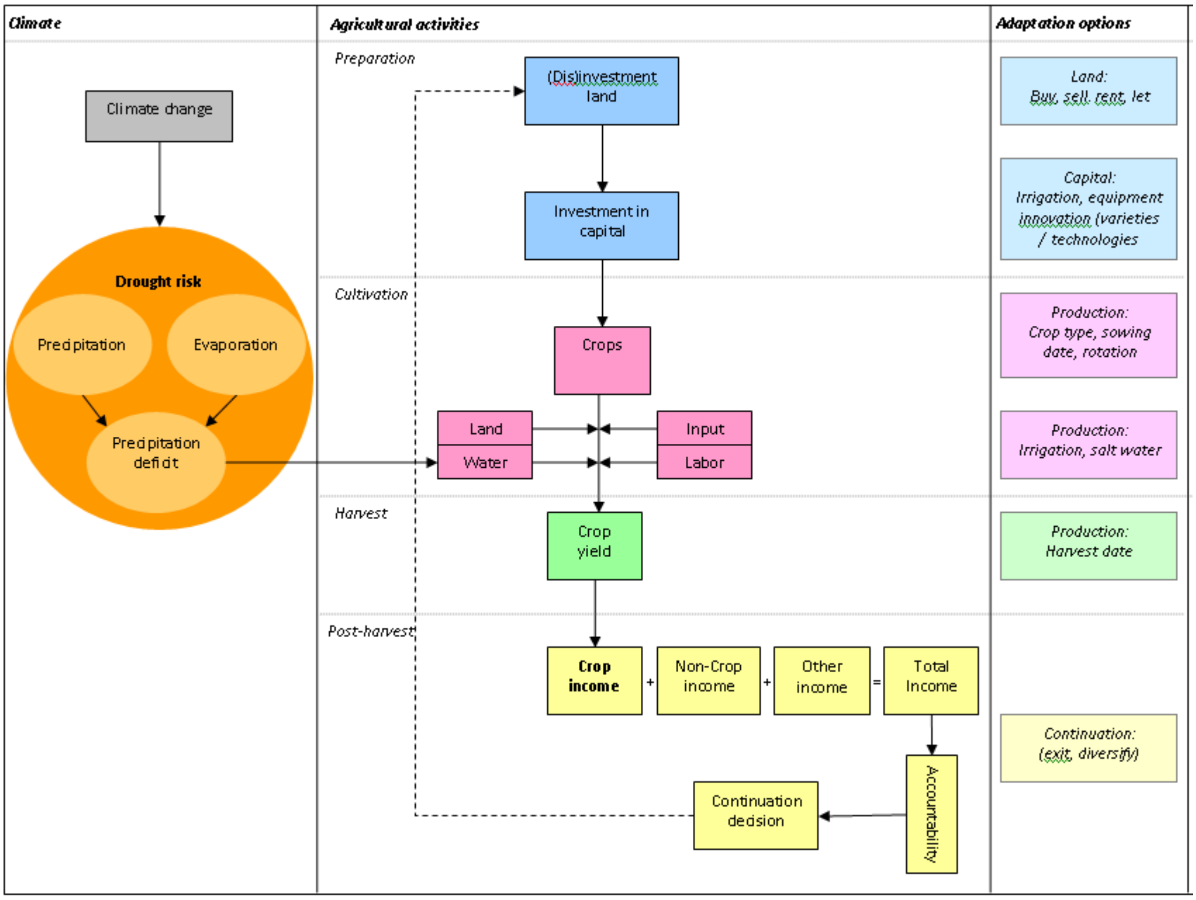

Figure 3.3 Droughts, agricultural production and adaptation options

So, drought adaptation takes place in all farm management decisions. The adaptation strategies listed above cover land decisions, capital decisions, production decisions and continuation decisions. Now that we roughly understand what kind of decisions a farmer has to take during a season, what the effects of droughts are on the production process and how a farmer can adapt to these effects within his decision-making process, we come to the question how farmers make adaptation decisions under drought risk in the next chapter.

4. Individual decision-making under risk

Theories on individual decision-making under risk differ mainly from each other on the way agents form their risk perception. Several perspectives on the role of expectation formation for decision-making exist in different disciplines within social science research. Section 4.1 gives an overview of the most important theories that have developed over time. Then, section 4.2 discusses theories that explicitly relate all relevant factors to an agent's decision to adapt. Eventually this literature review results in a conceptual framework to investigate farmers' adaptation decision-making under drought risk using survey analysis.

4.1 Moving away from the rational agent

In economics, the basic approach to analyze individual decision-making under risk is expected utility theory based on the rationality assumptions formulated by von Neuman and Morgenstern, (1947). This theory states that in a risk context, agents evaluate the probability weighed utility outcomes of all possible decisions maximizing their expected utility. Expected utility theory is based on several assumptions regarding individual behavior:

1. Perfect information. All agents have full information and are able to process the information. In the context of risk, this implies that they are able to quantify the risk that they face and that they know the consequences of the risk.
2. Perfect rationality. Given this information, they are able to make the best decision.
3. Agents are optimizers. The best decision for a producer is the one that maximizes his profits; the best decision for a consumer is the one that maximizes his utility.
4. Absence of interaction and therefore absence of learning. Because all agents have full information, there is no need for interaction and learning.
5. Agents are homogenous. Because all agents have the same information, are rational and optimizers they can be considered homogenous.

The reliance on these strong assumption forms an important drawback of expected utility theory. In reality, individuals do not show these characteristics, instead they can be considered irrational. There are several alternative theories that describe individual decision-making under risk in literature. In the next two sections, we will describe two of them: Prospect theory and Risks as Feeling.

4.1.1 Prospect theory

Psychology distinguishes between a wide range of processes and experiences that shape an agent's risk perception and that influences an agent's expectation formation (Kahneman and Tversky, 1979). According to psychology agents rely on mental processes, called 'heuristics' when they have to make a decision under risk. Relying on heuristics reduces the complicated task of assessing the probabilities and outcomes of all possible decisions, like in expected utility theory. Three well-known heuristics are the 'representative heuristic', the 'availability heuristic' and the 'anchoring and adjustment heuristic'. When agents rely on the representative heuristic, they make judgments about the probability of an event based on the generalization of a component or process underlying this event. For example, someone makes a judgment about the probability of a drought based on the precipitation in the month before. There are situations that people assess a probability by the ease that examples come to mind, this is the availability heuristic. Someone makes, for example, a judgment about the probability of drought based on the ease that examples from the past or from other agents come to his mind. When an agent relies on the anchoring and adjustment heuristic, he will choose an anchor for his probability estimate and adjusts it to reach his final estimate. The fact that individuals rather rely on heuristics causes some systematic errors called biases in their expectation formation.

(Kahneman and Tversky, 1979) show empirical examples of biases in agents' decision-making under risk compared to decisions based on expected utility theory. They show for example that agents overweigh outcomes that are certain relative to outcomes that are uncertain. This violates the assumption that agents weigh outcomes based on probabilities only and is referred to as the certainty effect. Furthermore, it shows that agents are not risk averse when outcomes are negative, instead they are risk seeking. Finally, they show that people discard components shared by all decisions under consideration, and focus on components that distinguish them. This causes inconsistent preferences, because a pair of decisions can be decomposed into common and distinctive components in more than one way. Sometimes this leads to different preferences.

Based on these observations, (Kahneman and Tversky, 1979) developed prospect theory, which incorporates some psychological perspectives into the economic framework of expected utility theory. In prospect theory, agents assign values to individual gains and losses instead of outcomes and the decision weights replace the probabilities which are use to weigh the outcomes. The decision weights are lower than the probabilities, except in the case of low probability outcomes. This accounts for the certainty effect. The utility function shows diminishing marginal utility, is concave for gains, the function shows increasing marginal utility, and is convex for losses. This change accounts for the fact that agents are risk seeking when outcomes are negative rather than risk averse.

4.1.2 Risks as feelings

Many years later, it became more widely recognized that people do not base their expectation on the calculation of probabilities and outcomes of uncertain decisions nor that they rely only on the above mentioned 'heuristics' (mental processes) for decision-making (Finucane, Alhakami *et al.*, 2000) (Slovic, 2010). (Slovic, 2010) argues that feelings play an important role in probability judgments for decision-making. He refers to it as the affect heuristic. Like the representative, availability and anchoring heuristic, the affect heuristic serves as an incentive for decision-making (Bateman, Dent *et al.*, 2007). The advantage of the affect heuristic is that it occurs rapidly and automatically making it more easy and quick to rely on this heuristic than weighing the gains and losses (like in expected utility theory or prospect theory) or to rely on examples from memory (like in the other cognitive heuristics). This is especially the case when decisions are complex or when cognitive resources are limited.

The above-mentioned theories give important insight in the way people form expectations about uncertain events. However, these studies do not explicitly address other factors than risk perception that might influence a person's decision to adapt, for example gender, trust in government and the perception of the effectiveness of adaptation strategies. Moreover, these theories do not directly relate risk perception to the actual behavior of agents. There are theories that explicitly formulate a framework to assess the socioeconomic and psychological factors, which explain a person's decision-making concerning adaptation measures in the context of risk. The next sections will describe several of these theories and some applications of those theories to climate change issues like flooding and droughts.

4.2 Protection Motivation Theory

This section review Protection Motivation Theory (PMT), a theory that explicitly relates socioeconomic and psychological factors to adaptation. First, we will give a short introduction what PMT is and then we will give some examples of application of PMT to climate change issues.

4.2.1 Introduction

Protection Motivation Theory (PMT) originally explains the effects of fear threats on health attitudes, behavior and responses in order to understand an individuals' intention (motivation) to adopt recommended preventive health behavior, Figure 4.1 (Rogers, 1975) (Maddux and Rogers, 1983). Since the development of PMT theory, it has been applied to a wide range of topics beyond health related issues, for example to injury prevention, political issues and environmental studies, (Floyd, Prentice-Dunn *et al.*, 2000).

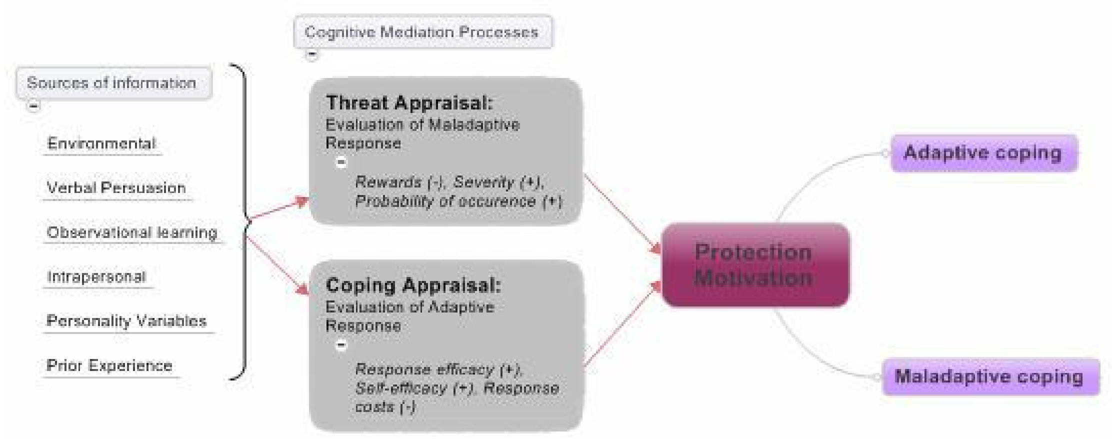

Figure 4.1: Protection Motivation Theory Model (adapted from (Floyd, Prentice-Dunn *et al.*, 2000)

PMT describes two processes that construct an individuals' motivation or intention to protect itself against a certain threat. These cognitive processes are fed by information from several resources, like information from the physical environment, from agents in their social network or from experience. The first process is threat appraisal in which an individual evaluates the severity (perceived severity) and probability (perceived probability) of occurrence of an event in the case of a maladaptive response; someone has to believe that he will be exposed to a threat and that this threat might cause harm when he does not take any adaptive measures. A person will compare this assumed threat with the rewards of maladaptive responses (For example, a smoker might compare the risk of lung cancer with the enjoyment of smoking). These two factors might cause fear that stimulates protection motivation. Without the appraisal of a certain threat, the second process of coping appraisal will not be initiated; if a person does not perceive any risk he will not search for and evaluate adaptive responses.

In the coping appraisal process, a person evaluates the ability to cope with and avert the threat. The coping appraisal process has three components. First, someone must believe that an adaptation measure will be effective in reducing harm (also called perceived adaptation efficacy) and that he has the ability and will to perform the response (also called perceived self-efficacy). Furthermore, a component related to perceived self-efficacy is perceived costs; including the assumed costs of an adaptive response. Self-efficacy and adaptation efficacy positively influence the coping appraisal process, while adaptation costs have a negative influence on coping appraisal. An individual's threat and coping appraisal positively influence a persons' protection motivation; the intention to (not) initiate, continue or inhibit adaptive responses that prevent damage. The protection motivation might result in adaptive coping or maladaptive coping. Adaptive coping modes are responses that prevent damage. Maladaptive coping modes includes avoidant reactions due to denial of the threat or wishful thinking, it also includes adaptive coping responses that are not effective. A person would show adaptive coping behavior when the risk perception resulting from the threat appraisal process and perceived adaptive capacity resulting from the coping appraisal process are both high. Low risk perception and/or low perceived adaptive capacity would both result in maladaptive behavior.

4.2.2 Applications to climate change studies

(Grothmann and Patt, 2005) argue that studies to individual climate adaptation so far fail to consider psychological factors such as risk perception and perceived adaptive capacity. Based on PMT they develop the Model of Private Proactive Adaptation to Climate Change (MPPACC). Like in PMT, they distinguish between two processes: 1) climate change risk appraisal and 2) adaptation appraisal. Like in PMT, a person first evaluates his climate change risk appraisal before he will even consider the evaluation of adaptation strategies.

MPACC adds to existing PMT models by adding variables that explain the risk appraisal and adaptation appraisal processes. The model adds:

1. Cognitive biases and heuristics
2. Risk experience appraisal
3. Reliance on public adaptation

The model adopts the view from psychology that heuristics cause biases in a person's risk perception. These heuristics that cause biases, affect people's judgments under risk irrationally. Risk experience appraisal is supposed to positively influence risk perception and to influence the bias in decision-making. Because private adaptation to climate change can be achieved by others' adaptive actions (for example public agencies), reliance on public adaptation is included in the model.

(Grothmann and Reusswig, 2006) apply the PMT model to a case study investigating residents' proactive adaptation to flood risks in Germany. They extend the model with threat experience, reliance on public adaptation and actual barriers that directly influence protection motivation. Results show that the PMT model explains private proactive adaptation better than a standard socio-economic model including private ownership and household income variables.

(Bockarjova, van der Veen et al., 2009) investigate the relation between flood risk perception and the readiness of individuals to undertake protective action in the Netherlands. For their analysis, they use the extended PMT-TTM approach. The Protection Motivation Theory-Trans Theoretical Model (PMT-TTM) suggests that people at different adaptation decision-making staged are differentially affected by perceived probability, severity, self-efficacy and response efficacy (Block and Keller, 1998). This is in contrast with basic PMT that assumes homogenous effects among groups. Besides the standard PMT variables, they include subjective knowledge and trust in the government in their model. A survey among 1400 Dutch citizens located in flood-prone areas was conducted to gather data. Results show that respondents in different adaptation stages have different factors that explain their behavior. PMT-TTM has also been applied to other climate change issues. (Martin, Bender et al., 2007), investigate the cognitive perceptual process that homeowners experience when faced with the decision to protect their property and themselves from a risk such as wildfires.

(Kuruppu and Liverman, 2011) used the MPPACC model to study the determinants of adaptation motivation of inhabitants of the Republic of Kiribati (islands in the Pacific) to resist climate change induced changes in water resources. They extend the MPPACC model with the TTM that distinguishes between several phases op adaptation.

There are many applications of PMT theory to climate change issues available. Unfortunately, there are no applications of PMT theory to climate related drought issues. The studies show that PMT offers a good basis to assess individual decision-making under risk.

5. Review of empirical climate induced agricultural drought adaptation studies

In order to test the relation between factors that shape an individual's risk perception and actual adaptation a survey is needed. The following section gives a brief overview of empirical studies that used survey to investigate individual adaptation to climate change.

(Nhemachena and Hassan, 2007) develop and apply a method to assess farmers' adaptation in southern Africa. The study used cross-sectional data from eleven African countries. The survey dedicated specific questions to measure a farmer's perception of climate change. Furthermore, it included 25 adaptation options for climate change that the farmers could choose from based on the ones that they actually use. Descriptive statistics were used to characterize farmer perception on change in precipitation and temperature as well as various adaptation measures being used by farmers. Results show that nearly half of the respondents perceive a long-term increase in temperature and decrease in precipitation. The most important adaptation options include crop diversification, using different crop varieties, changing planting and harvesting dates, increase the use of irrigation, increase the use of water and soil conservation techniques, and diversify from farm to non-farm activities. To analyze the determinants of the use of adaptation options they develop a multivariate probit model. Results show that access to credit, free extension services, farming experience, mixed crop and livestock farms, private property and perception of climate change are important determinants of choice of farm level adaptation.

(Krömker, Eierdanz et al., 2008) use PMT to study the determinants of an agent's drought susceptibility in regions of India, Portugal and Russia. Data was collected using expert interviews and a survey among 65 selected households. The study does not intend to test a model of adaptation motivation; instead, it aims at applying the PMT model to investigate the susceptibility of different groups of agents. They apply fuzzy set theory to analyze their data. They were able to identify different groups and subgroups with regard to their susceptibility and factors that explain their susceptibility.

(Tadesse Deressa, Hassan et al., 2009) analyze the factors that determine the choice of adaptation strategies in crop production systems in the Nile basin of Ethiopia based on a cross sectional household survey among 1000 households. Half of the respondents indicated that they perceived temperature increase and precipitation decrease and half of the respondents indicated that they have adapted to climate change. The most important barrier to climate change was a lack of information. A multinomial logit model was used to analyze the determinants of farmers' choice of adaptation strategies in the Nile basin in Ethiopia. The model includes only socio-economic and institutional variables. Institutional factors include extension on crop production, access to information and access to credit. Results show that education, income and access to information and credit enhance adaptation.

(Apata, Samuel et al., 2009) examine farmers' risk perception about climate change induced droughts and salt problems and their strategies they employ to adapt. The study administered a questionnaire among 350 respondents. The data was analyzed using a logit model. Results show that altered climate change and noticed frequency of droughts had no significant effect on the adoption of an adaptation strategy, while increases in temperature, intercropping, farm size, farming experience educational status and access to extensions and credit influence adaptation positively.

(Hisali, Birungi et al., 2011) study the determinants of adaptation strategies for agricultural production in Uganda. Data was gathered using a national household survey and was analyzed using a multinomial logit model. Reducing consumption, running down past savings, technology based options and borrowing were indicated as the most important adaptation strategy. Access to credit would enhance the ability of households to adapt.

6. The conceptual model to assess a farmers individual drought adaptation

From the previous sections it is clear that several theoretical frameworks exist that explain protective behavior under risk. We will adopt PMT to assess farm-level drought adaptation

PMT has been successfully applied in many studies and risk contexts, and in the context of climate change (examples). Due to the numerous applications, information is available on the measurement of the factors incorporated in PMT. This supports the development of a consistent survey. However, PMT only offers a framework to assess whether a farmer is motivated to engage in adaptation or not. Therefore, we will use the extended PMT-TTM model.

PMT-TTM distinguishes between several stages between these two extremes. The basic premise is that different groups can be distinguished based on those who have not yet decided to adapt, those who have decided to adapt and those already performing adaptation behavior. PMT-TTM distinguishes between three stages: pre-contemplation, contemplation, and action. Pre-contemplators resist to change, and do not seriously consider changing their behavior, because they underestimate the probability and severity of an event. Contemplators acknowledge that they have a problem, but are not ready to change their behavior. People in the action phase already show adaptive behavior. PMT-TTM can be used to test whether a group can be treated as homogenous with respect to the adaptation stage of a group. In the case, there exist differences among these groups. Insight in these variables can support differentiated communicating strategies among groups.

In the context of this study, PMT-TTM allows to distinguish between farmers that do not consider adaptation, that consider adaptation, and those who actually adapted. Using this approach offers the possibility to assess whether different groups can be distinguished based on the stage of adaptation and which factors explain differences in attitudes towards adaptation. Policy makers can use this knowledge to develop strategies to influence farmers to adopt the desirable adaptation strategies.

Figure 6.1 presents the complete conceptual model; we will summarize briefly the main components. In the Netherlands, Climate change increases drought risk for the agricultural sector. Droughts affect the water availability, which is an important production factor for crop production. Decreased water availability causes a reduction in crop yield and consequently in farm income. Farmers have several options to adapt to decrease their drought vulnerability. The choice whether or not to adapt and the choice among adaptation options is a choice under risk. We adopted PMT-TTM that distinguishes between several socioeconomic and psychological factor to explain a farmers drought risk adaptation. Furthermore, it helps to gain insight in the factors that determine the adaptation stage of a farmer.

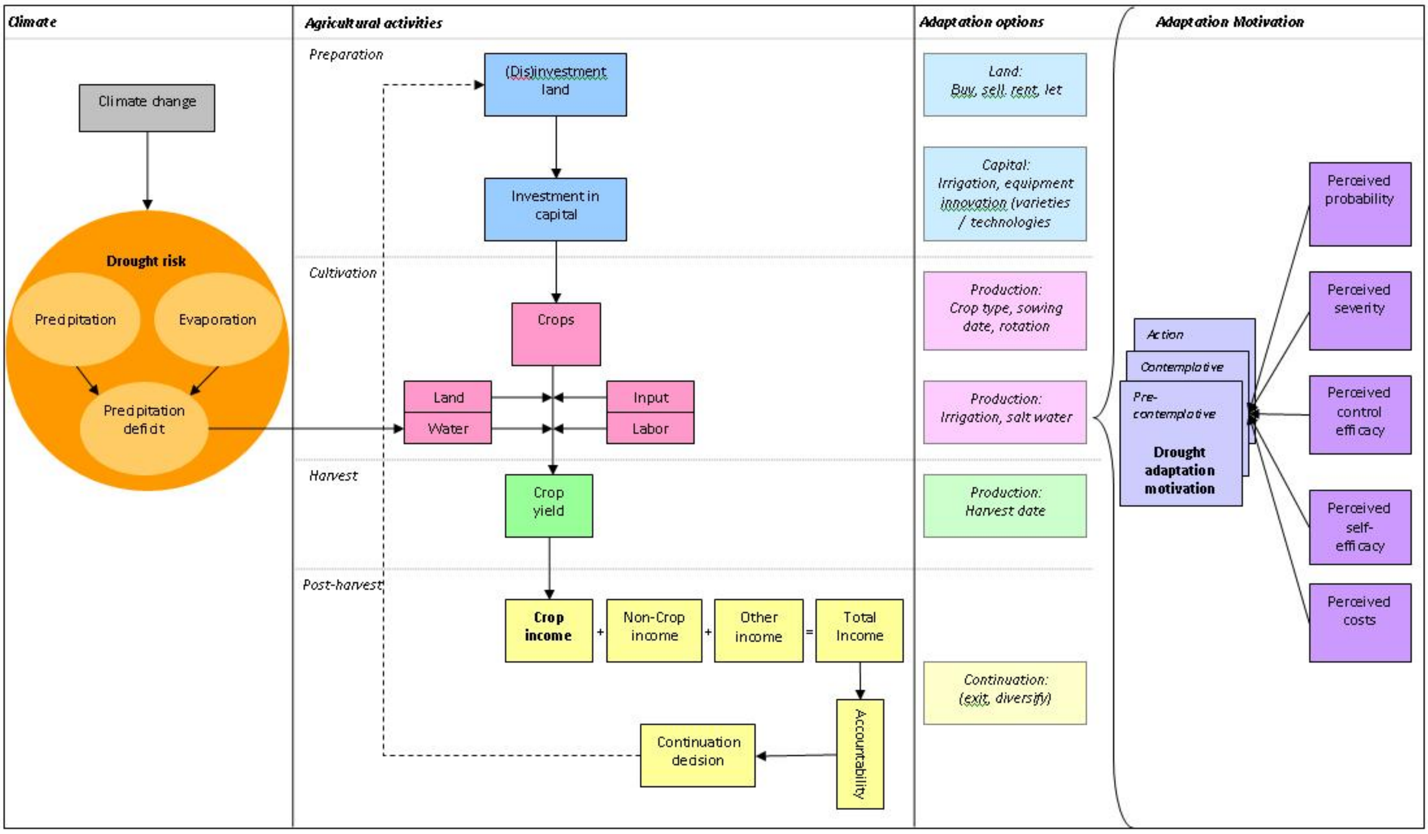

Figure 6.1 The conceptual model: droughts, agricultural production, adaptation and adaptation motivation

7. Future research

The conceptual model presented in section 6 forms the basis to understand a farmer's adaptation under climate-induced risk. Based on the model some hypothesis will be formulated with regard to the factors and relations among factors that explain a farmer's adaptation. These hypotheses will be tested empirically. We will use a survey among farmers to gather data on the factors mentioned in PMT-TTM.

The ultimate goal of this project is to understand the factors affecting farm level adaptation and the relation with the vulnerability of the agricultural sector at a regional scale. We will investigate this relation using Agent-Based Modeling. The conceptual model presented in this study will form the basis for the model. The empirical data that we will gather with the study will be used to calibrate and validate the model.

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