Viability of an alternative cropping system using shallow freshwater lenses in Tra Vinh and Ben Tre, Vietnam

A case study of the viability of an alternative cropping system for high value, small scale agricultural production on sand dunes.

BSc. Thesis by Sep Bregman (980112122080)

5 April 2020

Water Resources Management group

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A case study of the viability of an alternative cropping system for high value, small scale agricultural production on sand dunes.

Bachelor thesis Water Resources Management submitted in partial fulfilment of the degree of the Bachelor of Science in International Land and Water Management at Wageningen University, the Netherlands

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This research gave me a unique insight in the dynamics, current and future problems facing the coastal Mekong Delta. It was a pleasure to work together and talk to the most amazing Vietnamese people during the fieldwork and I am grateful for all the special moments with all the people I met. With this thesis I want to give an insight on the problems facing the Mekong Delta and its amazing people and possible solutions to these problems.

Abstract

This research was part of the Freshwater Availability in the MEkong Delta (FAME) project, in the coastal provinces of Tra Vinh and Ben Tre, Vietnam. The Mekong Delta experiences problems with land subsidence and increasing relative sea-level rise. The field sites of the FAME project are sand dunes and contain shallow freshwater lenses. This water lens can be artificially increased, and this water can be extracted, which FAME wants to implement in the higher area. Another project working on these dunes of the International Fund for Agricultural Development (IFAD) which has a goal to reduce poverty and inequality in the areas they work in. This thesis compares the IFAD project to the FAME project. The farmers already use the shallow lenses for irrigation of cash crops in the dry season, but the amount is not always enough. Per field site, the amount of water that is extracted is calculated and the amount of extra water that can be stored in the dune, together with the salinity intrusion in the surrounding low area, it gives an idea of the feasibility of the FAME project. In this research, the effect of climate change to the system are explained and how this can negatively influence the balance of land and water management and the socioeconomic status for farmers living on these dunes. Furthermore, the goals and target groups of the different projects are very similar, and the FAME project can possibly support the IFAD project.

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Abbreviations

ASR	Active Storage and Recovery
BT02	Ben Tre 02 field site
BT03	Ben Tre 03 field site
FAME	Freshwater Availability in the MEkong delta
IFAD/AMD	International Fund for Agricultural Development/Adaptation of the Mekong Delta
TV02	Tra Vinh 02 field site

Typology

Aquifer	Layer of soil particles with large pores which contains large volumes of water.
Cash crop	Crop that is grown, because it has larger market value than other crops.
Domestic water use	Water that is used in households for cleaning, cooking and other household chores, including watering the garden.
Dune pans/tops	Dune pan being a lower area between two dune tops, but still being higher than the surrounding low area around the dune.
Fresh water	Water that is not damaging crops, because the salinity levels are low enough.
Wells	Extraction point for groundwater.

1. Introduction

1.1 Background

The Mekong Delta in Vietnam is the main rice producing region in Vietnam; for domestic use, and export (Vormoor, 2010). Due to the favourable climate in the Mekong Delta up to three harvests of paddy rice can be achieved, which was promoted by the government of Vietnam in the 1990s (Berg, 2002). However the three-times-per-year cropping system is used less in the coastal provinces and regions because of the higher risk of damage by brackish/saline water during the dry period (from December till April), but also because the production of rice in the dry period did not generate a lot of extra income (Vormoor, 2010). Next to rice, production of fruit and vegetables takes place as well as, more economically important, shrimp and fish from aquaculture (JICA, 2016). The low-lying delta is sensitive to climate change and in particular sea level rise. The relative sea level rise is accelerated by the subsidence of the Mekong plains, mainly because of groundwater extraction in the delta and it is partly caused by less deposition of sediments during floods and due to compaction. The extracted groundwater is from ancient phreatic aquifers and will not be replenished in the future (Minderhoud, 2019). The Vietnam Mekong Delta is sensitive to the impact of climate change, impacting lives and livelihoods of farmers. Climate models predict an increase of temperature and chance of cyclones leading to smaller rice yield. The change in climate also makes it difficult to plan cropping cycles, because the uncertainty of rainfall also increases (Vien, 2011).

In the coastal Ben Tre province, an urgent problem is the saltwater intrusion. In the dry season the saltwater flows upstream into the river and canals and intrudes inland through surface- and groundwater. The intrusion area in the dry season has been steadily moving further inland over the years. To produce crops during the dry season people try to store fresh water during the rainy season in ditches and canals (JICA, 2016). By analysing satellite images Veettil et al. (2019) concluded that in the three coastal districts (Thanh Phu, Ba Tri and Binh Dai) aquaculture ponds doubled between 2000 and 2015 at the expense of rice production fields and mangrove forest important for coastal protection. In combination with the high risk of yield reduction by saltwater intrusion the farmer also gets higher profits from shrimp or fish production. In some parts of Ben Tre a rotation scheme is used with shrimp in the dry season in brackish water and the cultivation of paddy during the rainy season to reduce the risk of diseases in the shrimp ponds and the risk of yield reduction of rice (Ministry of Agriculture, JICA, 2016). Ben Tre is a big producer of fruit and coconut, with around 50% of the farms producing fruits. Coconut is increasingly grown, because it is salt tolerant (Vormoor, 2010).

The adjacent coastal province of Tra Vinh differs from Ben Tre province in the area that is used for crops. A relative larger area of Tra Vinh is used to produce paddy rice, a smaller portion for perennial crops like fruit trees and coconut trees and a smaller portion of land is used for aquaculture (JICA, 2013). Tra Vinh experiences the same problem with salt intrusion in ground and surface water as Ben Tre (Birkmann et al., 2012).

Ben Tre and Tra Vinh can cope with the increasing salt levels in the water used for agriculture in different ways. In both provinces the farmers near the coast are increasingly switching to shrimp production that uses brackish water and can be very profitable (Thu & Populus, 2007; Veettil et al., 2019). A problem of converting from paddy rice to shrimp farming is that the brackish water gives problems for neighbouring farmers. The brackish water leaches to the other fields and is flushed into the different canals, thereby increasing the area with salt intrusion (Tho et al., 2008). One other way of coping with the salt intrusion is to use saline water in the dry season to produce shrimp and in the rainy season have one harvest of rice. The salt accumulated in the dry season needs to flush away by rain, after which a rice crop can be produced. This is a so-called rice-shrimp rotation scheme. This is more sustainable in water and soil quality and reduces the risk of disease outbreaks during shrimp production, but still uses a large amount of fresh water (Birkmann et al., 2012; Lan, 2011).

Figure 1 The three field sites BT02, BT03 and TV02 (Google Earth Pro, n.d.).

Figure 1 shows the field locations. TV02 is located in the province of Tra Vinh, Vietnam and both BT02 and BT03 are located in the province of Ben Tre in Vietnam. The field sites have been chosen because they are old sand dunes. The dunes contain shallow freshwater lenses. Shallow freshwater lenses are often described as freshwater that lays on top of the denser brackish or salt groundwater (De Louw et al., 2011). This freshwater comes directly from rainwater infiltrated into the soil or water infiltrated beneath creek and riverbeds (Pauw et al., 2015). With high saltwater seepage, these lenses can be just a few meters thick and the saltwater can damage crops through capillary rise (De Louw et al. 2011). These freshwater lenses can be trapped in elevated areas like sandy dunes along the coast. In the research area, there are old dunes which contain freshwater lenses in the sandy layer during the dry period. The freshwater in the lenses can be increased using several methods of artificial recharge with different efficiencies (Hoogvliet et al., 2014; Pauw et al., 2015). In general, the artificial drainage of saline water is done by draining the saltwater and replacing it with freshwater that is infiltrated artificially or naturally and thus increases the shallow freshwater lenses (Hoogvliet et al., 2014). These old dunes are not very suitable for shrimp production, because the soil is too sandy and it needs clay or silt to hold the water in the ponds; so, this is not a suitable solution to the lack of freshwater (Kungvankij et al., 1986). These higher dunes do not use the water from the canals and only use the shallow lenses. The future of the amount and timing of precipitation in the area is uncertain (Vien, 2011). It is possible that the water in these dunes is not recharged during dry years and the farmers are starting to experience water shortage or will pump up saltwater. Presently the water is used for agriculture, but it is uncertain if there is enough water in the future with the current agricultural practices and climate change estimations. The people living on the TV02 field site are extra vulnerable, because the people living there are already poor and are Khmer minorities (IFAD, 2014). They often lack access to education, have lower incomes, limited access to financial services, lower market access and have limited area of agricultural land (Tung, 2018; Dang, 2012). The dunes were often the poor lands with low agricultural outputs (Dang, 2012), but right now they have potential of producing cash crops with the help of the freshwater lenses. Both BT02 and BT03 have no large number of minorities but have more substantial amounts of people classified as poor or near poor (IFAD, 2014).

This research will be part of the Freshwater Availability in the MEkong delta project (FAME). The Royal Netherlands Enterprise Agency will collaborate with RoyalHaskoningDHV, Deltares & Utrecht

University, Wageningen University (WUR) and the Center of Water Management and Climate Change (WACC) from Vietnam as main partners. Students from Utrecht University and engineers from Deltares will investigate the amount of freshwater that could be stored in shallow lenses in old dunes using an artificial infiltration system. This bachelor thesis investigates the possibility to change water management techniques at farm scale level, to overcome the difference in existing and future water use and supply in Ben Tre and Tra Vinh province in the Mekong Delta.

1.2 Problem description

The coastal provinces in the Mekong Delta experience a large threat from intrusion of saline water in the canal and river systems and in groundwater during the dry season. This is caused by shortage of fresh water in Tra Vinh and Ben Tre. The provinces at the coast encounter a faster sea level rise. Lands are still subsiding even after implementing a lot of regulations on groundwater extraction and use. This is, however, not the only problem, the annual flooding of the Mekong Delta after the rainy seasons get a lot smaller and they carry less sediments, because of more dams with sediment-traps in upstream countries. The relative sea level rise is thereby increasing fast. Another factor causing subsidence, is the natural compaction and, more importantly, compaction by buildings and infrastructure (Minderhoud, 2019).

The surface waters in the Mekong Delta are increasingly protected against saltwater intrusion through sluice gates in projects of the Vietnamese government. But the saltwater can reach the surface water through the groundwater. Another solution is transforming the rice fields into fulltime shrimp ponds or to change to a profitable rice-shrimp rotation scheme (Thu & Populus, 2007; Veettil et al., 2019). These ways of coping with saltwater intrusion can also be one of the reasons of saltwater intrusion deeper inland. The salt/brackish water in the ponds will leak into other fields or will be flushed into the canal and river systems (Tho et al., 2008). In recent years a lot of farmers (mainly in Ben Tre) changed from rice into coconut farming. The palm trees are more salt tolerant than the rice crops (Vormoor, 2010).

The FAME project tries to find alternative cropping than rice, shrimp and coconut production in the provinces of Ben Tre and Tra Vinh. The project locations are higher areas, which are old sand dunes. Producing rice, shrimp or coconut is not possible, because the subsoil and/or water availability is not sufficient. Farmers already found ways to cope with these problems and produce seasonal vegetables. In normal years they can grow short season vegetables two or three times per dry season, using the shallow freshwater lenses captured in the dunes. Climate change makes the amount of water from precipitation and the length of the rainy season unpredictable (Vien, 2012). The freshwater lenses are not fully recharged by the precipitation and it will be harder to extract the water farmers want to use for their crops, which negatively affects the crops, or farmers cannot crop for one or several of the dry season crops. Farmers make a lot more money from these cash crops than other crops grown in the area. The uncertainty of the rains, however, make the income of these farmer uncertain as well. The dependency on the amount of water in these freshwater lenses is large and over extraction is a likely future problem. The problem in this area is partly caused by climate change and partly by wrong water management on the farms. Because the farmers depend on such a small plot of land, they want to produce to the maximum and possibly irrigate too much water. The water is likely to evaporate or create runoff. This second problem could be countered by technical solutions or by trying to change the habit of the farmers to irrigate too much water. The farmers living on these dunes are poor and/or from an ethnic minority, which ought to be less resilient against climate change (IFAD, 2014; Tung, 2018; Dang, 2012).

1.3 Research objective and questions

To create knowledge on possible farming alternatives for farmers in the Mekong Delta, by comparing the IFAD/AMD project with an alternative cropping system that can be utilised for high value, small scale agricultural production using shallow freshwater lenses in Ben Tre and Tra Vinh provinces during the dry season.

Main research question

How does the IFAD/AMD project compare to an alternative cropping system that can be utilised for high value, small scale agricultural production using shallow freshwater lenses?

Sub research questions (SRQ)

1. What is a suitable cropping system with given cropping patterns and market opportunities in the selected potential pilot areas?
2. How effective is the current International Fund for Agricultural Development/Adaptation of the Mekong Delta (IFAD/AMD) agricultural development support?
3. What is the water balance of surface storage ponds/canals and can they be used for dry season irrigated agriculture?
4. Can the water in the lenses deliver enough water for crop demands?
5. Is it economically viable to run the new cropping system?
6. What is a suitable design and what are the requirements for the new agricultural systems?
7. What is the viable cropping area to use for the new agricultural system?

2. Conceptual framework and Methodology

2.1 Conceptual framework

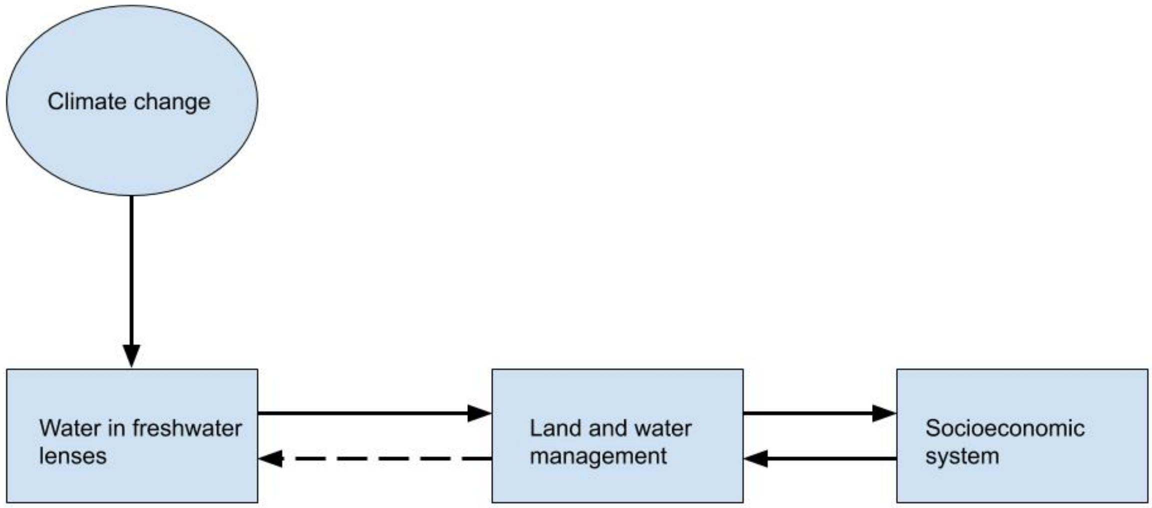

Figure 2 Conceptual framework of interaction between three components that defined the way of farming at the field sites. Climate change can affect the whole chain starting at the amount of water that will be stored in the freshwater lenses.

A big part of the livelihoods at the three field sites in Ben Tre and Tra Vinh depends on agriculture. Figure 2 describes how several parts in the chain interact. Farmers largely depend on the stored water in the sand dune, because their land and water management are influenced by the amount of water that is available. The land and water management influence the water in the freshwater lenses, but the extent of this effect is not really known. But the land and water management cannot be seen independently from the socioeconomic system. The land and water management changes to a system where farmers have maximum profit, but land and water management also influences the socioeconomic system of the livelihoods, when drought can mean no income. The current system can be sufficient and profitable for the climatological situation right now, but not robust enough to overcome a time with climate change in the future. This makes the farmers vulnerable to climate change if there is no change and they are not aware of the dangers (Abid et al., 2019).

The FAME project aims to improve the livelihood situation by increasing the amount of stored water or to change the land and water management to secure and improve the livelihoods. Thereby it is essential to understand the water balance of the sand dune area.

$$P - ET \pm Q \pm Uv \pm Ul - DL = \Delta S$$

Where P is precipitation, ET is evapotranspiration, Q is in- or outflow of surface water, Uv is the vertical movement of the groundwater, Ul is the lateral movement of the groundwater, DL is water used for households and livestock and ΔS is the change in storage.

The outcome of the water balance will be important to be able to decide if and where intervention is necessary. As mentioned before, the precipitation is less predictable with climate change and is therefore an important focus of the FAME project. There is a possible technical intervention to prevent shortages in the groundwater system of the sand dune. This intervention is a system that pumps up water from the surrounding low areas and will pump it in the infiltration wells placed on top of the dune. It is possible to install a horizontal infiltration well, up to 80 meters, to infiltrate the water quickly in large areas. This increases the ΔS artificially (Hoogvliet et al., 2014; Pauw et al., 2015). On the field site of Tra Vinh (TV02), the local authorities and IFAD/AMD implemented a different way to increase storage by constructing a big surface pond. The FAME project also researches if this pond is a sink or a storage of water.

DL is included in this thesis. The amount of water used in this factor depends on the amount of livestock and the domestic uses of the water by farmers.

The ET in the water balance is depending on several factors, of which the most important ones are the local weather, management and environmental factors and the crops the farmers grow (Allen et al., 1998). The ET can be found in chapter 3.2. Local weather is something that cannot be changed, but the management and crops can change. Management includes the amount irrigated and the way of irrigation. Part of this thesis is to research if changes can be made to the water management in the field, as well as the possibility of changing to different crops. In TV02, IFAD/AMD are running a project to strengthen livelihoods in a time of climate change. This includes investing in agricultural changes to secure income for these livelihoods (IFAD, 2014). This thesis also includes research if the FAME project contributes to the project by IFAD/AMD and can possibly be funded to this project.

Q, Uv, Ul and ∆S are being monitored and modelled by Deltares and the master students from Utrecht University. The ∆S is important to know how much water is used by farmers.

2.2 Methodology

To be able to compare the IFAD/AMD project to an alternative cropping system using the shallow freshwater lenses, several ways of data producing and gathering were used.

For this research, the main source of information came from semi-structured interviews. The semi-structured interviews consisted of 34 questions and were ordered in three main water uses, namely domestic use, crop use and use for livestock/cattle, as seen in ANNEX A. At the end of the interview there was room for questions about remarks water users made, curious answers and to talk about the local farming practices when needed. These interviews were conducted with the help of translators and were held in Vietnamese. In total 83 interviews with farmers and other water users were conducted, with 28 interviews held on the Tra Vinh field site, 25 at the BT02 and 30 at the BT03 field site. The farmers were chosen on basis what was seen during scouting and using the digital elevation models of the area to find the borders of the dunes. Farmers were selected with spatial distribution criteria with the aim to cover most of the dune transect (from the edges to the centre and high part) to find out if there are different problems on different parts of the dune. The farmers where randomly chosen in the sample areas, but also a bottled water factory as an extra.

Due to time restraints, it was not possible to meet and interview a local IFAD/AMD official in Tra Vinh to talk about the project they were running. One additional small and short interview was done at the provincial irrigation department. This was a one-hour interview, without being informed beforehand, so both for the interviewer as interviewee it was not possible to prepare sufficiently for this interview.

To calculate the water use of the farmers for crops the FAO's CROPWAT8.0 model was used. This is an indication of the water use of the crops, where the main inputs are derived from the interviews with farmers. The interviews gave an estimation of the water use for crops, as explained by the farmers themselves. In this model, data from literature was combined with the interviews to run a crop water use simulation, as well as soil data produced for the FAME project and observations of cropping systems and crops during the fieldwork. The different cropping schemes of farmers were simplified to make for easier modelling, while still being an estimation that was close to the real situation. This implied combining certain crops into one group and make an average cropping year for the area used by the interviewed farmers for the locations TV02 and BT03. The output is then used in the analysis of this thesis. It was not necessary to put the data of BT02 in CROPWAT8.0, because this field site only has built up areas and roads on the sand dune. The main water use here was domestic use and livestock. Soil data was provided by master student Josh Shankel from Utrecht University, working on the same project. Weather data came from a weather station in Ba Tri for BT03 and from a weather station in Càng Long in Tra Vinh for TV02. This data is the long-time average spanning from 1979 till 2010.

Literature study was done to get to know the areas irrigation, crops and cropping systems. This literature is supporting the data from the interviews and observations or helped to interpret the data from the interviews and observations. Next to external data, data produced by the student of Utrecht University (taking part in the same project) was used to get a complete picture of the local situation and to improve the inputs in the CROPWAT8.0 model. Anne Kruijt, working as an intern for Deltares, monitored the groundwater quality and amount, which was also used in this thesis.

3. Results

3.1 Field site characteristics

3.1.1 Introduction

As mentioned in the introduction and the problem description, all three of the field sites are positioned on a system of sand dunes. But there are differences in the use of land on the sand dune, use of land in the surrounding low areas and the use of water in the freshwater lenses. Field locations TV02 and BT03 are the ones most alike, with BT02 being different. The different dynamics in land and water management and the socioeconomics of the field sites will be discussed in this subchapter.

3.1.2 BT02

Ben Tre 02 field site shows the biggest difference to the other field sites and cannot be compared to the other field sites. The dune is small compared to the other sites and the land use mainly consists of buildings, small gardens and the central road. There is no agriculture on top of the dune, and it is not the biggest user of the water from the freshwater lens. At this Ben Tre field site 25 surveys/interviews were conducted. This area differed from the other sites because the houses were all centered on top of the dune and the surrounding area was low.

In total farmers used 734 to 837 liters per family per day. Which is in total an extraction of water between 18,340 and 20,936 liters a day. This is a large amount, because out of the 25 farmers, 13 used the government tap-water for domestic use, which was not considered in the calculations for the groundwater use. This gives the DL of the water balance mentioned chapter 2.

The wells were only used for domestic use and livestock right now. The pumping-wells were 5.5 meters deep on average and the open wells around 4.4 meters. All the open wells are normally single point wells, whereas 5 farmers used a single point well, 4 used a double point well and one farmer had a system with a horizontal filter for their pumping well. The wells never dry up but decrease in discharge or water quality occurs during the onset of the dry season. In the open wells the water level went down 1.7 meters on average from rainy to dry season. Farmers reported salt and pH problems in the wells, which occurred mainly in March, April and May. The farmers closer to the edge of the dune reported more salt problems, but this water is still used for cattle. These farmers would then use the government tap water for domestic use.

For agriculture, almost exclusively the surface water system is used. The farmers mainly have rice and grass fields, which are low fields with natural inflow for irrigation. Fields need to be made higher than the canal water level to make it suitable for vegetable or coconut farming. The surface water is reported to be too little or it contains too much salts; this starts at the end of February according to most farmers. As observed during the surveys, most grass fields lay next to the dune, because the groundwater-level is a bit lower than closer to the canal and the grass fields are closer to the farm so it can be harvested daily for cattle. Groundwater is sometimes used for watering the gardens.

The amount of groundwater is showing some fluctuation at this field site, but it goes down steadily during the time that was monitored. From October 23 till December 14, the groundwater went down with 400 mm. This means an average daily decrease of 7.7 mm. The groundwater shows some days of sudden increase, which, at other field sites, meant there had been some rain. We cannot say for sure this is the case here, because there was no rain gauge installed at the field site. Rain in the tropics can be very local, so it did not show at the closest rain gauge at BT03. Another possibility is that it is from watering the garden where this monitoring well was placed. The farmer uses water from a ditch to water this garden and the peaks of the increase are very similar.

3.1.3 TV02 and BT03

These two field sites are a bit more similar in the way that groundwater is mainly used for agriculture and both dunes are larger than the BT02 field site. TV02 already has an AMD project running, together with a dugout pond to store rainwater. Below, the different land uses are described, both with similarities and differences as came forward from the interviews with farmers. The cropping schemes are simplified, because the farmers grow a wide variety of crops that cannot be fully shown, and they have very different cropping schemes as well. This is a cropping scheme that an average farmer could have. The scheme is based on average year with average amounts of precipitation in the rainy season. The schematic cross-section also provides a schematic indication of how ΔS works.

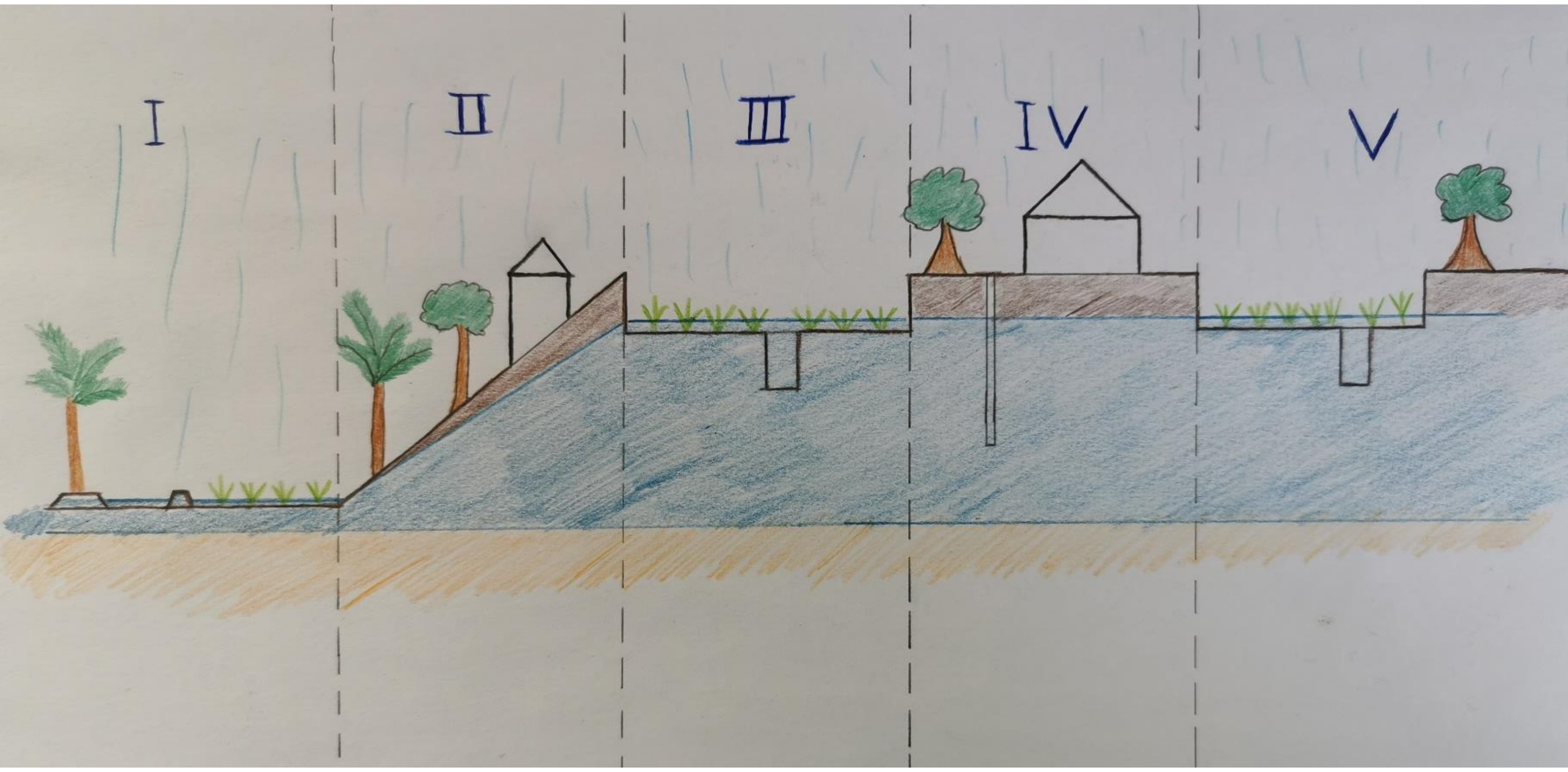

Figure 3 Schematic cross-section of the dunes during the rainy season and early dry season.

Table 1 Schematic overview of an average cropping scheme in normal rainy season, with average amount of precipitation.

BT03	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**
I	Coconut	Coconut	Coconut	Coconut	Coconut	Coconut	Coconut	Coconut
II and IV	Jasmine, fruit trees	Jasmine, fruit trees	Jasmine, fruit trees	Jasmine, fruit trees	Jasmine, fruit trees	Jasmine, fruit trees	Jasmine, fruit trees	Jasmine, fruit trees
III	Peanut	Cucumber/ Peanut	Cucumber	Cucumber	Rice	Rice	Rice	Rice
TV02	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**
I	Shrimp	Rice/ shrimp	Rice/ shrimp	Rice/ shrimp	Rice/ shrimp	Rice/ shrimp	Rice/ shrimp	Rice/ shrimp
II and IV	Water-melon	Water-melon	Water-melon	Water-melon	Water-melon	Water-melon	Water-melon	Carrot
III	-	-	Rice	Rice	Rice	Rice	Rice	Rice

Text below refers to figure 3 and table 1.

I. This area is low and consists, in the case of the Tra Vinh field site, of paddy rice fields and shrimp farms. At the BT03 field site it consists of paddy rice and coconut farms. In both Tra Vinh and BT03 the canals carry freshwater at this moment for cropping rice. During the rainy season there should be enough water and water of good quality to fill the aquifer with freshwater.

II. The lower part of this area sometimes uses surface water, but the higher parts already use wells located at the depth of the investigated aquifer. The area is sometimes not as clear because of excavation practices to make fields bigger and square. On these sides the crops consisted of coconut farms and rice, but also some seasonal fruit and vegetables. Also, farmers live on these slopes.

III. In the dunes there are parts that are a bit lower, possibly a dune pan. In the rainy season farmers in Tra Vinh grow rice twice without active irrigation. Rain is enough for the fields to fill up. At the BT03 field site there is only enough water in the fields at the end of the rainy season to grow paddy rice. At both locations farmers say that the groundwater reaches above field level, this could be an indication that the shallow aquifer is filled to a level that it cannot be filled anymore. On both locations, it was not very usual to find houses in these dune pans.

IV. These areas are possibly the dune tops. In Tra Vinh the main crop during the rainy season is watermelon, which is cropped up to three times a year. At BT03 the dune tops mainly have fruit trees, jasmine tea and gardens. On both locations, farms were built on these higher spots.

V. The dune continues with alternately areas III and IV, and eventually II and I.

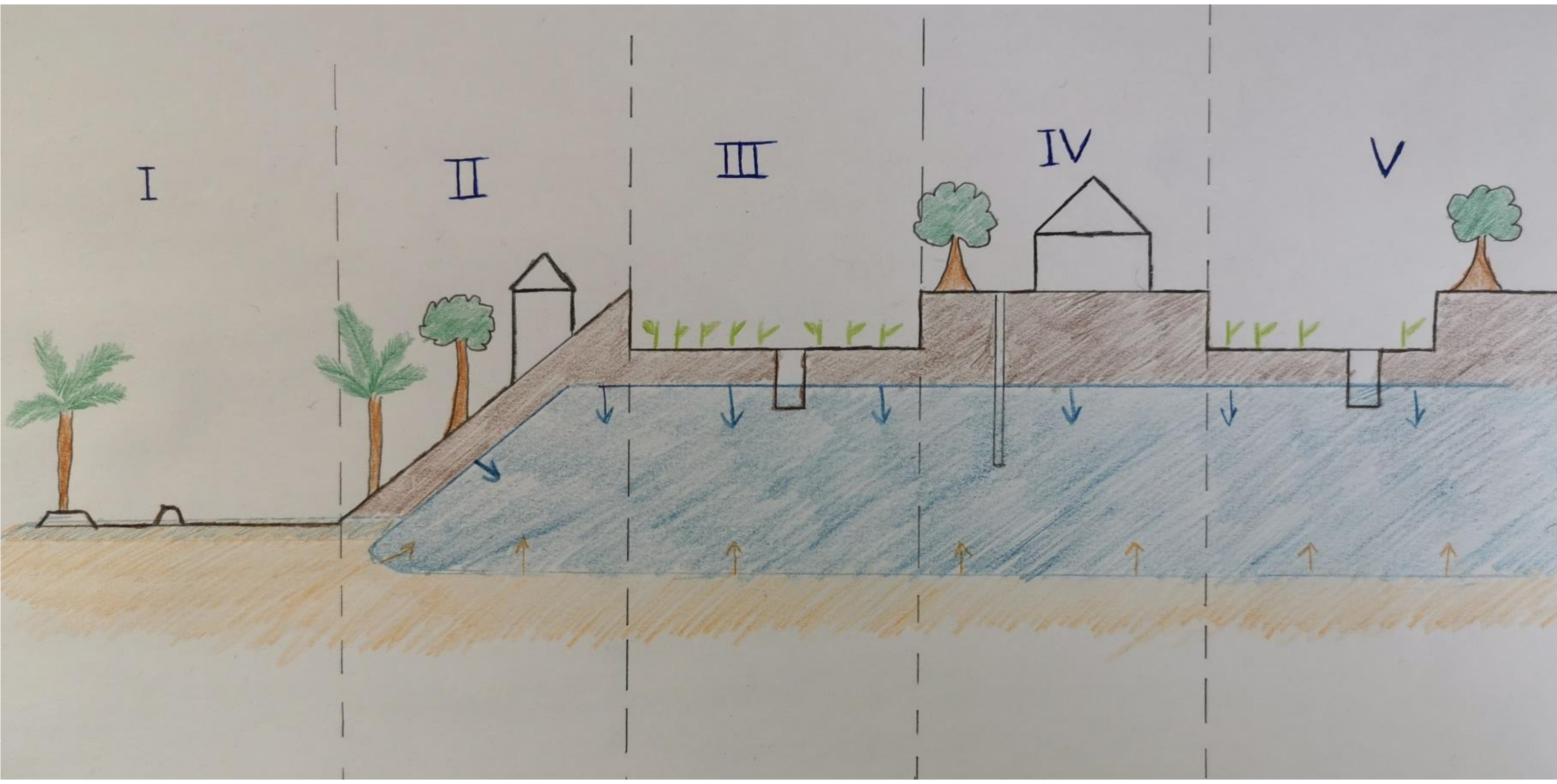

Figure 4 Schematic cross-section of the dunes during the early dry season till the end of February.

Table 2 Schematic overview of an average cropping scheme in a normal start of the dry season, with no water shortage in the wells.

BT03	**December**	**January**	**February**
I	Coconut	Coconut	Coconut
II and IV	Jasmine, fruit trees	Jasmine, fruit trees	Jasmine, fruit trees
III	Cucumber, Peanut	Cucumber, Peanut	Cucumber, Peanut
TV02	**December**	**January**	**February**
I	Rice/shrimp	Rice/shrimp	Rice/shrimp
II and IV	Carrot, Peanut	Carrot, Peanut	Carrot, Peanut
III	-	-	-

Text below refers to figure 4 and table 2.

I. This area is filled with another paddy rice crop in normal years. The salinity of the surface and groundwater is slowly increasing, depending on measures of the government. The water is for the biggest part of the time still usable for crops and the quality could be high enough to store in the dune. Saline water will infiltrate in the canals and groundwater and replace more and more freshwater. In normal years the surface water is of sufficient quality and quantity in December and January, with February getting increasingly worse. The months with higher quality water and room in the aquifer will shift, depending on the amount of rain in the rainy season and the month when the rainy season ends. So, this is the only window of opportunity when water is still available and of good quality.

II. The groundwater level is decreasing in this area and slowly moves towards the middle of the dry season. On the slopes, towards the canals in the low area, the groundwater in the wells has more salts. The area starts to rely on the groundwater for irrigation through waterholes and pumping wells.

III. In Tra Vinh, these lowlands will be bare for the whole dry season, there are no wells in this area. In BT03 on the other hand, short season high value vegetables and peanuts are produced in the low areas. The main form of irrigation is from waterholes, which are connected to the groundwater. With enough water during the whole dry season crops can be grown. The groundwater level will drop significantly when used for agriculture. Meanwhile, the saline groundwater will move up when the freshwater is extracted. The surface water is of good quality around this time of year to fill up the shallow aquifer. Between field level and the groundwater is room to store this water. The amount of water that can be stored, will be explained at the further information for BT03 and TV02.

IV. In the higher areas of Tra Vinh, people start to grow almost exclusively peanuts and carrots. When there are predictions of very dry years, the area where it is grown, is made smaller to make sure that they can irrigate their crops enough. In BT03 people still irrigate the fruit trees to make sure they survive the dry season. The pumping wells in Tra Vinh are located on the high parts and reach deeper than the waterholes in Ben Tre, but some farmers also have these pumping wells in Ben Tre.

V. The dune continues with alternately areas III and IV, and eventually II and I.

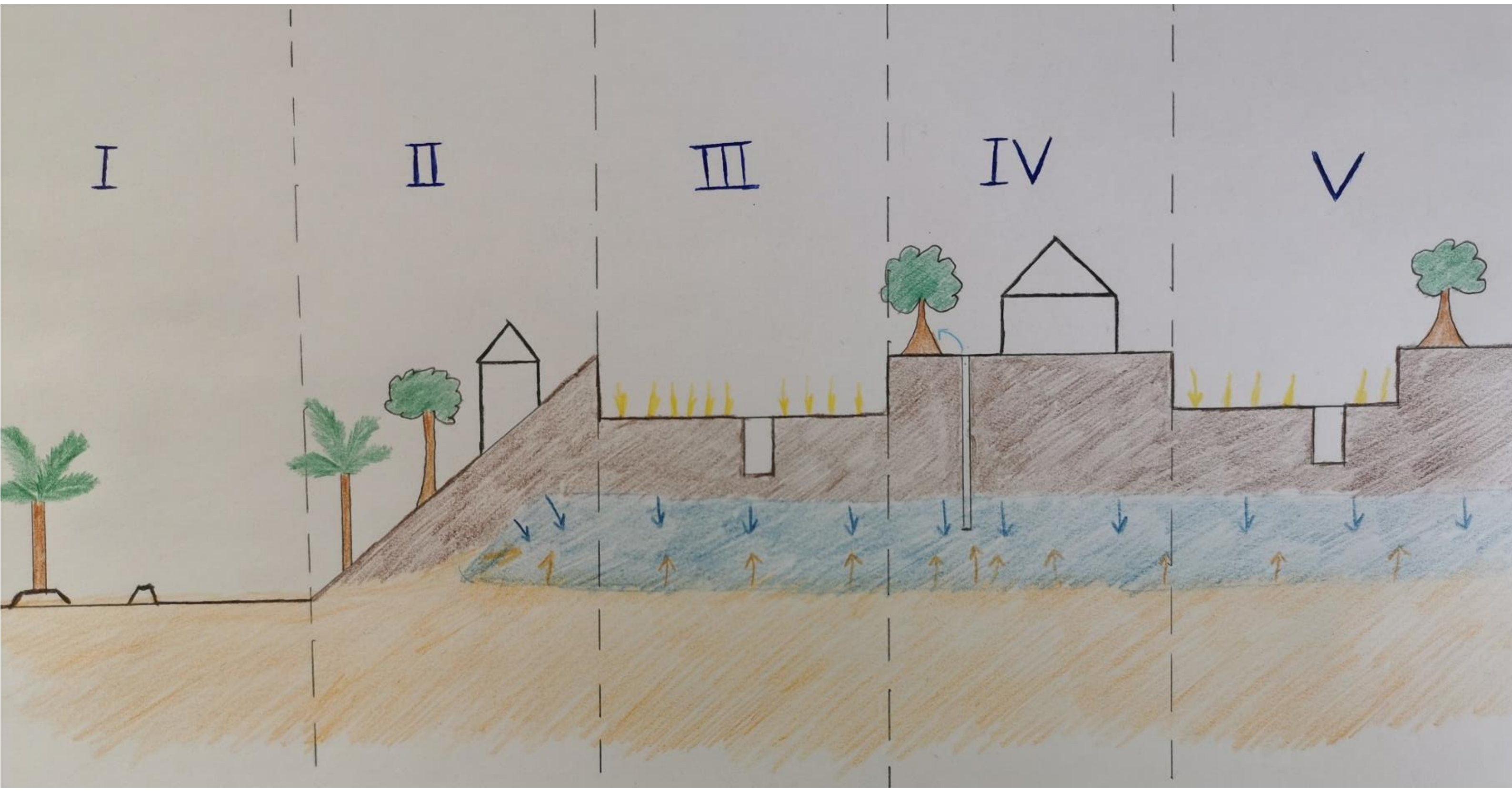

Figure 5 Schematic cross-section of the dunes from March till the end of the dry season.

Table 3 Schematic overview of an average cropping scheme in the month with the most problems concerning water shortage in the shallow aquifer.

BT03	**March**
I	Coconut
II and IV	Jasmine, fruit trees
III	Cucumber, Peanut
TV02	
I	Shrimp
II and IV	-
III	-

Text below refers to figure 5 and table 3.

I. This low area has dry fields. The canals are (almost) dry or filled with water with high salinity. The water is not suitable anymore for infiltrating in the aquifer. The ground water is also saline in this area. To cope with more salt in the future, farmers change their fields to coconut or start shrimp farms.

II. The saltwater is intruding in the dune area from the sides. This results in saltwater in the wells, unsuitable for crop-production. In normal years, almost no seasonal crops are grown during this time. In extreme dry years and years with less precipitation during the rainy season though, the saline water will move into this area earlier and thereby damage crops which still need irrigation or farmers cannot irrigate anymore and let their crops dry out on the field.

III. This area is still bare in Tra Vinh, but in BT03 there is still crop-production. The farmers can still extract groundwater during this part of the year, but at the end of the dry season, the farmers must dig out their waterholes to reach the groundwater level. In dry years, the groundwater will drop significantly and will be out of reach of the waterholes and the pumping wells. Pumping wells have a smaller discharge in the driest months of the year as well. Also, the shallow water lens is in danger of shrinking so much, that the saline groundwater will reach the pumps, as it is already moving upwards.

IV. In Tra Vinh, most farmers will have a few months break to avoid a failed harvest because of drought or salinity, only for livestock and domestic use it is still extracted. During this time, farmers prepare the land for the crops in the rainy season. In BT03 the fruit trees and jasmine bushes are still irrigated to protect them from drying out.

V. The dune continues with alternately areas III and IV, and eventually II and I.

Further information TV02

At the AMD site in Tra Vinh 28 surveys/interviews were conducted close to the artificial pond. The pond has been built by the government and is linked to groundwater of the dune. The government is still working on a distribution system to use the water for agriculture. For a long time only the farmers living next to the pond used it, but now a pilot test is started to connect 10 to 12 farmers to the pond, with a solar pumping system.

In total for domestic use and livestock combined the water use would be between 13,735 and 131,342 liters a day and on average between 491 and 4770 liters per farmer per day. The difference is mainly caused by a farmer who claims he can have a maximum of 3000 cows in his stables, at that moment, only 10 were staying at the farm. After a walk around the big cattle farm, the estimated number of cows that fit in the stables, is lower, but the farmer confirmed 3000 cows several times. The calculations on the water use are further explained in ANNEX B This gives an indication of DL in the water balance as explained as conceptual framework.

When looking at the well-types and problems there, is a clear picture of the situation. The main source of water is a shallow pumping-well. Of the 28 farmers, 27 only used the pumping well and one farmer used both a pumping-well and an open well. The shallow pumping-wells are on average 7.4 meters deep. Most farmers used a single point well, with only two of them having the option to combine a second point well to increase the discharge of the wells in the dry season. Several farmers reported a decrease in discharge from their well and sometimes even had to wait for the well to fill up again. Three farmers reported salt in their wells, but still usable for their crops. The decrease and salinity happened the most in the months February, March and April. Farmer Phúc (big cattle farmer) has got no problems with extracting the amount of water he needs, because "my equipment is better than the equipment of other farmers" and he has a lot of wells scattering his fields with stronger pumps attached. The curious thing is that surrounding farmers encounter water shortages, because they cannot extract the amount of water needed for watermelon, carrot or peanut, so they changed to sweet potato. The big farm is operating for 5 years now and the surrounding experience the change to water shortage in the last three years, which they blame the bad type of soil. This then indicates that the water table is drawn down by this farmer and possibly affecting neighbouring wells

Most farmers used their wells to irrigate their crops by hose, with some exceptions: two farmers used drip irrigation, one farmer used buckets, two used micro-sprinklers and one farmer overhead-sprinklers. Farmers use plastic foil covers for watermelon and vegetables grown in rows to decrease weeds and evaporation from the soil surrounding the crop, but they would still apply most of the water on top of the foil which then was flowing off the foil. Also, the carrot had a straw mulch covering the ground. The farmers learned this from watching each other, from the government or the companies supplying the seeds. The farmers also saw a demonstration of micro sprinklers on a pilot plot and then copied the system themselves. An estimation of the water use by crops is given in subchapter 3.2.

Table 4 shows the average gross income per 1000 square meter of crops farmers grew in at the field sites and profit for some crops as mentioned in literature.

Table 4 Important crops in the sand dune area and the revenue per 1000 square meter. Numbers average of the data from the interviews.

Crop	**Revenue (million VND/1000 m^2)**	**Profit (million VND/1000 m^2)**
Watermelon	6.3	
Peanut	13	9 (Mann et al., 2015)
Carrot	2.4	
Rice	2.6	1.4 (Van Thinh & Vang, 2020)
Maize	2-3	
Sweet potato	9	
Chili	7.5	
Tomato	1.1	

Groundwater at this field site went down with 270 mm from October 3 till December 10. During this time span, the rain gauge measured 30 mm of rain. This meant a decrease of 4.2 mm/day of the groundwater table. This field site had a very stable period where the groundwater table was almost the same for a while. The time with a steady decline is around 20 days long and goes down with over 17 mm/day. This decrease is way bigger than the averaged 4.2 mm/day. The water level of the AMD reservoir on site, shows same kind of decrease of water level as the groundwater. This is an indication that the groundwater is connected to the reservoir and the reservoir can be a sink for the system. Most probably, the amount of rain reaching the groundwater is less than the total amount, so this gives an indication of the ΔS in the local water balance.

Further information BT03

At this Ben Tre field site 30 surveys/interviews were done.

On average a water user uses 1883 to 2110 liters per day. The difference is mainly caused by a bottled water factory. The calculations are further explained in ANNEX B.

The water users in this area (mainly farmers) have a lot of different types of wells. 12 users only have a hand well, 11 have pumping-wells and 7 people have both hand- and pumping wells. The average depth of the pumping well is 8.1 meters deep and for the open wells this is 6.2 meters deep. Both much deeper than at other locations. Also, a lot of the people with pumping wells have double or more point wells. Some people report that their wells are dry in the dry season, but this occurs in the shallower open wells only. In the pumping wells there is a decrease in the discharge from the wells and people sometimes even must wait some minutes so the well can gather enough water. In the open wells the water level drops 2.8 meters from rainy to dry season. Eight people report low pH in their wells. All these problems occur at the end of February, March and April.

For irrigation a lot of farmers still depend on deep waterholes in the fields 2 to 3 meters deep, from which they pump water out onto the field. When the groundwater level drops significantly, these waterholes need to be dug out to reach the groundwater level. Most irrigation is done by hose and hand and has a high frequency, only one farmer had overhead sprinklers. To decrease weeds and evaporation, farmers would cover the ridges of vegetables that grew in line with plastic foil, like cucumber varieties. Around fruit trees they would put palm leaves as mulch and weed prevention as well. The estimation of the water use by crops still will be done in Chapter 3.2. Table 5 shows the average gross earnings of crops mentioned by farmers at the field site and profit for some crops as mentioned in literature.

Table 5 Important crops in the sand dune area and the revenue per 1000 square meter. Numbers average of the data from the interviews.

Crop	Revenue (million VND/1000 m^2)	Profit (million VND/1000 m^2)
Cucumber and bean varieties (cucumber, sopropo, luffa and winged bean)	6.5 to 10	
Rice	2.6	1.4 (Van Thinh & Vang, 2020)
Fruit trees (guava and sugar apple)	2.3 to 3.2 (per month in rainy season)	8 (total year) (Renaud & Kuenzer, 2012)
Jasmine	10 to 25 (per month)	
Peanut	13	9 (Mann et al., 2015)

This field site showed a groundwater level drop of almost 300 mm from October 24 till December 12. In this time there was 60 mm of rain, giving an average decrease of 7.3 mm/day. The amount of rain reaching the groundwater is less than the total amount of rain, so this gives an indication of the local ΔS.

3.2 Water storage

3.2.1 BT03

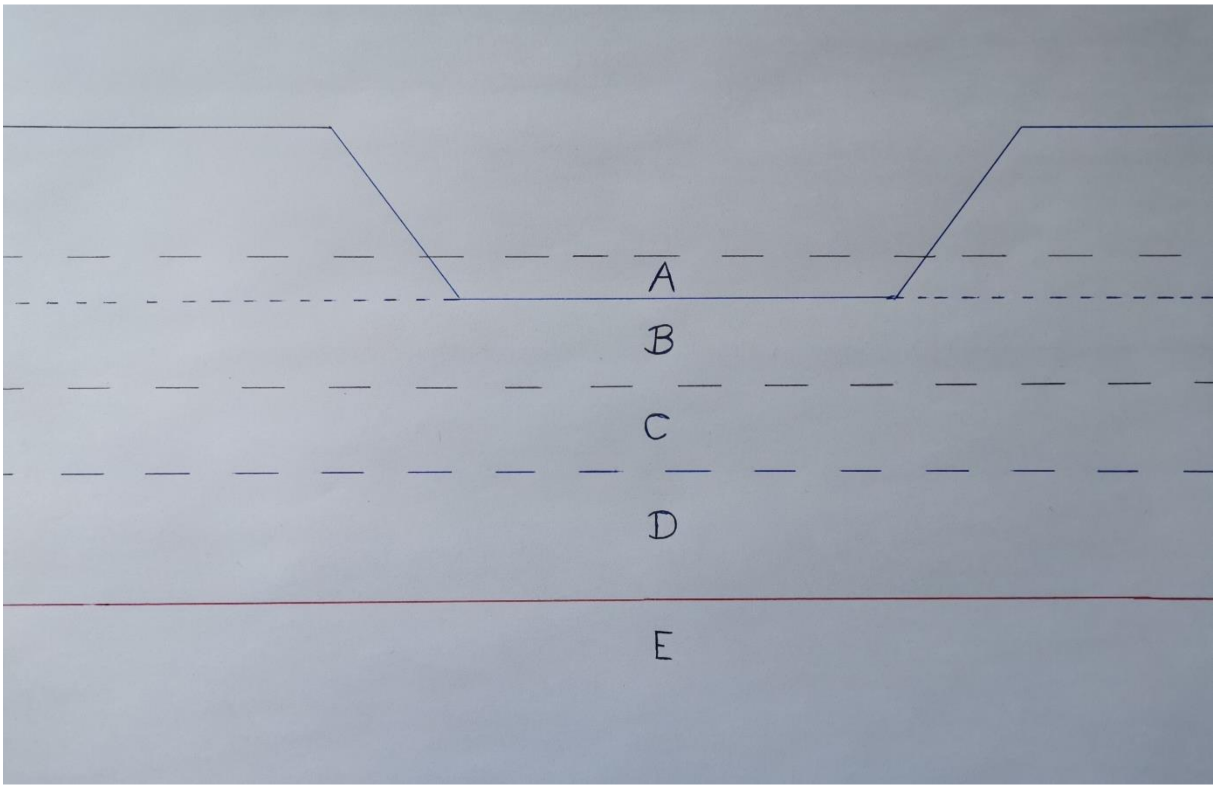

Figure 6 Schematic overview of different water levels, taken into consideration for calculating the amount of water that can effectively be stored in the upper layer of the aquifer.

From corings in the dune at BT03 by Josh and Anne of Deltares, Josh modelled that between 400,000 and 479,000 cubic meters (depending on pore space) can be stored in a 50 hectares big area in the middle of the dune. Figure 6 shows the situation in the middle part of the dune, also zone III, IV and V in figure 3 to figure 5, with the continuous blue line. In figure 6, A is the layer that creates standing water in the dune pans, creating an area suitable for paddy rice. B is the layer of soil in the rootzone of crops in the dune pans. C is the layer of water that can be added till the rootzone of vegetable crops grown in the dry season. The layer D is layer of saturated soil, that will decrease when the water is used for vegetable crops. Finally, E is the layer of soil proofed to be the layer with the lowest permanent groundwater level.

The amount of water modelled by Josh, are for the layers B, C and D. This amounts to a storage possibility between 800 and 958 mm. At the end of the rainy season, all the mentioned layers contain water. When farmers start growing vegetable crops at the start of the dry season, the A and B layer are already dry and the D layer shrinking fast. In normal years, during the window of opportunity in the months December and January, the C layer could be filled till the rootzone of the vegetable crops (B).

The rainy season in 2019 was short and did not deliver enough rain to fill to layer A. This meant that in October, farmers had to pump up groundwater to irrigate the rice crops. At the start of December, the D layer was 1.3 to 1.6 below field level. This meant at the start of December, the C layer could store between 324 and 384 mm of water from the measured groundwater level to the rootzone of cucumber, which is halve a meter. The window of opportunity for filling this layer shifted to earlier months. When the rice is still in the paddy phase of the growth, the water can be stored to layer A, because paddy rice can cope with this amount of water. This results to a situation of groundwater as experienced in the normal years, because the water after the paddy phase needs to sink to create a suitable rootzone and the groundwater cannot be filled anymore after that, because the window of opportunity has already passed. The amount of water that can be stored is enough for 44 to 52 days, when considering the amount of water that is used during the long time average.

3.2.2 TV02

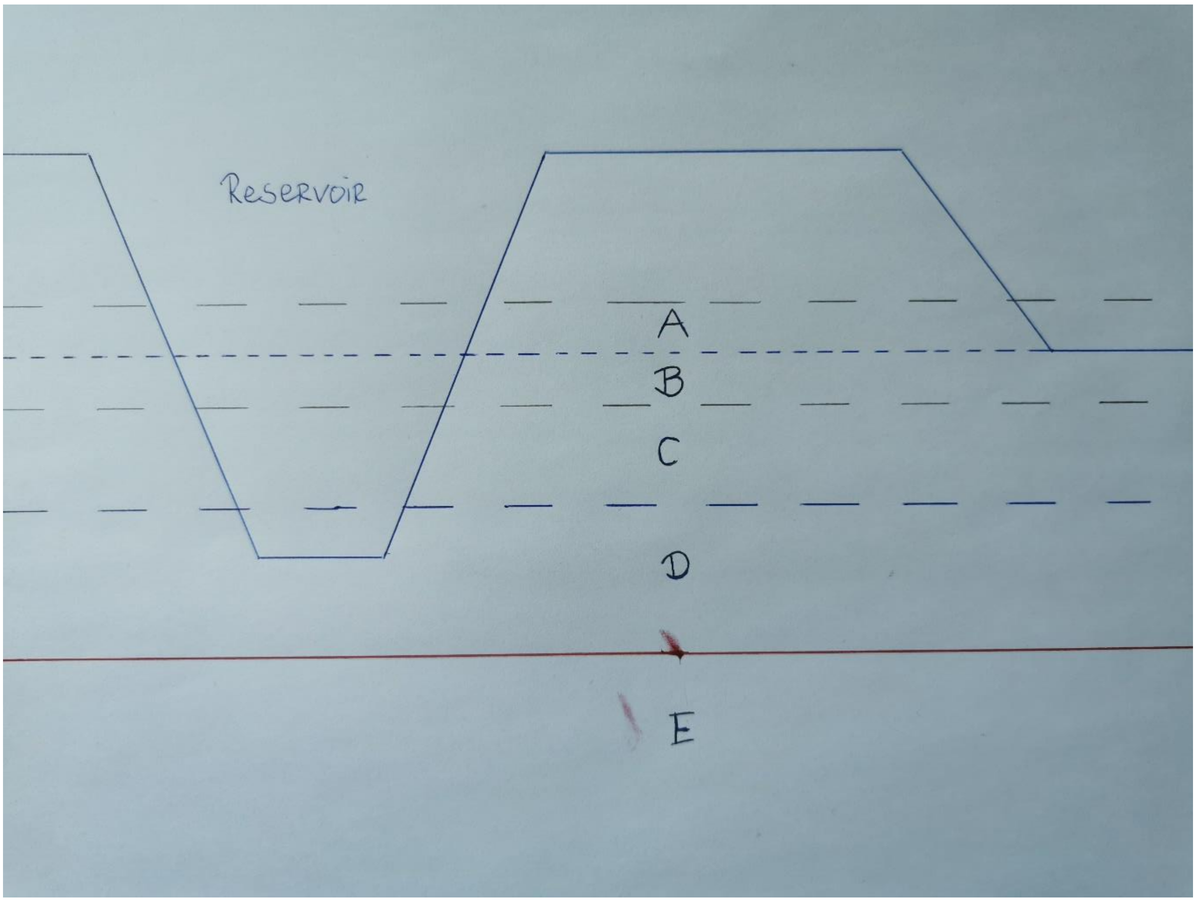

Figure 7 Schematic overview of different water levels, taken into consideration for calculating the amount of water that can effectively be stored in the upper layer of the aquifer.

Josh modelled that the dune at TV02 can hold between 1.9 and 2.3 million cubic meters of water over an area of 214.5 ha. Figure 7 shows the same layers as figure 6, with the same explanation for the letters that are shown. Only difference is the reservoir made by the government, which cuts through several of the layers and is connected to the groundwater and show the same fluctuations as the groundwater.

The modelled amount of water is for the layers B, C and D, translating in an amount between 880 and 1075 mm. The dune pans that overflow during the rainy season, are left bare during the dry season. This means the groundwater can be filled up to layer B, without affecting crops. At the end of the rainy season in 2019 (which ended earlier than most years), only between 302 and 363 mm could be stored in layers B and C. A problem could be the reservoir in this area. Water that is stored in the soil, can flow to this reservoir and water can evaporate from this uncovered waterbody. Another problem is the amount of water the farmers use during the day, the long-time average measured for the site was a use of 4.2 mm/day, but the end of the measurement without rain showed a decrease of 17 mm/day. For the long time average it is an amount stored, that is enough for between 71 and 86 days. For the last measurement on the other hand, this just enough for 17 to 21 days.

3.3 CROPWAT8.0

At both TV02 and BT03, agriculture is one of the largest freshwater user from the lenses in the dunes. The lenses are in danger of running out of water in the last part of the dry season, because there is no precipitation filling the lenses, but the plants use up a lot of water from the stored water. It is important to get an estimation of the evapotranspiration from crops in the dry season. It gives an indication of ET in the water balance as explained in chapter 2. The CROPWAT8.0 modelling is therefore done on the most important dry season crops, mentioned in table 6. The model uses some standard inputs and changed inputs as mentioned in ANNEX C. The interviews gave an amount of time the farmers irrigate and the size of their field, combined with the average pump capacity gave an average amount of irrigation. The amount of irrigation also depends on the crop and the fraction of area that is irrigated with pump and hose (which is the common way of irrigation). The frequency for vegetable and seasonal crops was once a day and for jasmine and fruit trees once every three days. The modelling done for this chapter is an indication of the ET value of the local water balances.

Table 6 Crops grown in the dry season per field site, with the months they are grown in normal years.

BT03	**Dry season crops**	**Months**	**Estimated amount of irrigation (mm/day)**
	Jasmine and fruit trees	December-March (full dry season)	8.3
	Cucumber varieties	December-March	17.1
	Peanut	December-March	11.4
TV02			
	Peanut	December-February	11.4
	Carrot	December-February	11.4

3.3.1 BT03

At BT03, crops are still being grown in March that is described by farmers to be the one with decrease of discharge of the pumping-wells and/or drying up of the waterholes that scatter the landscape. This means that, even in normal years there are problems with the amount of water from the lenses. For the permanent fruit trees, it seems like the farmers give an amount of water to overcome the dry period and keep the tree alive, but the vegetables and peanuts are irrigated to produce the maximum amount that is possible. After filling in the data from soil, climate, rain and crop, CROPWAT8.0 gives an output like figure 9. This output shows the irrigation requirement and efficiency of dry season cucumber.

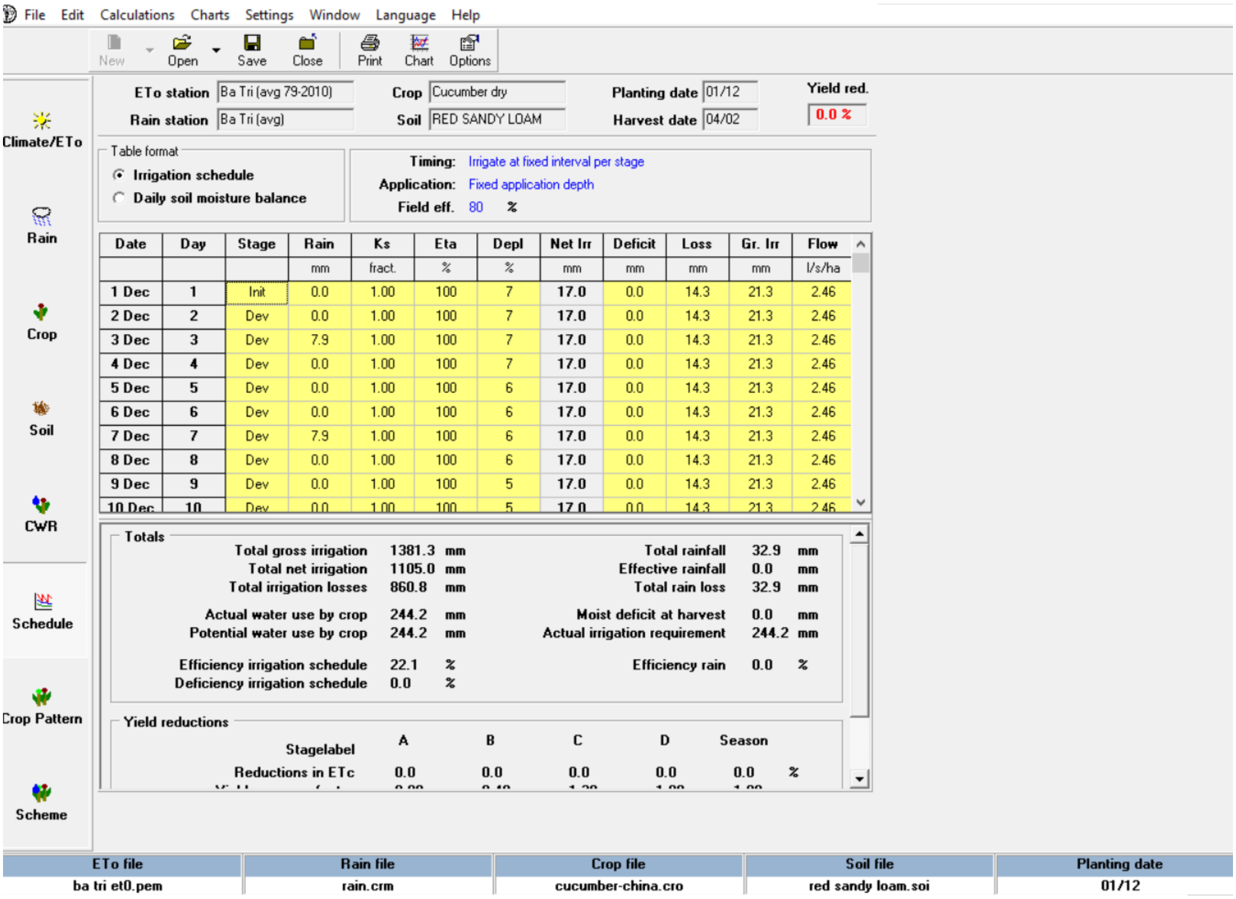

Figure 8 CROPWAT8.0 output of dry season cucumber grown in December and January.

The water use shows the total amount of evapotranspiration of the crop in mm/day. The second peanut crop starts in March and will continue to grow into the rainy season. Also, the jasmine and fruit trees grow in both the rainy and dry season. Efficiency of irrigation is the crop water requirement divided by the applied irrigation times 100 per cent. The efficiency is higher when the percentage is higher. Rice has got a very high efficiency in normal years, because the required amount of water is coming from rain only and no supplementary irrigation is needed.

Table 7 Water used (evapotranspiration) of several crops in an averaged cropping schedule.

Crop	Start	Days till harvest/removal	Irrigation requirement (mm/growth season)	Average water use (mm/day)	Efficiency of irrigation (%)
Cucumber	December	66	244.2	3.7	22.1
Bitter cucumber	February	66	311.3	4.7	28.2
Peanut	December	96	396.6	4.1	38.0
Peanut	March	96	469.6	4.9	44.9
Jasmine and fruit trees.	December	121	376.0	3.1	36.1
Rice	September	120	360.6	3.0	100

There are no real problems reported at BT03 for normal years, but as experienced this year (2019), the rains did not last as long as in normal years. This meant that farmers were irrigating their rice with groundwater to prevent water shortage for their crop. Rice is not a profitable crop, so the water use comes at the cost of other crops that the farmer can sell for a higher price. When there is one month less rain while growing rice, the farmers irrigate at least 90 mm of groundwater. All this used water cannot be used for cucumber or peanut. These crops have around 2 or 3 times more profit than rice. For farmers it would be profitable to still be able to grow these crops. The 14 farmers with rice fields already need 3825 cubic meters of water to irrigate 4.25 hectares combined. The amount of water that can be stored, can handle such numbers, as not all the area consists of agricultural area.

3.3.2 TV02

In TV02 the period with the problems of decrease of discharge is avoided for agriculture. This means they will leave the fields bare for at least a month a year, till the rainy season starts again. The area has less trees and mainly has seasonal crops for their cropping system. Table 8 shows the outcome of the modelling in CROPWAT8.0 of the several crops. The average water use shows the evapotranspiration per crop.

Table 8 Water used (evapotranspiration) of several crops in an averaged cropping schedule.

Crop	Start	Days till harvest/removal	Irrigation requirement (mm/growth season)	Average water use (mm/day)	Efficiency of irrigation (%)
Peanut	December	96	396.3	4.1	41.7
Carrot	December	45	160.9	3.6	36.6
Carrot	January	45	196.2	4.4	44.6
Rice	September	120	361.6	3.0	100

On the higher dune tops there is a gap in the cropping schedule around March. This gives possibilities to have a short season crop scheduled there. The area already has carrots growing and it is a short season crop to fill in this gap. Another option is to crop peanut after the first carrot scheduled, using a part of the time for the first watermelon crop. The only problem is the decrease of discharge from pumping wells, which can be an indicator of water shortage. Table 9 shows how much water is needed to support crops that can be grown in March. This shows that at least 155 mm is needed to grow carrots in March alone (water use times days of March). Peanut needs just a little bit less at around 152 for March alone. Both crops also need some time growing in April, this is officially the month where the rainy season starts, but with climate change the start gets less certain. To be sure that there is enough, at least 223.2 mm is needed for carrot and 260 mm for peanut. For a hectare this is already between 2232 and 2600 cubic meters of infiltrated water needed to be sure farmers have enough water in that area.

Table 9 Water use of crops that can be grown in the break of March.

Crop	Start	Days till harvest/removal	Irrigation requirement (mm/growth season)	Average water use (mm/day)	Efficiency of irrigation (%)
Carrot	March	45	223.2	5.0	50.7
Peanut	January	96	473.4	4.9	49.8

The extra cropping can give a farmer just a little bit of extra income with cropping carrot three times in the dry season. The combination of carrot once and peanut once, is more profitable. When growing carrots two times is replaced by peanut once, it is still almost 3 times more profitable in gross earnings.

3.4 IFAD/AMD

3.4.1 Target group and goals

The project of IFAD/AMD is broad and is formulated as "Sustainable livelihoods for the rural poor in a changing environment". With the project objective being "Strengthen the adaptive capacity of target communities and institutions to better contend with climate change", both mentioned in the project description (IFAD, 2014). The expected outcomes of the goal are:

- Reducing child malnutrition by 40 per cent.
- 30,000 poor and near poor households with at least 25 per cent growth in the household assets ownership index.
- 60 per cent decrease in income poverty in project communes with focus on (near) poor, ethnic minority and women-headed households.

The project also wants to improve climate resilience of those 30,000 households and wants to invest in profitable adaption in farming systems. All the above is described in IFAD, 2014. The project takes place in the provinces of Tra Vinh and Ben Tre, with TV02 being part of one of those project areas. The goals of the project specifically mention focus on (near) poor, ethnic minority and women-headed households, which are present at the field site at TV02. The area has almost 3000 households of which 41.7 per cent is poor, 4.6 per cent near poor and 29.6 per cent is ethnic minority (IFAD, 2014). These goals are closely related to the socioeconomic system and the land and water management of the area as explained as part of the conceptual framework in chapter 2. The project is in close cooperation with several institutes and government departments responsible of the water management and resources. Thus, giving an integrated approach to the implementation of adaptation strategies to climate change.

3.4.2 Results

In the latest report of the AMD project coordination council of the Tra Vinh People committee (PPC), they give a brief update on the progress of the project in the whole province during 2019. The most important part of the report is about capacity building of change and investment in sustainable living. This report is in Vietnamese and is translated poorly, but the results for most parts are clear. In the Long Son commune (TV02) a test case was executed where 129 farmers would get a workshop on peanut growth and rotation with other crops. There are more workshops and education plans to prepare farmers and other vulnerable households for climate change. This includes educating people on seeds, sustainable living and giving the underprivileged people a professional education. The report also shows that a new irrigation system was tested to pump up water with a sustainable source to power those pumps. The system was tested on 5 hectares of agricultural area, owned by 9 households. Both farmers and the PPC is satisfied with the results. Climate change workshops were given to 419 participants of the region. Furthermore, the exchange with Ben Tre markets to a place where agricultural produces could be sold. They were building salt monitoring stations in Tra Vinh and these stations should be finished in March this year.

3.5 FAME

3.5.1 Target group and goals

The FAME project is focused on scoping, piloting and providing advice on upscaling to partners in Vietnam on implementing of shallow Aquifer Storage and Recovery (ASR). ASR could provide solutions on water-quality and availability problems faced on farm-level in Ben Tre and Tra Vinh provinces in the Mekong Delta, Vietnam. The target groups are water managers and farmers. The aim of this project seems a technical solution for the water storage, but also considering the land and water management.

3.5.2 Expected results

Part of the project is to help water managers and farmers detect, understand and analyse the interaction between water supply and water demand in the shallow aquifer and create understanding, if ASR is implemented, how it could help famers tackling todays and future problems involving the subsoil water storage.

FAME wants to upscale from pilot sites when there is experience on a suitable water management framework to ensure sustainable use and it should help fighting salinization. Farmers should then have enough clean water to grow crops and without too much use of deeper aquifers or creating subsidence.

4. Discussion and conclusion

4.1 Discussion

4.1.1 Validity and limitations of research method

The results mentioned above, show the delicate relation between the groundwater and the farming practices on three sand dunes in Tra Vinh and Ben Tre provinces in the coastal Mekong Delta, Vietnam. The data was obtained through interviews held on the three selected field sites and supported by literature and data from two Utrecht University students working as intern at Deltares. The interviews held, were semi-structured to create a dataset that could be compared but leaving room at the end to ask more questions, relevant to that situation. This method gave a quick overview of the practises used by the farmers. Although being a quick method, the farmers sometimes seemed to avoid addressing problems with water, farming or land ownership, while these problems were mentioned in literature. This can be explained because there is still a lot of censorship on what people say (Vásquez et al., 2019). Furthermore, the knowledge of the researcher should be considered, as it is difficult for a researcher to bring the interviews together and to create the full overview of the local situation. The interviews were held with a random sample of farmers living scattered in the selected area. It meant that interviewing them took little preparation of already finding farmers to talk to, but also did not give farmers the chance of preparing for the interview content. Choosing the areas beforehand was a good way of getting to know different practises from up on the dune top and more to the sides.

Even with the results from the interviews were in a format that they could be compared, it still needed literature research to complete them and for them being ready for the modelling. For the crop water requirements, a lot of different assumptions had to be made. But in most cases, the literature and data from research from the students from Utrecht University, could substantiate the results from the interviews and modelling.

A Khmer minority was living in Tra Vinh, but my interpreter could not speak the Khmer language, so these potentially interesting group was underrepresented in the interviews, because they were also not able to answer questions in Vietnamese. Important is to know these farmers' problems in the area, because the project of the IFAD/AMD is focussed on these minorities as well. Another important group mentioned by IFAD/AMD are female headed households. But during the interviews, none of the female farmers interviewed, were head of the family and were mainly supporting their husband or family members in the field or did not have agricultural land. Choosing the areas based on the area of the dune showed that people from the edge and the top of the dune had different problems, but for both groups applies that they answered similar on the questions asked for the whole group. The groups confirmed several times what other farmers already said, showing that the interviewed farmers are representative for the local population of farmers.

The conceptual framework covered the areas needed to answer the (sub) research questions, but the research mainly focussed on the land and water management component and the storage component. For this research it was enough to get an indication on how farmers use the groundwater in agriculture, domestic and livestock application. The main socioeconomic situation was covered by the revenue of the crops. Other external factors than climate change were not researched as well, for instance pests and diseases in crops on land and water management or push- and pull factors for people working on the lands. Climate change can also influence the land and water management or the socioeconomic situation, but this is not included in this thesis, because it focuses on the amount water that changes in the storage of the freshwater lens. Having an overview of the water balance was necessary to understand the lenses. For this research it gives enough information to come a conclusion.

4.1.2 Research validity

This thesis aims to create knowledge on possible farming alternatives for farmers by comparing the IFAD/AMD project with an alternative cropping system that can be utilised for high value, small scale agricultural production using shallow freshwater lenses. The data collected for this project is new data from own research, as this area is not as well researched as the low-lying areas with rice and shrimp production. The new data could be combined with some other literature. When this thesis and the newly collected data are correct, the conclusion should be applicable to the three field sites.

The outcomes are suitable to compare with other data of sand dunes in the coastal area of the Mekong Delta. It is not possible to assume the same conclusion applies for every sand dune in Mekong Delta, Vietnam. The three field sites show that the water use is very different, and the crops produced on the dunes are different as well. The method of research is applicable to every individual dune to come to a conclusion for that case and may be compared to other dunes to look for differences. This limits the generalization of the data but will lay a base for further research on these dunes.

4.2 Conclusion

From interviews during the stay, it can be derived that the use of the shallow freshwater lenses is used optimal in the way that, with the current system, farmers are familiar with the changes in the shallow groundwater and their options of farming crops. At BT02 the farmers use the groundwater not as extensively as farmers living around the field sites in BT03 and TV02. Farmers at BT02 realize the different qualities of the groundwater and do not use it for agriculture, but mainly for livestock and domestic use. BT02 is a smaller dune, so their use is tuned in for a smaller amount of water that is available in the freshwater lens. TV02 and BT03 show extensive use for agricultural purposes of the freshwater lenses in the dune. Both sites use the lower dune pans for production of rice during the end of the rainy season, when natural paddies form. The dune is used for seasonal vegetables and seasonal fruits at TV02 and for jasmine and fruit trees at BT03. During the dry season, farmers at BT03 use the groundwater to grow seasonal vegetables in the dune pans. Leaving the option of growing one short season vegetable less during very dry years without enough groundwater. At TV02 on the other hand, the farmers have a break in growing crops on the dune tops and leave the dune pans bare, because of limited amounts of groundwater. In dry years the cropping area is decreased, if necessary. This shows that in normal years, farmers make most of the resource of the shallow freshwater lenses.

When an ASR system is implemented, several factors should be taken into consideration. One of them is the amount of water that can be infiltrated and when this water can be infiltrated, another is the added value of such a system in the area. First, the amount of water that can be infiltrated and the window of opportunity. The amount of water that can be infiltrated differs, it depends on the amount of rain that fell during the rainy season, the part of the cropping cycle where the farmers are in and the availability of fresh surface water in the surrounding canals and rivers. In most years, the salinity in the canals and rivers surrounding the field sites will be increasing towards the end of February. This means that only December and January can be used to fill the shallow freshwater lens. In dry years, this window will shift to earlier months, because the rains will not refresh the canals and rivers and the salinity will increase earlier. 2019 was a dry year and farmers had to irrigate rice with some of the groundwater, to still have enough yield. This water cannot be used for cash crops anymore, decreasing the income of the farmers. At BT03, in December 2019, there was room to store water for 44 to 52 days. This can almost provide enough for one cucumber crop most farmers grow in the dry season. But more importantly, it recreates a current normal year. Rice fields can be filled during the paddy stage and slowly decreases, like in a normal year, so farmers can grow vegetables, with an empty rootzone. Farmers need to have a very similar cropping schedule, and this can a be a problem. At the field site TV02, the water that could be stored, can be used for less days, only 17 to 21 days. This can only partially fulfill the amount needed for a crop of carrot. This amount of water can be more, when it

forms standing water in the dune pans, because it is bare land. Next to the small amount of days this extra amount can support, the reservoir can be a problem in the local groundwater, because it can be a sink where water from the groundwater is only evaporating. When the daily use at this field site would go down, the amount of water could be used for irrigation of a very short season crop.
At field site BT03 the installation of ASR would result in that farmers can crop the same amount of times. This is for very dry years where the rainy season ends earlier than expected. Farmers can still crop two or three cash crops during the dry season, securing their main form of income. In normal years, it does not seem to have an additional benefit, as farmers use the freshwater in a very efficient way. At TV02 the amount of water can only support carrots, which is a crop in their current cropping schedule. Carrots are not cash crops and it will not increase the income of farmers by much. Only when other cash crops with such a short growth time will be available. It is difficult to say if this technical intervention could be profitable. Concluding from this, installing the ASR system would be economically viable at BT03, where this intervention secures income from two or three cropping cycles of cash crop. TV02 is less economically viable, because the crops grown during the dry season are not cash crops and the extra income from the amount of water that can be stored is low.

The IFAD/AMD project does have very similar goals and target groups as the FAME project. The IFAD/AMD project is already in the phase where it is testing and applying solutions in the dune area of TV02. But in their report, they state that they try to provide local solutions to the larger problem of climate change and salinization. The FAME project can provide a local solution for dune areas. The FAME project gives farmers living on the dune security of income or potentially an increase of income when they can crop even more cash crops. The IFAD/AMD also includes institutes and government departments in the approach of implementing climate change adaptation strategies. This also connects to the FAME project and farmers are educated in the use of crops. The ASR technique can possibly profit from the salt monitoring stations that are being built by the IFAD/AMD. The main difference between FAME and IFAD/AMD, is that the latter its main purpose is improving the socioeconomic situation of the farmers and FAME right now seems to mainly focus on the storage and the land and water management. IFAD/AMD is already changing the land and water management at TV02 with the introduction of cash crops and educating farmers on how to use them. When FAME is proven to be a successful way of improving the resilience to climate change on a local scale, it could become part of the IFAD/AMD project. Therefore, the IFAD/AMD project is very similar to a high value, small scale agricultural production using shallow freshwater lenses.

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Annex A

Questions Interviews

1. Do you have a well?
2. Since when does the farmer use this well?
3. To what depth does the well go?
4. What design does the well have?
5. What is the capacity of the well? (pressure/discharge of pump)
6. What is the water in the well used for?
7. Are there problems with the amount of water coming from the well in the dry season?
8. Are there problems with salinity in the well in the dry season?
9. What months do these problems occur?
10. Is there a difference with the past years in availability and quality?

11. Do you use the surface water that is in connection with the main canals?
12. Are there problems with the quantity?
13. Are there problems with salinity in the ditches?
14. What months do these problems occur?
15. Is there a difference with the past years in availability and quality?
16. If you have more water would you use it?
17. If there is less would you change it?

When water is used for crops:

1. What crops are irrigated with this water?
2. What crops does the farmer produce during the dry season?
3. Does the farmer have a break in producing?
4. What is the cropping schedule (with months) of the farmer?
5. What crops does the farmer has knowledge of for producing (what did he produce in the past)?
6. What kind of irrigation system does the farmer have?
7. How often does the farmer irrigate his crops?
8. How long does the farmer irrigate his crops?
9. How big is the field the farmer irrigates?
10. Does the farmer produce the crops for own use or is it to sell at the market?
11. What is the average price the farmer can sell a kilogram for at the market?
12. How many kilograms does the farmer produce on average per year?

When water is used domestically or for cows:

1. What kind of domestic activities is the water used for?
2. Does the domestic activity depend on the quality of the water from the well?
3. Is there a change in use from the rainy season into the dry season?
4. How many buckets of water does the person think they extract per day for domestic use?

5. How many cows does the farmer have?
6. Do they also get the water from the groundwater-well?
7. How many buckets do the cows drink per day?
8. Are the cows fed by grass from own land and is this grass irrigated? (Go to crop questions)
9. What are the cows bred for?
10. How many cows are sold at the market every year?

11. How much does the farmer get for a cow?
12. How old is the cow when the farmer takes it to the market?

13. How many buckets of milk do the cows produce per day?
14. How old are the cows when they start producing milk?
15. At what age are the cows sold after producing milk?

Annex B

BT02

The farmers used their wells mainly for domestic use and livestock. Farmers use an estimated 534 to 579 liters per family per day for their domestic activities, which includes drinking (cooked, but sometimes uncooked), cooking, washing clothes, showering and watering the garden. For cows the farmers used between 200 and 229 liters per family per day.

TV02

On average people used around 360 litres per day per family for domestic use, which includes drinking (cooked, but sometimes uncooked), cooking, washing clothes, showering and watering the garden. The amount of water used for livestock differs largely because of one farmer, who claims to have a capacity of around 3000 cows, but now only had 10. So, to calculate the current water use only the 10 cows are taken into consideration, but the amount will go up when he has 300 times as many cows. So, in the lowest estimation farmers use 134.8 liters on average for their cows, but the highest estimation is 4564.8 liters per farmer. Table 10 shows the amount of water that is pumped up and the average infiltration depth that is corresponding to this amount.

Table 10 Irrigation information.

Average infiltration depth	9 mm/day
Irrigated area (m^2):	
Hose	77400
Overhead sprinklers	40000
Drip irrigation	10000
Micro sprinklers	7000
Buckets	2500
Total irrigated area	156900
Discharge pumps	8.7 m^3/hour
Pumped up volume	1482.1 m^3/day

BT03

The farmers used an average of 1154 to 1373 litres per day for domestic uses, which includes drinking (cooked, but sometimes uncooked), cooking, washing clothes, showering and watering the garden. For cows the farmers use between 77.8 and 89.4 litres per day. Extra attention needs to be drawn some different water uses in the area. One farmer has on average 70 to 80 pigs in her stables, which vary a lot in what they drink, depending on different factors. For the calculation it was assumed that the pigs drink around 12 litres a day (Almond, 1995), which is around 840 to 960 litres per day. Another big user is a company which produces bottled water and they pump up 20 cubic meters (20,000 litres) a day from shallow groundwater wells. This makes the average that a user of the shallow groundwater uses way higher. Table 11 shows the amount of water that is pumped up and the average infiltration depth that is corresponding to this amount.

Table 11 Irrigation information.

Average infiltration depth	10 mm/day
Irrigated area:	
Hose	49700 m^2
Overhead sprinklers	4000 m^2
Total irrigated area	53700 m^2
Discharge pumps	8.7 m^3/hour
Pumped up volume	549.3 m^3/day

Annex C

BT03 inputs

Climate and ET0

The inputs for the climate and ET0 screen were from long term averages. The dataset is running from 1979 till 2010 at a weather station in Ba Tri district of Ben Tre province. Input is shown in figure 9.

Country: Vietnam — Station: Ba Tri (avg 79-2010)

Altitude: 2 m. — Latitude: 10.03 °N — Longitude: 106.60 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	23.2	28.9	81	242	8.2	19.4	4.06
February	23.7	29.4	82	267	9.3	22.3	4.56
March	24.7	30.7	81	267	9.6	24.0	5.09
April	25.8	32.3	81	191	9.3	23.9	5.24
May	25.6	32.6	83	113	7.0	19.9	4.43
June	25.1	32.0	85	144	6.0	18.1	4.05
July	24.6	31.4	86	131	6.2	18.5	4.01
August	24.6	31.1	87	155	6.0	18.5	3.98
September	24.6	31.0	87	105	5.8	18.1	3.87
October	24.6	30.3	88	109	5.8	17.3	3.63
November	24.3	29.7	85	168	6.8	17.6	3.70
December	23.2	29.0	83	179	6.8	17.0	3.56
Average	**24.5**	**30.7**	**84**	**173**	**7.2**	**19.6**	**4.18**

Figure 9 Inputs climate for BT03.

Rain

Rain inputs came from the same weather station in Ba Tri district of Ben Tre province. The dataset is from the same time frame as well. Input is shown in figure 10.

Station: Ba Tri (avg) — Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	5.0	5.0
February	2.7	2.7
March	7.7	7.6
April	40.7	38.0
May	199.7	135.9
June	219.9	142.5
July	219.7	142.5
August	196.9	134.9
September	234.3	146.5
October	284.5	153.4
November	103.5	86.4
December	27.3	26.1
Total	**1541.9**	**1021.4**

Figure 10 Rain input for BT03.

Crop inputs

The crop inputs are based on the values mentioned in the report of FAO n.56 (1998). The local crops and their growth circumstances were closely matched to other crops if not available. The Kcini needed to be adjusted for irrigation frequency, irrigation depth, wetted fraction and ET0, all done in equation

59 as mentioned in FAO n.56. The values in table 12 were used in FAO n.56 equation 59 and result in the values mentioned table 13.

Table 12 Calculation of infiltration depth.

Wetted fraction	Cucumber	0.6
	Peanut	0.9
	Fruit trees	0.4
Assumed irrigation frequency (day)	Cucumber	1
	Peanut	1
	Fruit trees	3
Irrigation depth (mm)	Cucumber	17
	Peanut	11
	Fruit trees	26

Table 13 Results of equation 59 on the Kcini.

Month	Cucumber adjusted	Osopro adjusted	Peanut adjusted	Fruit trees adjusted
January	-	-	-	-
February	-	0.66	-	-
March	-	-	0.95	-
April	0.66	-	-	-
May	-	-	-	-
June	-	-	-	-
July	-	-	-	-
August	-	-	-	-
September	-	-	-	-
October	-	-	-	-
November	-	-	-	-
December	0.67	-	1.00	0.32

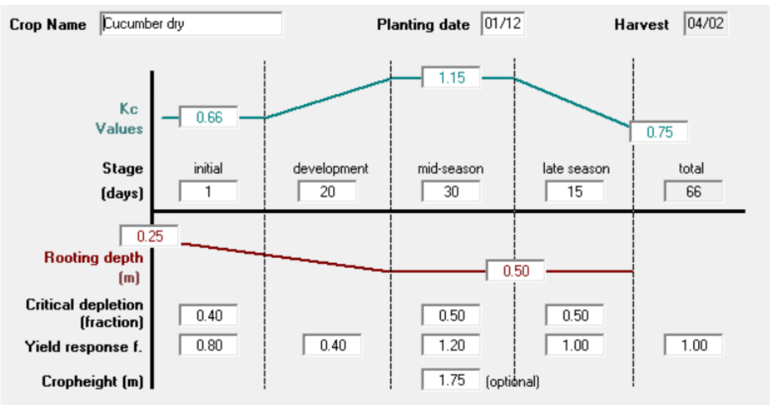

Figure 11 Input for cucumber in the dry season. The two cycles of cucumber and one cycle of sopropo only differ on the Kcini value and planting date.

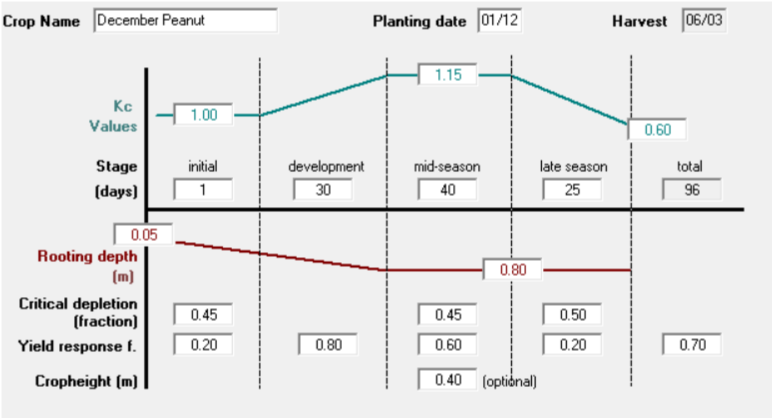

Figure 12 Input for peanut in December. The second cycle of peanut only differs in the Kcini value and the planting date.

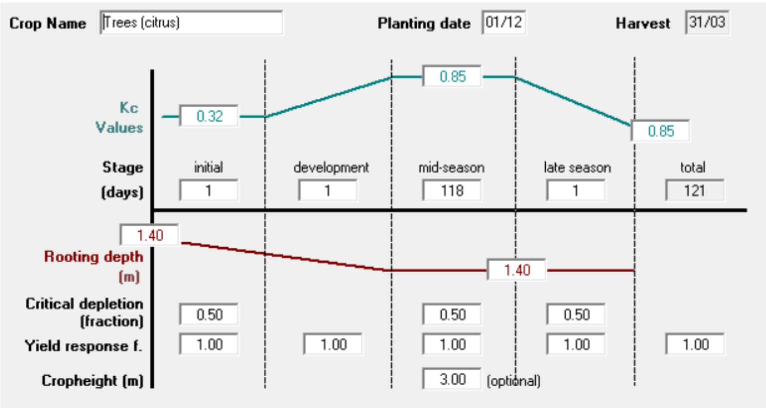

Figure 13 Input for several fruit trees. Used is the standard value of citrus from FAO on CROPWAT8.0. Only changes are the length of stages, so it fits the dry period and the Kcini value was adjusted to the local situation.

Soil inputs

From corings, the topsoil was determined to be a sandy loam soil. As the exact characteristics of the soils on the dune were not researched, the standard values for Red Sandy Loam were used, as provided by CROPWAT8.0.

TV02 inputs

Climate and ET0

The inputs for the climate and ET0 screen were from long term averages. The dataset is running from 1979 till 2010 at a weather station in Càng Long district of Tra Vinh province. Input is shown in figure 14.

Country: Vietnam | Station: Càng Long
Altitude: 2 m. | Latitude: 9.98 °N | Longitude: 106.20 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	22.7	29.8	81	171	8.2	19.4	4.00
February	22.9	30.6	79	204	9.3	22.3	4.69
March	24.0	32.1	79	186	9.6	24.0	5.17
April	25.1	33.4	80	140	9.3	23.9	5.26
May	25.2	32.8	85	109	7.0	19.9	4.40
June	24.8	31.8	86	145	6.0	18.1	4.00
July	24.4	31.2	87	157	6.2	18.5	3.98
August	24.4	30.9	88	184	6.2	18.8	3.99
September	24.5	30.9	88	126	5.6	17.8	3.79
October	24.5	30.6	87	109	6.0	17.6	3.71
November	24.2	30.4	85	131	6.8	17.7	3.70
December	23.0	29.7	83	144	6.7	16.9	3.53
Average	24.1	31.2	84	151	7.2	19.6	4.19

Figure 14 Inputs climate for TV02.

Rain

Rain inputs came from the same weather station in Ba Tri district of Ben Tre province. The dataset is from the same time frame as well. Input is shown in figure 15.

Station: Càng Long | Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	3.0	3.0
February	3.8	3.8
March	14.7	14.4
April	43.7	40.6
May	189.8	132.2
June	209.8	139.4
July	223.4	143.5
August	234.9	146.6
September	247.7	149.5
October	295.2	154.5
November	126.8	101.1
December	36.6	34.5
Total	1629.4	1063.0

Figure 15 Rain input for TV02.

Crop inputs

The crop inputs are based on the values mentioned in the report of FAO n.56 (1998). The local crops and their growth circumstances were closely matched to other crops if not available. The Kcini needed to be adjusted for irrigation frequency, irrigation depth, wetted fraction and ET0, all done in equation 59 as mentioned in FAO n.56. The values in table 14 were used in FAO n.56 equation 59 and result in the values mentioned table 15.

Table 14 Calculation of infiltration depth.

Wetted fraction	Carrot	0.9
	Peanut	0.9
Assumed irrigation frequency (day)	Carrot	1
	Peanut	1
Irrigation depth (mm)	Carrot	10
	Peanut	10

Table 15 Results of equation 59 on the Kcini.

Month	Carrot adjusted	Peanut adjusted
January	0.99	(0.99)
February	-	-
March	(0.92)	-
April	-	-
May	-	-
June	-	-
July	-	-
August	-	-
September	-	-
October	-	-
November	-	-
December	1.01	1.00

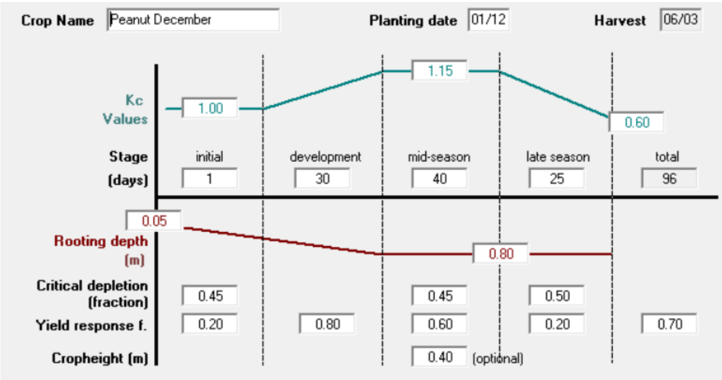

Figure 16 Input for peanut in December. The other possible cycle of peanut only differs in the Kcini value and the planting date.

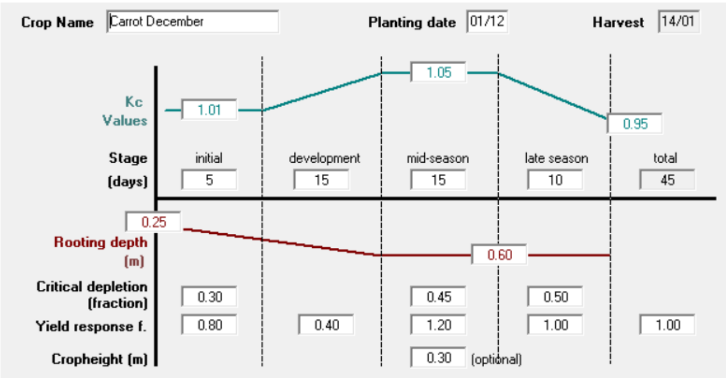

Figure 17 Input for carrot in December. The other cycles of peanut only differ in the Kcini value and the planting date.

Soil inputs

From corings, the topsoil was determined to be a sandy loam soil. As the exact characteristics of the soils on the dune were not researched, the standard values for Red Sandy Loam were used, as provided by CROPWAT8.0.