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Water management and water availability in a sub-watershed, Tamil Nadu, India

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Abstract
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India is a country with progressing technical and economical development, but the development is not evenly distributed. Farmers in the Indian rural areas are struggling. There are worries that climate changes could have a negative impact on agriculture. This study was performed in Kancheepuram with support from the non-governmental organization Hand in Hand.

The aims of this study were to analyze effects on agriculture due to watershed management in a village and to describe the crop patterns in a village and compare the yield with a village without watershed management.

Data was collected by interviewing farmers in the villages Arapedu and Tenpakkam. In Arapedu watershed management was applied and in Tenpakkam it was not. Data collected by Hand in Hand on precipitation, village records, well inventory and maps were analyzed.

The water level in the wells increased in most wells between 2007 and 2008, but due to short data series it was not possible to affirm if this was due to the watershed management or increased rainfall in the early months of 2008 compared to 2007. No evidence of change in precipitation in the area was observed. Only precipitation data was analyzed since other climate data was absent. Hand in Hand was working within a broad spectrum in the village. Apart from the watershed project they are working with empowerment of women´s situation, self-help groups, microfinance and against child labor.

This study period was too short to confirm effects of watershed management. However this study can be used as a baseline study for future evaluations.

Key words: Rainwater harvesting, watershed management, Tamil Nadu

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Referat
Vattenhushållning och vattentillgång i ett delavrinningsområde, Tamil Nadu, Indien
Marie Nordh Hagberg

Indien är ett land med framåtskridande ekonomisk och teknisk utveckling, men den goda utvecklingen är ojämnt fördelad. Fattiga bönder på den indiska landsbygden har det ofta svårt. Den begränsande faktorn för deras skörd är tillgången på vatten. Det finns en oro för att klimatförändringar skulle kunna försvåra ytterligare för jordbruket. Hand in Hand är en hjälporganisation som bland annat är verksam i Kancheepuram, där denna studie genomförts.

Syftet med projektet var att analysera om riktade förändringar av mikroavrinningsområdet kan förbättra odlingsförutsättningarna för bönderna, att beskriva byns odlingsmönster samt jämföra med en by där inga reformer genomförts.

Data samlades in genom intervjuer med bönder i byn Arapedu, som genomgått optimering av avrinningsområdet, och byn Tenpakkam, som inte genomgått några reformer. Data insamlat av Hand in Hand bestod av nederbördsdata, förteckningar över odlade grödor, vattennivå i brunnar samt kartmaterial, behandlades.

Vattennivån i de flesta av de undersökta brunnarna ökade mellan 2007 och 2008, men eftersom dataserierna var så korta var det inte möjligt att säga om denna ökning i vattennivå var tack vare reformerna i avrinningsområdet eller om den skett på grund av att det regnade mer de första månaderna av 2008 i jämförelse med de första månaderna 2007. Inga bevis på förändringar i nederbörd i området kunde påvisas. Då övriga klimatdata saknades var det endast nederbördsdata som analyserades.

Hand in Hand genomför projekt på bred front i byn. Förutom effektivisering av vattenanvändning försöker man utrota barnarbete, stärka kvinnors ställning och främja entreprenörskap genom självhjälpsgrupper och mikrolån.

Den här utvärderingen genomfördes för tidigt för att kunna säkerställa några resultat av reformerna i avrinningsområdet, men den kommer att kunna ligga till grund för framtida utvärderingar.

Nyckelord: Regnvatten uppsamling, vattenhushållning, Tamil Nadu

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Preface

This master thesis was carried out as the final part of my Master studies in Aquatic and Environmental engineering at Uppsala University and has 30 ECTS points. The master thesis was done to describe help of Hand in Hand in evaluating their watershed management projects. It was made as a minor field study and supported by Sida administered by Internationella programkontoret. Without their scholarship it would not have been possible to conduct this study.

I would like to thank my supervisor and examiner Professor Allan Rodhe, Department of Earth Sciences at Uppsala University, for his support, inputs and endless patience. Thank you associate professor Rajinder Saxena at Department of Earth Sciences, Uppsala University for being the subject reviewer. Also, I would like to thank the Hand in Hand watershed team; supervisor Mr Mageswaran, interpreters Mr Prabu and Mr Varadharajan and GIS analyst Mr Chellapandi. You were all fantastic during those warm days in the field. Thank you also Mr Sundar, Canteen personal (for the best food), Theres and Camilla (for your friendship and support) and Jonas (for your encouragement and support). Finally thank you all wonderful friends at Geocentrum for those supportive talks during lunch and coffee breaks.

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Populärvetenskaplig sammanfattning

Indien är ett land i snabb utveckling, men den goda ekonomiska utvecklingen är ojämnt fördelad mellan samhällsklasser. Det finns en stark medelklass i Indien som består av 300 miljoner människor. Men de ca 800 miljonerna som lever i fattigdom i städernas slum eller som småbönder på den indiska landsbygden har det svårt. Det finns en oro för att klimatförändringar skulle kunna försvåra ytterligare för jordbruket, då nederbörden är en avgörande faktor för böndernas avkastning från jordbruket. I Indien används 82% av färskvattenkonsumtionen till bevattning inom jordbruket. Ett problem med den tekniska utvecklingen är att den gjort det möjligt att nå ännu djupare ned i grundvattenreservoarerna i jakten på sötvatten. Detta gör att många magasin riskerar att utarmas då uttaget sker med högre takt än grundvattenbildningen. Nederbörden i Tamil Nadu kontrolleras främst av monsunen. Det är ännu inte känt om och i så fall hur monsunen skulle kunna påverkas av förändringar i det globala klimatet.

Hand in Hand är en hjälporganisation som bland annat är verksam i Kancheepuram, där denna studie genomförts. De började med att jobba för att stärka kvinnors ställning och få barn ur arbete och till utbildning. Organisationen växer snabbt och arbetar nu efter ett program bestående av fem stolpar:

- Att skapa jobb åt fattiga kvinnor genom att hjälpa dem att starta företag
- Att hjälpa barn i arbete att återgå till skolan
- Att ge tillgång till IT och främja datoranvändning i byarna samt stärka demokratin
- Att förbättra hälsan i utsatta grupper genom hälsoundersökningar, hälsokampanjer och sanitetsprojekt
- Att utveckla miljötänkandet genom hållbar avfallshantering och vattenprojekt

En tanke är att om man har tillfredsställande ekonomi har man en större benägenhet att bry sig om sin egen hälsa och att ta hand om miljön runt omkring. Arapedu är en by där Hand in Hand är aktiva genomför sitt program. I mars 2007 började man att utföra reformer i avrinningsområdet (”watershed management”) för att förbättra vattentillgången för bönderna som är verksamma där. Målet med reformerna är att minska erosion och öka infiltration i marken. Dessa reformer består i att man har byggt tre infiltrationsdammar, byggt vallar runt böndernas fält, grävt diken i anslutning till en brant sluttning, konstruerat filter i anslutning till brunnar, satt upp hinder i områden med kraftig avrinning samt planterat träd.

Syftet med projektet var att analysera om reformeringar av mikroavrinningsområdet kan förbättra odlingsförutsättningarna för bönderna, att beskriva byns odlingsmönster samt att jämföra med en by där inga reformer genomförts.

Data samlades in genom intervjuer med bönder i byarna Arapedu, som genomgått reformering av avrinningsområdet, och Tenpakkkam, som inte genomgått några reformer. Detta för att kunna göra jämförelser huruvida det fanns någon skillnad i avkastning från jordbruket mellan de två byarna. De två byarna låg i närheten av varandra och hade liknande förutsättningar. Marken i området var plan, bortsett från den branta sluttning som var belägen i Arapedus nordvästra utkant. I Arapedu bodde ca 280 familjer och i Tenpakkam ca 370. De data som Hand in Hand hade samlat in var nederbördsdata, förteckningar över odlade grödor, vattennivå i brunnar samt kartmaterial.

Nederbördsdata analyserades statistiskt för att undersöka om det fanns någon korrelation mellan nederbörd och tid, det vill säga om det fanns några tecken på förändring i nederbörd över tid. Inga bevis på förändringar i nederbörd kunde påvisas. Eftersom den här studien genomfördes innan alla reformer av avrinningsorådet egentligen var helt färdigställda var det svårt att visa huruvida reformerna gjort någon verkan. Ett test genomfördes, genom att plotta skillnaden i vattenmängd i brunnarna mellan 2007 och 2008 mot avståndet till närmaste infiltrationsdam, för att undersöka om det fanns någon koppling mellan ökningen i vattenmängd i brunnar och avstånd till infiltrationsdammar. Någon sådan koppling kunde inte visas. Inte heller gick det att visa att den ökning som skedde i vattenmängd i brunnarna mellan 2007 och 2008 var tack vare reformerna i avrinningsområdet eller det faktum att det regnade mer under årets första månader 2008 mot 2007.

Enligt de register som lokala tjänstemän förde över vad bönderna odlade i byarna var jordnötter den populäraste grödan i både Arapedu och Tenpakkam. Efter jordnötter kom ris och casuarinaträd. Enligt intervjuer förda med börderna var jordnötter, ris och grönsaken lady finger de mest populära grödorna. Lady finger är en fördelaktig grönsak att odla i varma klimat då den är särskilt tålig mot värme och torka. Skillnaden mellan intervjusvaren och de data som fanns i registren kan bero på att en del av de intervjuade böndernas mark inte fanns med i registren eller att det trots allt bara var en liten del av bönderna i byn som blev intervjuade. I Arapedu intervjuades 19 bönder och i Tenpakkam 16.

Den här utvärderingen genomfördes för tidigt för att kunna säkerställa några resultat av reformerna i avrinningsområdet, men den kommer kunna ligga till grund för framtida utvärderingar.

Glossary

Micro watershed – watershed 100 – 1000 ha in size (Jain, 2004)
NGO – Non Governmental Organization
SHG – Self Help Group
Sub-watershed – watershed 10 000 – 50 000 ha in size (Jain, 2004)
Tank – reservoir (water)

Table of content

1 INTRODUCTION

This study attempts to evaluate the effects of watershed management for increased agricultural production performed in a village in Tamil Nadu, India.

1.1 Tamil Nadu

Tamil Nadu is located in the south east of India, Figure 1. This study was conducted in the Kancheepuram district close to Chennai, the capital of Tamil Nadu. The main language is Tamil, but many people also speak English. Chennai is India´s fourth largest city and is a big center for the IT, auto and defense system industry and many international companies are active here. A big issue in the state is the power shortage, thus power cuts are frequent. Fortunately for the farmers they do not need to pay for their power use, but unfortunately they are the first to get cut off when the power shortage is severe. (Wikipedia, 2009).

About 62 million people live in Tamil Nadu. According to the state government records about 14 millions were active in the agricultural sector 2001. However the state government also describes 34 millions as unemployed, but a large portion of these non working might actually be small farmers, because 34 million people live in rural areas.

Tamil Nadu Figure 1, has an area of 130,058 km^2 and a population density of 480 people/ km^2, which is larger than the mean Indian population density 350 people/km^2 (Jain et al., 2007). The above numbers can be compared with Sweden having an area of 450,295 km^2 and a population density of 20 people/km^2 (Norden, 2009).

Figure 1 Tamil Nadu in the south east coast of India (ESRI, 2008). Arapedu, the project village, is marked.

1.2 Arapedu and Tenpakkam

The two villages that were studied are Arapedu and Tenpakkam. Arapedu is marked with a green dot in Figure 1. In March 2007 the nonprofit Swedish organization Hand in Hand (described in section 2.1) started watershed interventions in Arapedu. In Tenpakkam nothing has been done to improve the water supply. These two villages and Annanagar village are situated in Arapedu watershed. In the three villages in Arapedu watershed there are about 700 families. Most of these families are depending in one way or another on agriculture. The village Arapedu is slightly smaller than Tenpakkam. When the work is completed in Arapedu village Tenpakkam is next in line. Arapedu watershed is a micro-watershed inside Ongur sub-watershed.

1.3 India´s water resource problem

India has a growing economy. The people of India correspond to 16% of the world's total population. The country contains 2.45% of the world´s land area and 4% of its water resources. The country´s water resources are unevenly distributed in time and space. Of the yearly runoff 80 – 90% occurs during four months. The Ganga-Brahmaputra-Mahanadi basin holds 60% of India´s total water supply in an area that is only 1/3 of the country´s area. Water consumptions per capita and year was 650 m^3 in 2001 and is estimated to reach between 725 and 750 m^3/capita·year (Kannaiyan et al., 2001).

Table 1 Future water use estimations for India (Kannaiyan et al., 2001)

Year	Estimated yearly water use [km^3]
2010	694 - 710
2025	784 - 850
2050	973 - 1180

There is also the threat of land degradation due to groundwater depletion in low rainfall areas and poor drainage in high rainfall areas. Of India´s 432 km^3 yearly renewable groundwater 396 km^3 is within reach. Of the extractable water 71 km^3 (18%) is used for industrial and domestic needs, while 325 km^3 (82%) is used for irrigation. In agriculture 50% of the irrigation water is groundwater. In many parts of India the groundwater is getting overexploited. In areas where groundwater extraction needs to be restricted, the extraction is most intense. Of Tamil Nadu´s 385 main watersheds 138 are overexploited (Jain, 2007) making Tamil Nadu number four in India when it comes to overexploiting groundwater supplies. Mechanical development has made it possible to drill deep bore holes, even if it is not, as Kannayian (2001) points out, always wise to do so. The National Water Policy advises outtake to be limited to the renewable component of naturally occurring groundwater recharge. (Kannaiyan et al., 2001)

One fourth of the cropped areas are irrigated in India. The yield from these irrigated areas considerably exceeds the yield from the three fourths of rain fed agriculture, 58% versus 42% (Dhruva Narayana, 2002).

1.4 Hypothesis

The hypothesis of this study was: Watershed management has positive effects on agriculture at micro level.

Objectives:

1. To analyze effects of watershed management on agriculture in a village.
2. To describe crop patterns in a village.
3. To compare a village with and without watershed management.

2 BACKGROUND

In this chapter some background information about the organization Hand in Hand, climate conditions, rainwater harvesting structures and crops are described.

2.1 Hand in Hand

Hand in Hand (Hand in Hand) is a Non Governmental Organization (NGO) with its head quarters in Tamil Nadu, but they are also active in Pondicherry (India), South Africa and Afghanistan. Hand in Hand is a nonprofit NGO supported by Swedish investors. Even if they are non-governmental they work together with the local governments so they can learn from each other and avoid parallel work. Hand in Hand uses five pillars when implementing their Integrated Development Program:

- Self Help Groups (SHG), microfinance for enterprise and job creation
- Child labor elimination and education
- Citizens´ centers
- Medical camps and health campaigns
- Environmental protection through waste management and watershed projects

With these holistic pillars Hand in Hand aims for social, economical and environmental sustainable development. The belief is that people with better economy can afford to care about their health and environment. To avoid dependence on charity Hand in Hand tries to educate people to be self sufficient. However, when their interventions are done, Hand in Hand states that they leave at least one volunteer behind for follow-up (Hand in Hand, 2008).

To keep the administration costs low (3% of the budget) they employ few “western” people and do not have expensive office buildings. This also creates more work opportunities for the local people (Hand in Hand, 2008).

Some other groups that are running watershed projects in India are: National Watershed Development Project for Rain fed Areas (NWDPRA), Indian Council of Agricultural Research (ICAR), World Bank-assisted Pilot Projects in Rainfed Areas, Ministry of Rural Development, other NGO´s and NGO/government collaborations (Kerr, 2002).

2.1.2 The Arapedu project

Apart from the structures built in the watershed the farmers also get other benefits. The project also includes introducing new crops and agroforestry. Farmers get fruit trees free of charge, that will benefit the land and give an extra income. After the project is completed, money is set aside for maintenance work.

In March 2007 Hand in Hand started their NABARD financed (National Bank of Agriculture and Rural Development) watershed management project in Arapedu village. All farmers were informed about the planned project and were free to choose if they were interested in joining. Since the project was sponsored the farmers did not need to pay for anything at all, but they were obligated to put in some working hours. All farmers except one joined the project.

2.2 Climate

The Indian climate is dominated by the monsoon seasons; North East and South West monsoons. The Indian Meteorological Department divides the monsoon into four sub seasons; winter season (January-February), hot weather season (March – May), rainy season (June – September) and post-monsoon season (October - December). The most important mechanism for rainfall in Tamil Nadu is the monsoon. (Lal, 1999)

Winter season in Tamil Nadu is characterized by cooler temperatures, clear skies and winds. Hot weather season is warm and dry with mostly cloudless skies. Some rainfall may be recorded at the coasts. Dust storms can occur as well. Rainy season starts with a sudden burst of the summer monsoon in June, which causes turbulent weather that gives showers. The humidity increases and India gets comparatively lower day and higher night temperatures. In September the summer monsoon starts to retreat and gradually does so until December. It is due to this retreat of the summer monsoon that Tamil Nadu gets most of its annual rainfall during this period. While there is a weakening of the low pressure over the continent a low pressure center forms over the Bay of Bengal. Cyclones are formed in the bay and reach over land. This gives Tamil Nadu heavy rain storms in October and November in the Northern part and in November and December in the Southern part. An early retreat of the monsoon will have a negative effect on cropping. In October and November the area around Chennai gets on average about 550 mm of precipitation. (Lal, 1999)

About 20% of the variability in crop production in India is said to be caused by variation in climatic conditions; this variation could be even larger if the threat of global warming comes true (Kannaiyan et al., 2001). Bates et al. (2008) show indications that the amount of rainfall in the area has not changed during the last few years, but the intensity of the now fewer rainstorms has increased. High intensity rainstorms are more likely to cause soil erosion through ”splashing effects” and heavy runoff.

Between 1906 and 2005 the earth´s temperature increased by 0.76°C and most of the increase occurred during the last 50 years. In south Asia the temperature has been rising in the already warm dry months. Between 10°S and 30°N precipitation has been decreasing, Tamil Nadu is within the limits of this belt. Climate change could affect the recharge rate of ground water reservoirs, but little research has been done on this subject especially in developing countries. Very few studies have been done about how climate change could impact individual aquifers. (Bates et al., 2008)

2.3 Rainwater harvesting and structures

A watershed is the total area from which runoff gathers to a single point. One watershed consists of a number of sub-watersheds and these sub-watersheds may have a number of micro-watersheds (Seshagiri, 2000). The main purpose of watershed management in the study area is to decrease soil erosion and increase infiltration of water in order to increase soil moisture and ground water recharge, by capturing the excess surface runoff and increasing the time for infiltration.

It is important to note that rain water harvesting projects are not always successful (Kerr, 2002). A successful project is hard to copy since each watershed and village has unique conditions. Sometimes success is achieved thanks to charismatic leaders that can bring the villagers together and make the project flourishing. One problem is that the watershed boundaries do not necessarily correspond to human boundaries. This can cause problems when people that have not agreed to the activities get involved unintentionally. The structure built does often not benefit the upstream farmer on whose land it was constructed, but instead the farmer downstream. It is important that efforts and benefits are evenly distributed and compensation for uneven distribution should be possible. It is generally easy to show positive effects of watershed management in the first one or two years. Unfortunately many projects are not followed up and it is hard to tell if they have been successful in the long run. The water harvesting structures need maintenance and if there is no technical expertise for supervision it can be hard for the villagers to manage the maintenance themselves (Kerr, 2002).

These are methods for watershed management for improved water availability and use that are practiced in South India:

2.3.1 Cropping systems

Strip cropping with perennial crops means that the annual crop will be combined with perennial crops in a strip pattern on the field. This method can make the runoff less destructive and hence prevent soil erosion. *Diverse cropping* has the same effect, but here trees and/or shrubs are surrounding the annual crops as a protection.

2.3.2 Bunds

Field bunds (Figure 2) are often constructed as boundaries between different fields. They keep the water on the field so it has time to infiltrate. Often field bunds are combined with an outlet of stones in the down flow direction of the field. This makes it possible for the water to flow between the fields. Field bunds, like the one in Figure 2, were frequent in Arapedu village.

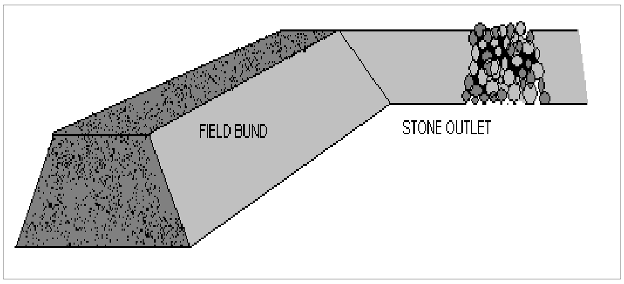

Figure 2 Field bund and stone outlet

2.3.3 Contours

In *contour bunding* bunds are formed along contours in the sloping land. *Contour cultivation* has the same principle, but in this method one cultivates strip cropping throughout the contours of the slope. These methods uniformly distribute the moisture in the field and prevent erosion (Seshagiri, 2000). On slopes the runoff and loose soil can accumulate down the slope and become destructive, but with contour bunding and cultivation this can be prevented (Ramaswamy and Palanisami, 2003).

Nala[1] *bunds* control the flow of runoff water and soil erosion. The bunds are constructed across nalas. When the nala has accumulated enough sediment the nala bed can be brought under cultivation (Seshagiri Rao, 2000).

2.3.4 Nalas and Gullies

Diversion drains prevent uncontrolled runoff water from non arable land from flowing into the fields and damaging arable land. *Nala training* is the method used for diverting

[1]Nala is a stream that develops during heavy rainfall.

the flow into canals instead of going into other neighboring fields (Seshagiri Rao, 2000).

Gully plug (Figure 3) is a bund constructed across a stream to conserve soil and water. This will also decrease the velocity of the stream flow, prevent soil erosion, increase infiltration and improve the soil. They are often constructed in series (Seshagiri Rao, 2000).

In gullies one can use stones or wood to build *check dams*, for collecting soil and store the moisture (Seshagiri Rao, 2000).

Figure 3 Gully plug in Arapedu.

2.3.5 Ponds

In *farm ponds*, runoff and rainwater can be collected and infiltrated into the groundwater reservoirs in an effective way. The ponds can be of various sizes and are simply dug into the soil. In the upstream side of the pond an inlet is constructed and on the downstream side an outlet. The inlets and outlets are constructed with boulders and cement (Seshagiri Rao, 2000).

2.3.6 Leveling

Land leveling is a method for reducing soil erosion. A gentle gradient is created on the land surface which makes the runoff flow slower and hence reduces soil erosion (Seshagiri Rao, 2000).

2.3.7 Recharge tube wells

Recharge tube wells are constructed for fast recharge (to avoid evaporation losses) of aquifers with fresh water from the surface. A hole is drilled to the desired depth. In the hole a filter of layered small rounded boulders, stone chips and sand is created. Boulders are put at the bottom and sand on the top of the hole (Ramaswamy and Palanisami, 2003).

2.3.8 Trench

In the close vicinity of steep hills *trenches* can be dug to slow down high speed runoff. Trenches also increase ground water recharge since they keep the water at one place and give it time to infiltrate and percolate through the soil. In Arapedu trenches were dug to protect fields close to a steep mountain ridge, Figure 4.

Figure 4 Trenches in Arapedu.

2.4 Crop facts

In Arapedu and Tenpakkam a number of different crops were grown. Some information about these crops is given below.

2.4.1 Paddy

Rice is the world´s most important cereal. In South and Eastern Asia it is the main food. When rice is cropped the crop is called paddy. When fully grown the crop is about one meter in height. Paddy is a semi-aquatic crop and the fields are flooded with 15-30 cm of water when planted; after bloom the water is led away from the field (NE, 2009). Normal water requirements are between 790 and 1500 mm for each season. Flowering, reduction division and primordial initiation are the stages in which paddy is most sensitive to water deficiency (Palanisami, et al., 2003). Potential yield for paddy in Coimbatore district in Tamil Nadu is 4750 kg/ha (Ramaswamy and Palanisami, 2003).

2.4.2. Groundnut (peanut)

Groundnut is an annual plant of the pea family of Fabaceae. It is an oilseed crop with oil content of 40-50%. The groundnut is a tropical plant that needs hot and humid climate to grow. Preferably it is grown in sandy loam soil. In order to get a good yield the plant needs plenty of water, though it can survive in quite dry conditions. After 4 – 5 months the crop is harvested. When harvested the whole plant is removed from the soil. India is the world´s second largest producer of groundnuts and Tamil Nadu is the second most productive Indian state (one million tons a year). (CRN India, 2008)

Potential yield for unirrigated groundnut is 2 – 3 tons/ha of unshelled nuts and for irrigated conditions 3.5 – 4.5 tons/ha (AGLW, FAO, 2008). If the groundnuts are rain fed it is most common to crop them in June to September or October to March. If irrigation is possible the groundnuts can also be grown in January to May. Sequential, multiple and intercropping systems can be used. For commercial production 500-1000 mm of precipitation during the growth period is needed, but for lower production it is possible with just 300-400 mm. Low rainfall and extended dry spells are the main reasons for crop failure in India. Rainfall is the most significant climate factor for a good yield and the inter-annual fluctuations are a major problem for farmers. The temperature is controlling the rate of development of the plant and with optimum between 23 and 30 ^{o}C (Vijaya Kumar et al., 2007).

2.4.3 Casuarina

Casuarina is of the family casurinceae. It is an actinorhizal plant, which means it is capable of biological nitrogen fixation (aAqua, 2007). Casuarinas are tall trees that can be up to 30 m high (Duken, 1983). The trees are fast growing and can reach 20 m in 12 years (Whistler and Elevitch, 2006). Casaurina has evergreen needle-like leaves and its seeds are capsuled in cones. The trees should be planted 2-4 m apart and might need irrigation in the first three years (Duken, 1983).

Casaurina is suitable for tropical or sub-tropical climate and is intolerant to frost and shade. Culturally its bark is used for medicine (Whistler and Elevitch, 2006). It is also used as timber, firewood and is good for mixed cropping systems. Firewood from casuarina has good energy value and leaves little soot. The timber is hard and is good for both housing and furniture. Negative properties of casuarina are that it can exhaust soil moisture, lower water table and restrict understory vegetation (Duken, 1983).

2.4.4 Sugarcane

India is the world´s second largest producer of sugarcane (FAO, UN, 2005). Most common sugarcane products in India are jaggery (”raw sugar”) and refined sugar. But it can also be used for ethanol (fuel), rum, soft drinks and molasses (Infoplease, 2007). After harvesting the residue can be used as fuel, raw material for paper (because of its high cellulose content) or for making mats, screens, baskets etc. The sugarcane origins from New Guinea (NE, 2008) and needs hot tropical climate. But it also requires a lot of water. For each cultivated ton of sugarcane 60-70 m^3 of water is needed, depending on climate conditions (Government of India, 2008). Potential yield for sugarcane is 12000 kg/ha in Coimbatore, Tamil Nadu (Ramaswamy and Palanisami, 2003). If the crop does not get sufficient supply of water it will fail. This makes more risky for the farmers. In order to get maximum yield the cane has to be crushed within 24 hours after harvesting. (Ravi, 2005)

2.4.5 Ladyfinger (okra, bhindi)

Ladyfinger is a vegetable well suited for hot climate. It has a green finger like fruit with white seeds (Russel, 2006). The plants suffer if moved; hence the seeds are preferably planted directly into the soil. A plant can be 1.5 m in heigh and show big beautiful flowers. About 60 days after plantation it starts to give yield. The vegetables are picked when they are about 7 cm long. When the plant starts to give yield they can be harvested every second days throughout the growing season (Kochhar, 2006). Water requirement for the entire growing period is about 250 mm (Kemble, et. al, 1995). For lady finger, the potential yield per season is 13500 kg/ha (Ramaswamy and Palanisami, 2003). In South Indian kitchen ladyfinger is a very popular vegetable.

2.4.6 Coconut

India is the number one coconut producer in the world. Tamil Nadu is the second largest state after Kerala when it comes to coconut production. The two states are responsible for 90% of India´s coconut yield. The coco tree is good in mixed cropping systems (Makrose, 2008). It tolerates water-deficient areas and poor soils. Some products from coconuts are copra, copra meal, coconut oil and desiccate coconut (CGIAR, 2007). The potential yield for coconut per annum is 12000 kg/ha (Agricultural University of Kerala).

A summary of how much water is actually needed to get the potential yield from crops grown in the study area is shown in table 2. This may vary depending on soil and temperature.

Table 2. Water required achieving potential yield in Tamil Nadu

Crop	Water need per kg crop [m^3]
Paddy	2
Groundnut	0.35
Sugarcane	0.1
Ladyfinger	0.2
Coconut	1

3 MATERIAL AND METHODS

Field work and collection of data were conducted in Tamil Nadu in collaboration with Hand in Hand. Most of the writing and data handling was completed in Sweden.

3.1 The study area

Arapedu and Tenpakkam are situated on flat land in the same mini-watershed. In the North West Arapedu is bordered by a ridgeline that causes high speed surface runoff in its vicinity. Except from this ridgeline the two villages have very similar characteristics. The characteristics of the area were described by looking at maps and visiting the two villages. Maps, which were gathered from local authorities and universities, were provided by Hand in Hand personal. The maps over Arapedu had also been processed in GIS by Hand in Hand staff. Except from the ridge line the area is very flat and has an altitude of about 40m above sea level (from GPS measurements, see further in 3.3).

In Arapedu watershed the three villages Arapedu, Thenpakkam and Annanagar are home for about 2000 people. In Arapedu village about 280 families are living and in Thenpakkam 370 families (Government of Tamil Nadu, 2009). These people are mainly small farmers. The people that do not own land make their living as laborers on other´s land or rented land. How much yield the farmers get from their crops depends on the amount of rain the monsoon brings. Farmers told that in good years they were able to grow crops two seasons, by the retreat of summer and winter monsoon. In bad years it can be hard to even grow crops in one season. The retreat of the summer monsoon in October/November is usually the safest rain period.

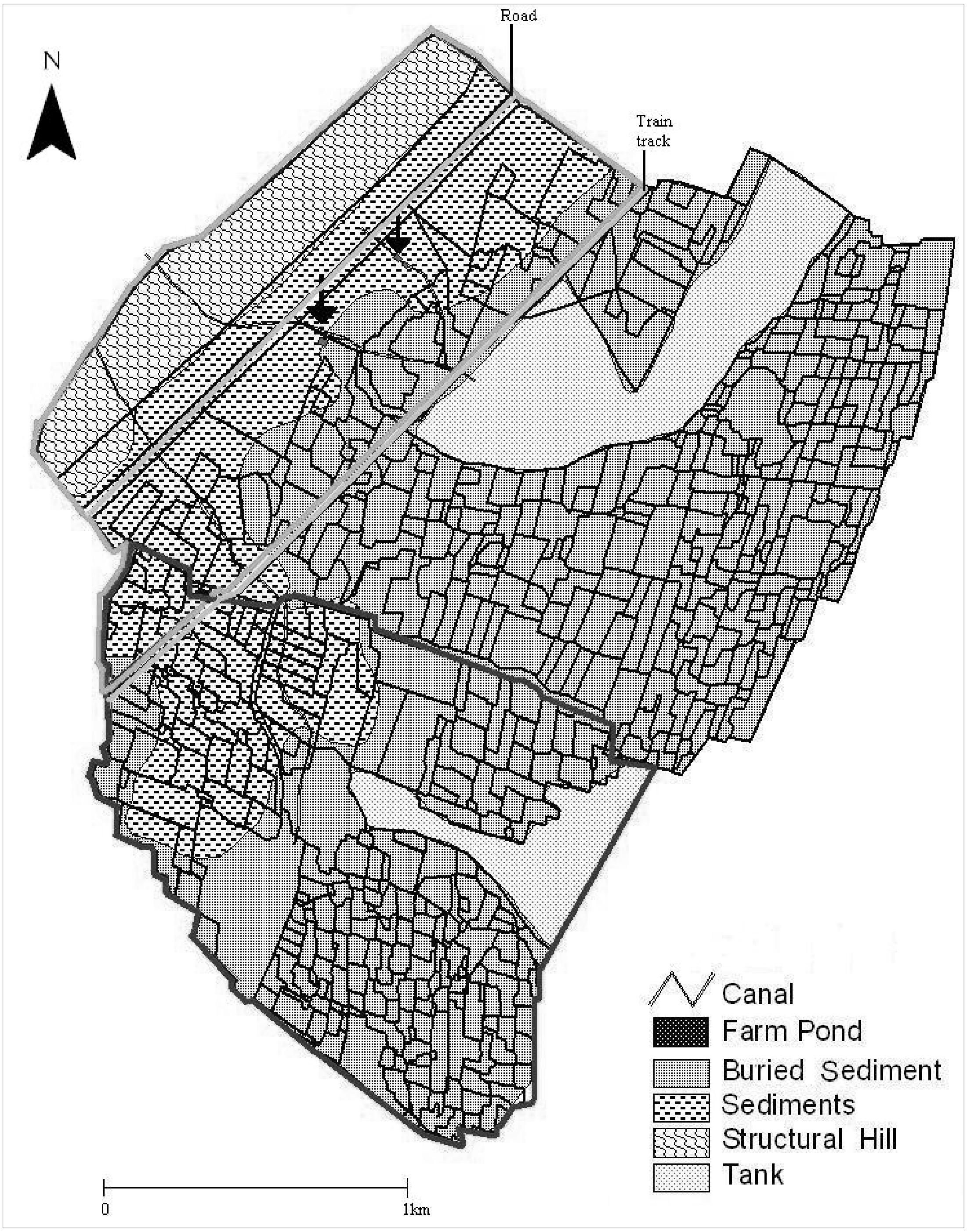

Figure 5 Arapedu watershed from geological map, approximate scale. The marked area in the southern part of the map is the area for which local authorities have kept records. Within the marked area in the western part the wells in the well inventory are located. Farm ponds are marked with arrows.

3.2 Watershed management

To identify what kind of watershed management had been done by Hand in Hand several visits to the project area were made. The team responsible for the project showed the management practices and described them. Hand in Hand provided a record of constructions they had made, which also was sent to NABARD (NAtional Board of Agricultural and Rural Development). The records included information about what kind of management had been made and the costs. In an early state of the fieldwork one of the farm ponds was not yet completed, which gave the opportunity to take part in the construction of the outlet of this farm pond.

The main focus when building these watershed structures was to increase infiltration and use the soil profile as storage for the water. This is generally the most effective and cheapest way to store water (Verma and Sarma, 1990).

3.3 Wells

When the building of watershed management structures started Hand in Hand also started to measure the water level in the open farm wells once a month beginning in May 2007. The monthly measurements taken by Hand in Hand were used in the well inventory (secondary data). The farm wells were first and foremost used for irrigation, but people did use them for drinking purposes.

This well inventory made by Hand in Hand included 66 wells in Arapedu village, located in the area shown in Figure 5. Depth of the wells and amount of water in them is taken from secondary data collected by Hand in Hand. During the first inventory of all the wells in 2007 multiple information about the wells, such as total depth and diameter, was collected. In later measurements the distance between the top of the well and the water table was measured to calculate the depth of the water, Figure 6, which then was noted. The precision of the measurements were 0.1 m.

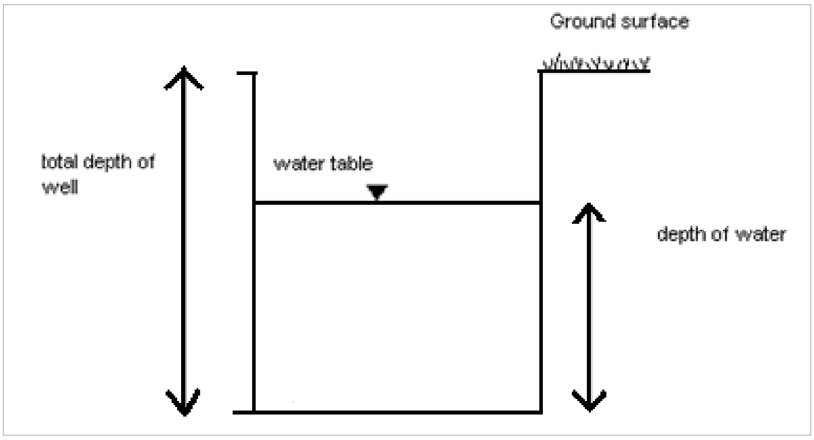

Figure 6 Open farm well.

The coordinates at which the wells were located was measured with GPS (Garmin GPSMAP 60CSx). While measuring the instrument was put on the ground, as close as possible to the well. Efforts were taken to make the measurement with clear skies, away from trees and power lines. The smallest well were 9 m in diameter and the largest 46 m – more like a small pond. The measurements of the location of the wells would have been more correct if it would have been possible to measure the location at the center of the well, now the location was taken at the part of the well where the staff were measuring the depth of the well. To be able to connect each well to earlier measurements, Hand in Hand staff working in Arapedu was acting as a guide. The wells were not further apart than it was possible to walk to them and complete the well inventory in two days.

Coordinates and heights were measured with the GPS. These measurements were then used for drawing isolines for the ground water surface in MATLAB. To find out how to combine the maps for crop patterns, geology and well GPS points was not an easy task, since some information was contradictory. More about the maps and the associated problems is found in the Discussion section.

3.4 Effects of watershed management

To evaluate the effects of watershed management made by Hand in Hand farmers were interviewed. Several visits to the watershed were made. To indentify the effects farmers in Arapedu and Tenpakkam were interviewed with identical question sheets, see Appendix, but the farmers of Arapedu were also asked if they had contributed to the watershed project. They were asked about their occupation, crops they were growing, how much land they had, their yield, number of cropping seasons, expenses, income and if their land was “dry or irrigated”. The question about irrigation was in some way misinterpreted (probably it was formulated incorrectly) and the answers could not be analyzed. Even if the questions were tested in another village beforehand to identify possible flaws and difficulties with the questionnaire, the flaws in the question about irrigation passed. The questionnaire made it easier to survey the crop patterns before and after the watershed management in Arapedu. Tenpakkam was chosen as a control village since no watershed interventions had been done there and it had similar land use characteristics as Arapedu.

The interviewed farmers were chosen with help of Hand in Hand staff working in the villages. Some farmers were contacted on beforehand and some chosen while walking around in the villages. It was attempted to make a fairly random selection of farmers. Before starting the interview the interpreters made a short introduction about the study and how their answers were going to be used. The results from the interviews have not been anonymized. Mostly the interviews were conducted in groups, often family members and neighbors were trying to help the interviewed by remembering how the yields had been earlier years. Two interpreters were translating the questions and answers. The answers were then filled into the question sheet prepared earlier, see Appendix. The questions were formulated in a quantitative way. Before finalizing the questions they were also tried out in a village not included in the study, to find possible errors or difficulties with questions and translations. Four farmers were interviewed during this test, all of them male. This test village was situated close to the office in Kancheepuram. The interviews were conducted one by one and in groups (when curious friends and family members came by). Four farmers, all male, were interviewed with help of two interpreters. During this test interview the farmers had no problem remembering crops and yield six years back in time. One of the interpreters later took part in the interviews of the farmers in Arapedu and Tenpakkam, the other did not.

3.4.1 Interviews in Arapedu

The interviews in Arapedu were divided into two full-day sessions. Interview 1-9 were conducted September 30th and 10-19 October 6th 2008. If each interviewed farmer is assumed to represent the whole family, which was true in case of agriculture. The sample size for Arapedu was 6.7% of the village population. For the most part there were two interpreters helping with translation, both having Tamil as native language with good English skills. The interpreters got the questions beforehand so they got the possibility to look through the questions and ask if there was anything they did not understand.

3.4.2 Interviews in Tenpakkam

In Tenpakkam, where no watershed management has been done, interviews 1 – 14 were conducted 24th of October 2008 (Figure 7). With the same assumption as for Arapedu, the sample size for Tenpakkam was 5.0%. Local employees of Hand in Hand helped to arrange the interviews. Some of the people were picked on the way when walking through the village. For the most part there were two interpreters. Both male and female farmers were interviewed, but the same problem as in Arapedu was experienced, women generally knew less about yield and earnings. Also all the women interviewed were uneducated, while all men had some education.

Figure 7 Interview with one of the farmers in Tenpakkam.

3.4.3 Village records

Local authorities compile, for each farming year, records of what each farmer has grown on his land. The village is divided into lots and every lot has a survey number and most lots also have sub survey number. All together, Arapedu and Tenpakkam each have about 3000 pieces of land described in these records. The records were written by hand in Tamil and were, with help of an interpreter, put into computer files so that they could be processed. It is not clear if the records holders take into account different crops that might have been grown at the same plot during different seasons.

For visualization, the records were then put into GIS. A map over Arapedu was scanned and used as a model when drawing the fields in GIS. Since it would not be visually more beneficial to show all the sub lots only the main lots were drawn in the GIS maps. However this means that some lots contain up to three different crops and further if the lot is not fully covered with crops this is not seen on the maps. How large area each crop is occupying each farming year is shown in tables. One map was created for each of the farming years 1991/1992, 1996/1997, 2001/2002 and 2006/2007. All maps and tables are shown in the results section.

3.5 Precipitation analysis

Climate data consisting of amount of rain for each month and number of rainy days for each month were obtained from Maduranthagam rain gauge station approximately 20 km south of Arapedu (approximate coordinates 12°41´N 74°58´E). Hand in Hand has access to monthly data from this station since January 1985. From the monthly rain and number of rainy days an average intensity [mm/day] was calculated. In the same way the average intensity for one year was calculated (total amount of rainfall/number of rainy days). The rainfall data is assumed to be normally distributed and was analyzed for trends concerning quantity and intensity. The existence of a trend was investigated with linear regression of rainfall versus time.

4 RESULTS

4.1 Watershed management

The following result of watershed development were found in Arapedu village: three farm ponds, well recharge pit in at least 8 of 63 wells, field bunds around all cultivated fields, water retention trench at the foot of the hill and agroforestry. Two of the farm ponds were constructed in series.

To make the constructions more steady different plants have been planted at the edges, on top of the field bunds and at the margins of the farm ponds and trenches. Plants are beneficial since they can hold the soil constructions together with their root system during heavy rain storms and protect them against erosion. The agroforestry part of the project had just started when this study was conducted. Farmers were getting consultation help for plating fruit trees that should to prevent erosion and give an extra income from the fruits.

4.2 Effects of watershed management

4.2.1 Interviews in Arapedu

One farming year is from March to March. The years asked about in these interviews are 2007-2008, 2006-2007 and 2001-2002. The last two years should be affected by the watershed management, while 2001-2002 should not and hence act as a control year. Unfortunately five of the farmers had problems remembering earlier years. The last two years were however for most people no problem to remember. Two farmers had been changing land or moving in from other villages and had hence no way of knowing the history of their fields. They could not know what had been grown on their field earlier. Age of the farmers ranged from 26 – 90 years, even though some where not sure of their age. Both men and women were interviewed. The women´s main responsibility was the household and they generally knew less about their crops. There were marginal to medium farmers, category A (<1 ha, marginal), B (1-2 ha, small) and C (2-4 ha, medium), in Arapedu village. Their fields were between 0.2 and 2 ha in size. Two of the farmers had inter-cropping systems where they grew paddy in rainy season and lady fingers or groundnuts in dry season.Table 2 gives a summary of village information based on the interviews in Arapedu.

All interviewed farmers, except one, had contributed to the watershed management. A couple of farmers said, without being specifically asked, that their yield had increased or that they now could crop one more season than before thanks to the interventions.

The inter-annual differences in rainfall make it hard for the farmers in this area. In some seasons they get more rain than they can handle and their fields get flooded, other years they get hardly any rain at all and suffer from draught, see 4.2.7 Climate analysis.

Table 2 Summary of village information in Arapedu

Number of farmers interviewed	19 (5 women)
Farmer categories	A (7) B (8) C (4)
Crops grown	paddy, groundnut, lady finger, ragi, flowers, brinja, gingerly
Number of labor days	90-365 (depending on available water)
Education level	0 (7), 3rd (1), 5th (5), 8th (2), 10th (3), 12th (1)

4.2.2 Interviews in Tenpakkam

The conditions were the same as in Arapedu, with the exception that in Tenpakkam there were no watershed management. The farmers had problems with remembering far back in time and the women generally knew less than the men. Also none of the women in Tenpakkam had any education, while the men had attended to school 2-10 years. The age of the farmers ranged between 27 and 80 years. In Tenpakkam the farmers were of category LL (land less, farmers who do not own land), A (< 1 ha, marginal), B(1-2 ha, small), C (2-4 ha, medium) and D(> 4 ha, large) hectares in size, most farmers were of category A. Table 3 gives a summary of village information based on the answers from the interviews in Tenpakkam.

Table 3 Summary of village information in Tenpakkam

Number of farmers interviewed	16 (6 women)
Farmer categories	LL (1) A (10) B (1) C (1) D (1)
Crops grown	paddy, groundnut, lady finger, ragi, chili
Number of labor days	90-365 (depending on available water)
Education level	0 (6), 2nd (2), 5th (3),6th (1), 7th (1) 8th (1), 10th (1)

4.2.3 Comparison of crops

The crops that were possible to compare the yields between the two villages were paddy, groundnut and lady finger (Figure 8). Also other crops were grown, but by too few farmers to make it possible to make a comparison between the two villages or between different years. Note that the paddy yield/hectare in Arapedu exceeds the potential yield (this will be discussed in 5.2). The potential yield was assumed to be the same as Tamil Nadu agricultural university had estimated, see 2.3 Cropfacts.

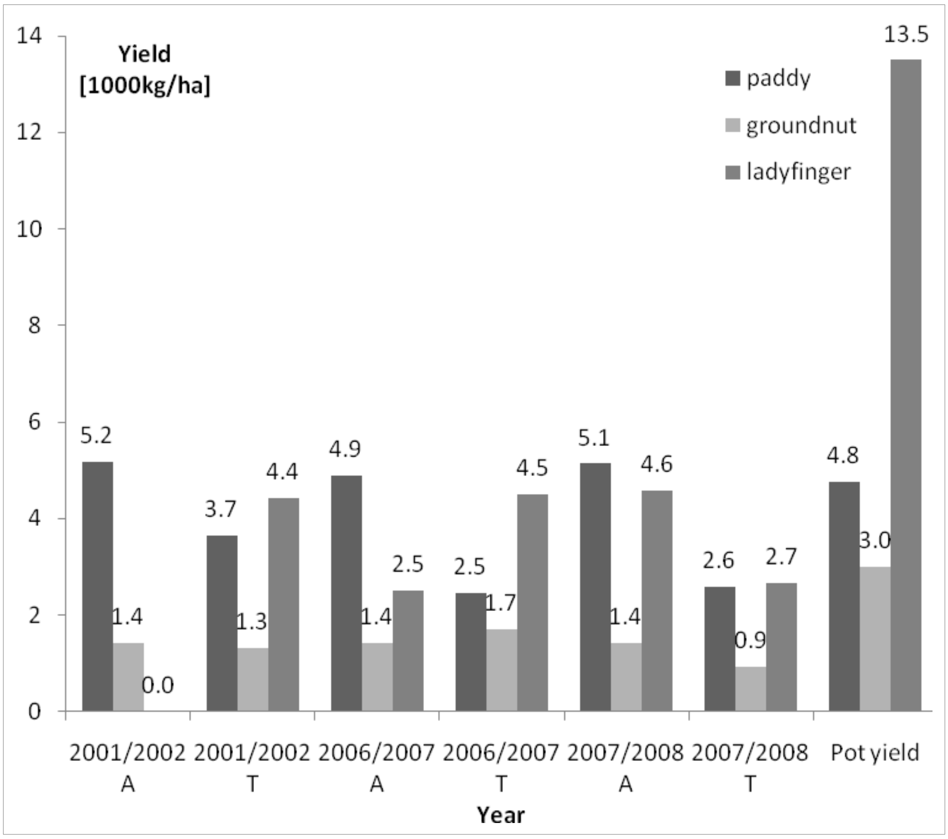

Figure 8 Yield per hectare for three farming years in Arapedu (A) and Tenpakkam (T). Approximate potential yields (see 2.3 Cropfacts) have also been added.

Before the project started in Arapedu none of the interviewed farmers were growing lady finger. When this crop was introduced it was a success and the yield per hectare increased. In Tenpakkam the yield per hectare for lady fingers decreased last year compared to the earlier years. The number of growing seasons for paddy seems to have gone down in Tenpakkam since 2001/2002, see Table 4, while in Arapedu it went up last year. Both farming years of 2006/07 and 2007/08 had some rain in the early months of the farming year which should make it possible to grow crops in two seasons. During the driest part of the year it was not possible for these farmers to grow anything. In more commercial agriculture with good irrigation systems it is possible to grow crops in three seasons in southern India.

Table 4 Growing seasons in Arapedu and Tenpakkam

Farming year	**Average number of growing seasons**					
	Paddy		**Groundnut**		**Lady finger**	
	Arap.	**Tenp.**	**Arap.**	**Tenp.**	**Arap.**	**Tenp.**
2007/2008	1.58	1.15	1.66	1.50	1.13	1.50
2006/2007	1.36	1.14	1.63	1.50	1	1.50
2001/2002	1.45	1.22	1.75	1.25	- -	1.67

One thing that can be misleading in these figures is that farmers could grow different crops in different seasons. However this concerns only one or two of the interviewed farmers and was not taken in account here.

Table 5 shows the amount of rain during the farming years shown in table 4. The farming years of 2007/2008 and 2001/2002 gave about the same amount of rain while 2006/2007 gave about 30% less than the other two years. The average rainfall for a farming year for the period 1985-2008 was 1168 mm. The lowest notation was 1986/1987 when only 262 mm of rain fell. The highest notation was 2007/2008 when 1673 mm of rain fell.

Table 5 Precipitation in studied years.

Farming year	Total precipitation [mm]	Average intensity [mm/day]	Rainiest month
2007/2008	1470	21.9	October
2006/2007	1092	20.2	November
2001/2002	1432	24.3	September

4.2.4 Life of a farmer

Farmers were interviewed not only about their cropping patterns. In order to learn more about the farmers also some deeper interviews were made. Below is an example of this kind of interview.

This farmer lives in Arapedu where he was born; he is married and has five children, four sons and one daughter, and ten grandchildren. His sons and their families would come and help him with the harvest during the harvest season. He grows 0.4 ha with ground nuts and 1ha with paddy. The 0.4 ha with paddy gave him 1500 kg of rice that he keeps for own use. He could sell five bags of unshelled groundnuts for 2000 Rs (rupees) a bag, which gave him a gross profit of 4000 Rs this particular season. He works about a month on his field by cultivation and harvest season, but otherwise he does not work much. For plowing his field he has two bulls to draw the plough.

The farmer never went to school and cannot read, but all his children went to school. He is positive towards the watershed management and has contributed as a laborer when the watershed management was implemented. Since February 2007 he has field bunds around his fields. His well was dug 30 years ago. During rainy season the whole depth of the well, 7 m, is filled with water, but during dry season it is almost empty. The previous few farming years it held enough water, which made it possible to cultivate two seasons instead of one and his hopes are that he can keep doing so with help of the watershed management.

Figure 9 Paddy field in Arapedu. The farmers in the picture are not the farmers interviewed.

4.2.5 Wells

In Figure 10 one can see the location of the wells as measured with GPS. The rectangles show the approximate location of the farm ponds.

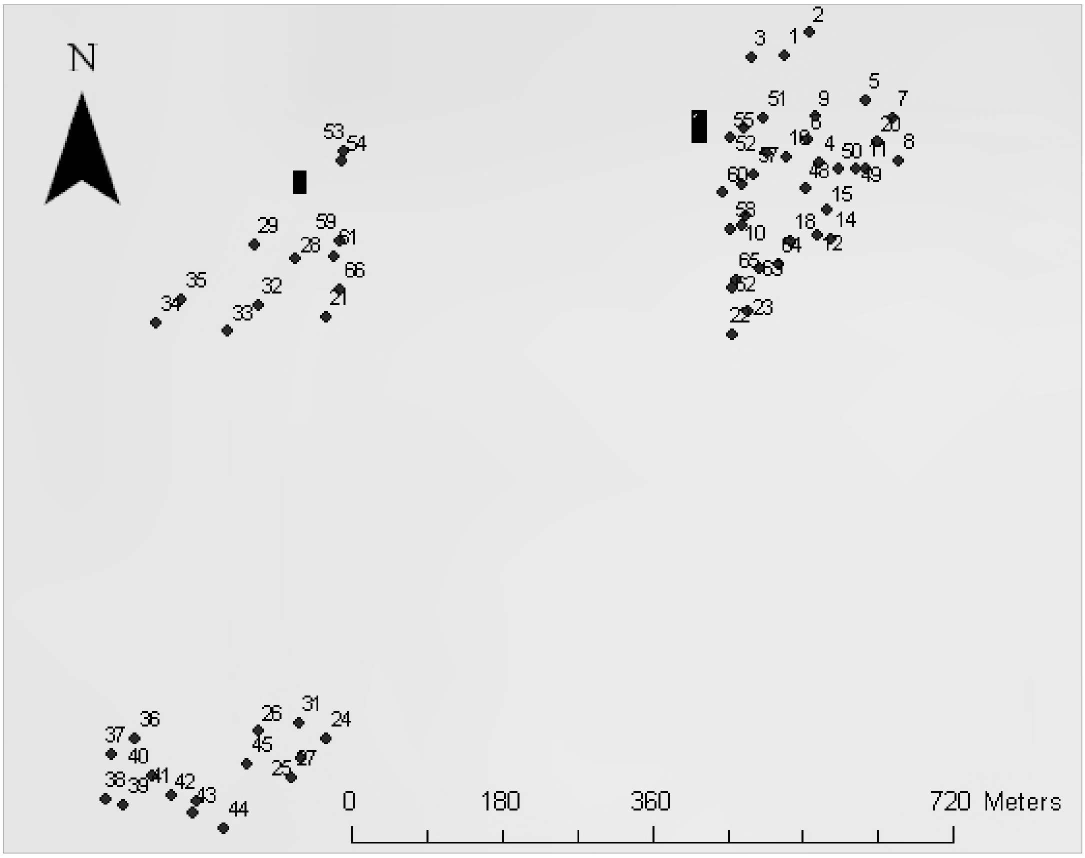

Figure 10 Location of wells (spots) and approximate location of farm ponds (squares). All located within the green area in Figure 5.

When comparing the water level in the wells between 2007 and 2008 one can see (Figure 11 – 14) that for May, June, July and August the levels in most wells were higher in 2008 than in 2007. Two wells are exceptions from this increase in three of the four months studied. The owner of these wells was the farmer that had chosen not to join the watershed interventions. When comparing this information with the written well inventory it was suggested that he was only the owner of one of the wells. As background information the precipitation from January to May/July is shown in table 6.

Table 6 Amount of precipitation

	Jan	Feb	Mar	Apr	May	Jun	Jul
Precipitation [mm] 2006/2007	0	40	0	40	37	81	132
Precipitation [mm] 2007/2008	34	65	203	0	0	No inf	No inf

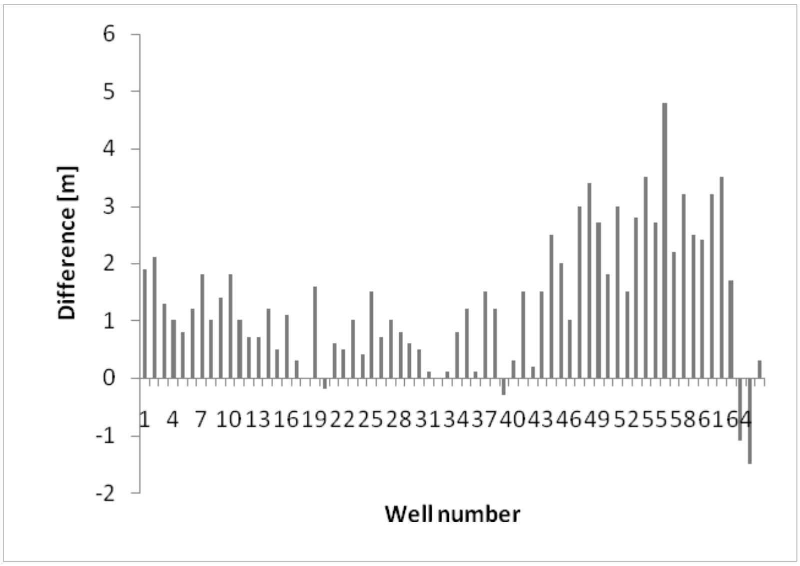

Figure 11 Difference in water level of the wells between May 2007 and May 2008. A positive value means higher water level in 2008 and a negative value means lower. Each bar represents one well.

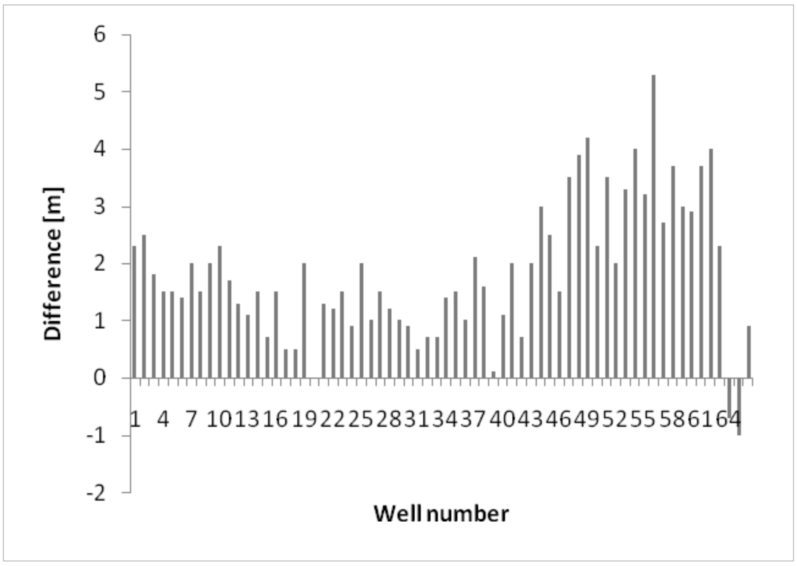

Figure 12 Difference in water level of the wells between June 2007 and June 2008. A positive value means higher water level in 2008 and a negative value means lower. Each bar represents one well.

In July the difference in water level between 2007 and 2008 was relatively small compared to the other three months, see Figure 13.

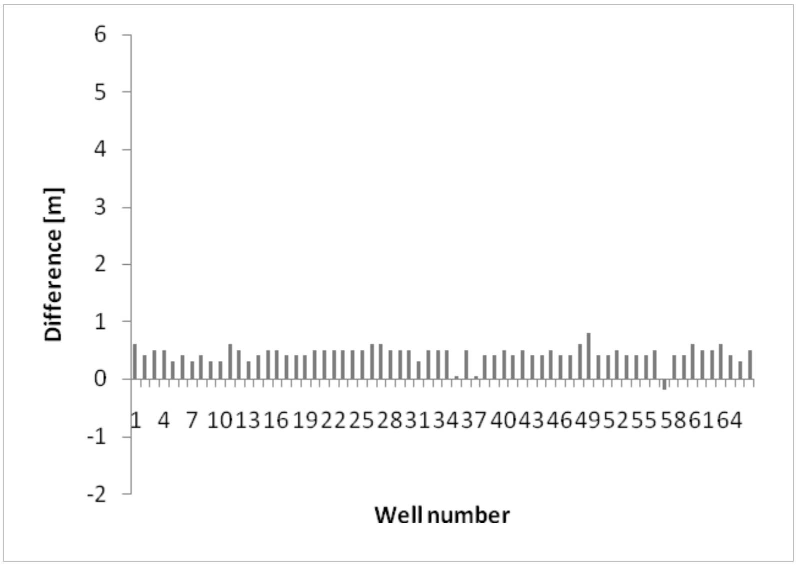

Figure 13 Difference in water level of the wells between July 2007 and July 2008. A positive value means higher water level in 2008 and a negative value means lower. Each bar represents one well.

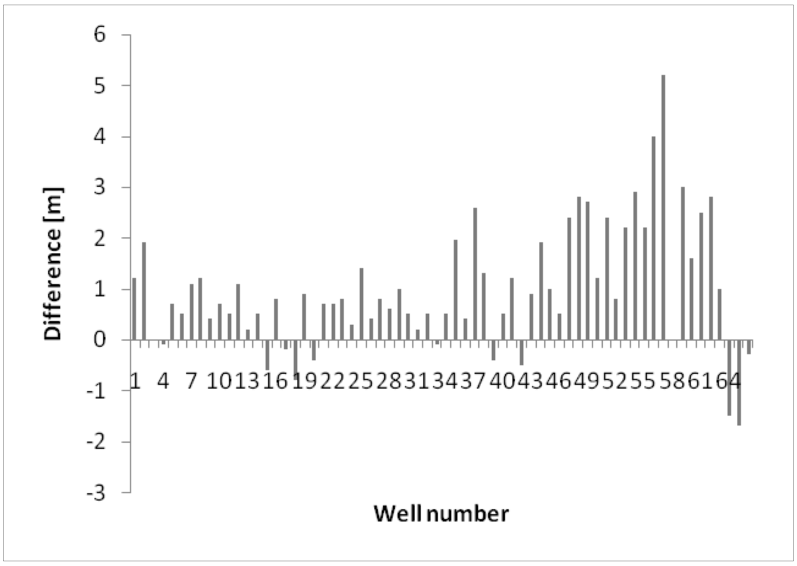

Figure 14 Difference in water level of the wells between August 2007 and August 2008. A positive value means higher water level in 2008 and a negative value means lower. Each bar represents one well.

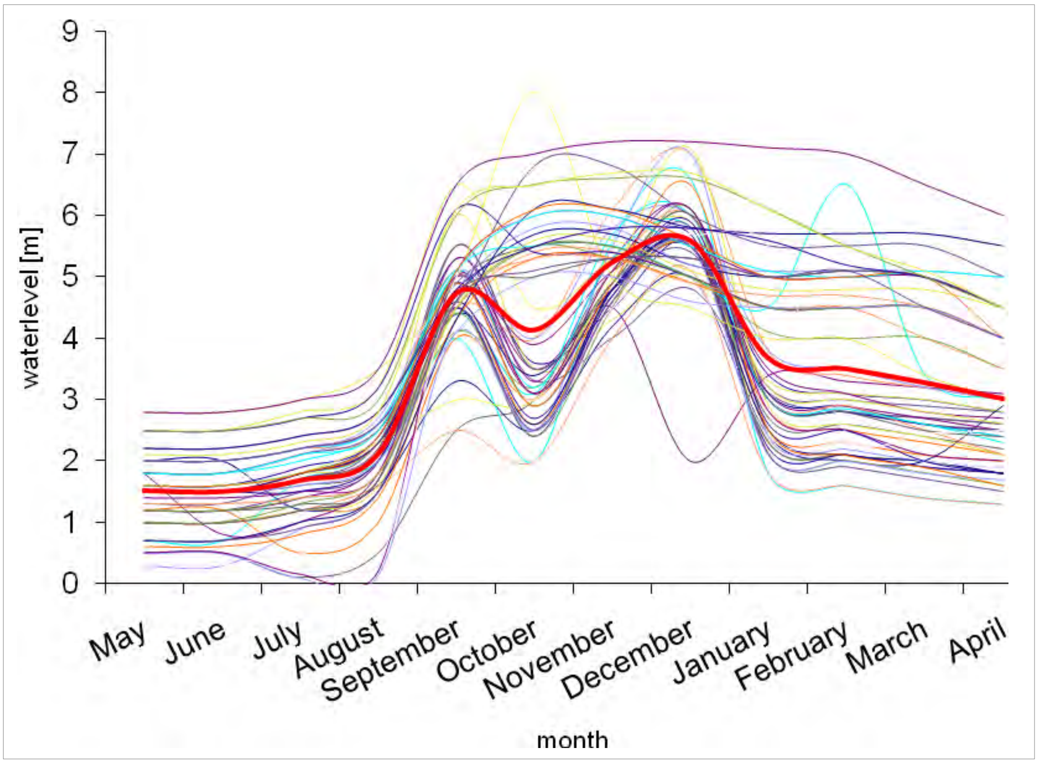

Figure 15 Water levels in the wells for one year. The first month is May 2007 and the last month is April 2008. Each line represents one well. The red thick line is the average water level.

Wells number 42, 51, 58, 60, 61, 65 and 66 do not have a dip in October like the other wells. Well 61 and 66 are located close to each other and close to a farm pond, 51, 58, 60 and 65 are all close to the other farm pond. Well number 42 is far apart from these other 6 wells. The October dip is probably due to a small amount of rainfall in September. Well number 1 has a dip in December, when no other well has.

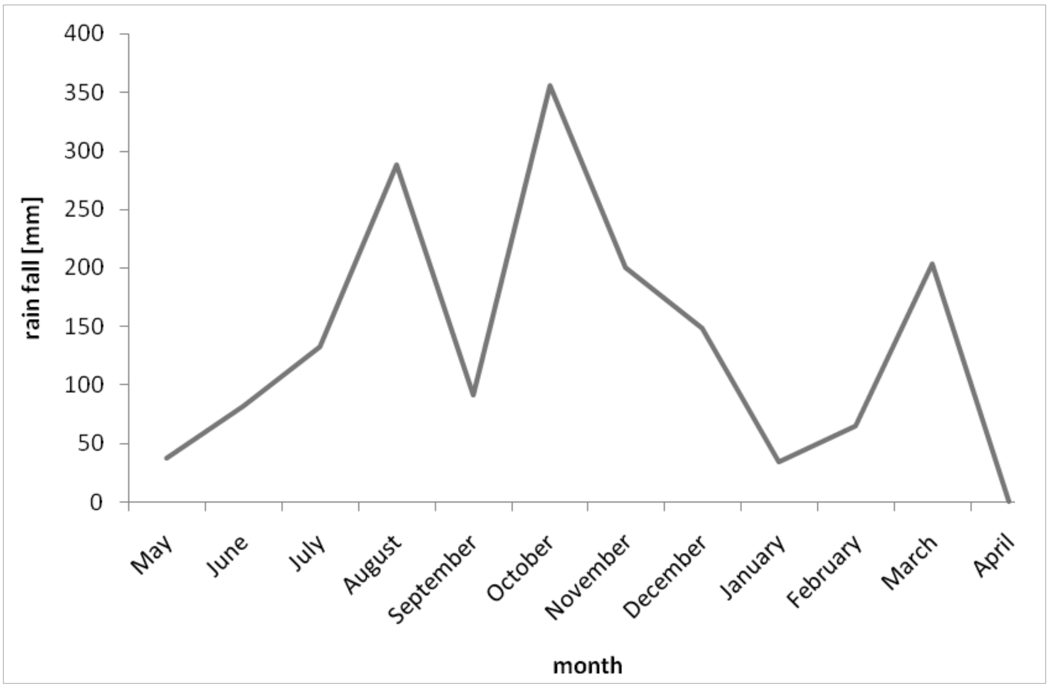

Figure 16 Amount of rainfall for the same period as Figure 15.

When comparing Figure 15 and 16 one can see how the amount of water in the wells and the rain is correlated. The low rainfall in May 2007 was followed by lower water level in most wells during the following month.

To describe the direction of the groundwater flow, isolines for the ground water levels were drawn, see Figure 17. The ridgeline was situated in the uppermost part of Figure 17. The water seems to be draining mainly to the south east. The error of the GPS was 2-4m which is relatively large compared to the small difference in altitude.

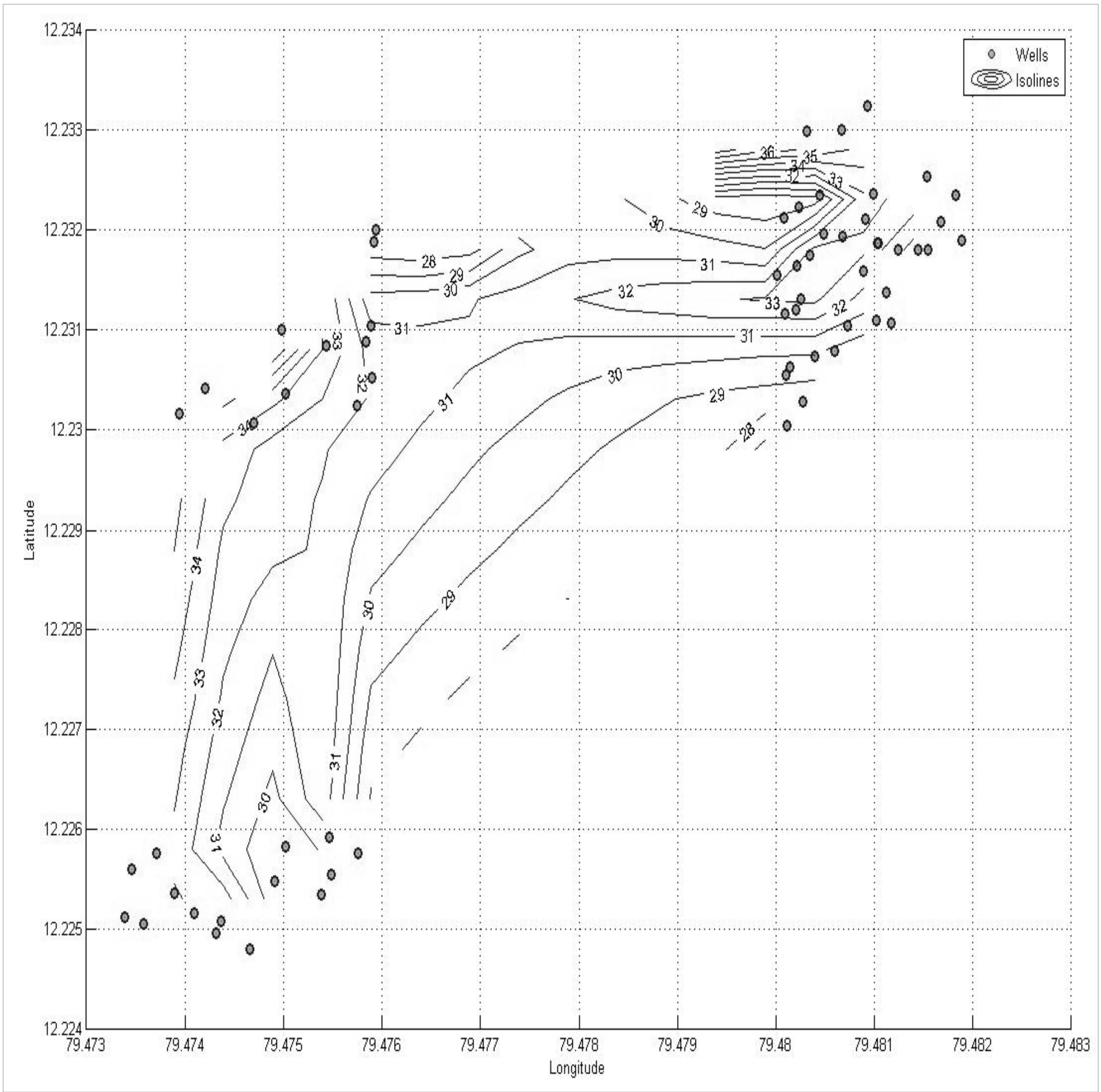

Figure 17 Wells and isolines for ground water levels in meters above sea level. This figure is drawn from the position of the water level in the wells in May 2007.

In figure 18 it was investigated if there was any connection between the distance to the closest farm pond and the water level in the wells.

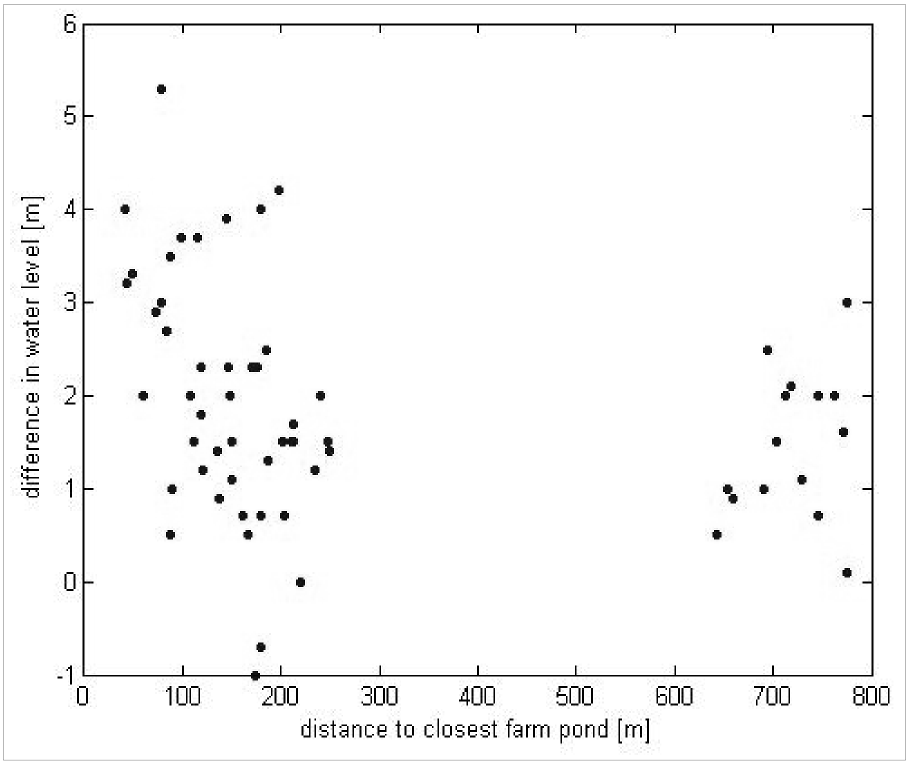

Figure 18 Difference in water level between June 2007 and 2008 plotted against the approximate distance to the closest farm pond.

The wells with the largest increase in water level seem to be situated close to the farm ponds.

4.2.6 Village records

Local authorities kept records of what the farmers were sowing on their fields. These records do not necessarily agree with findings by interviewing the farmers. The reasons for the dissimilarities were not clear. The records stated the size of the area on which each crop was grown, including agroforestry. In Tenpakkam the total cropping area and average size of the fields were bigger than in Arapedu (see Table 7).

Table 7 Farming areas for Arapedu and Tenpakkam four different farming years according to the village records.

Farming year	Rain [mm]	Total cropping area [ha]		Average area per field [ha]	
		Arapedu	Tenpakkam	Arapedu	Tenpakkam
1991-1992	1332	124.51	298.82	0.09	0.19
1996-1997	1718	216.87	257.78	0.13	0.19
2001-2002	1454	136.55	256.46	0.10	0.17
2006-2007	1092	187.31	212.49	0.09	0.16

Tenpakkam seems to have been cutting down on their cropping area gradually since 1991. The average area per single in Tenpakkam has decreased, while in Arapedu it has fluctuated.

Arapedu seems to be more dependent on the amount of rain fall when it comes to the total cropping area. The farming year 1991-1992 had more rain than average farming year, but the five previous farming years had less rain. The dryer farming years could have left them with little income and hence they could not afford to buy sufficient supply for cropping the next farming year. 2000-2001 was a farming year with a small amount of rainfall and 2001-2002 a smaller area was used for crops. The farming year of 2006-2007 had less than average rainfall, but the year before was good, so this probably gave the possibility to crop a big area 2006-2007. How the crops were distributed over the area the different years are shown in Figure 19 – 23.

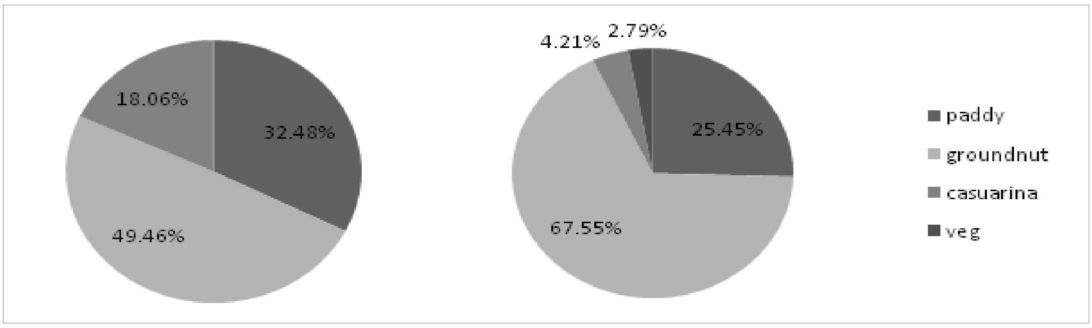

Figure 19 Distribution of crops at the cultivated area. Arapedu to the left and Tenpakkam to the right. Farming year 1991-1992.

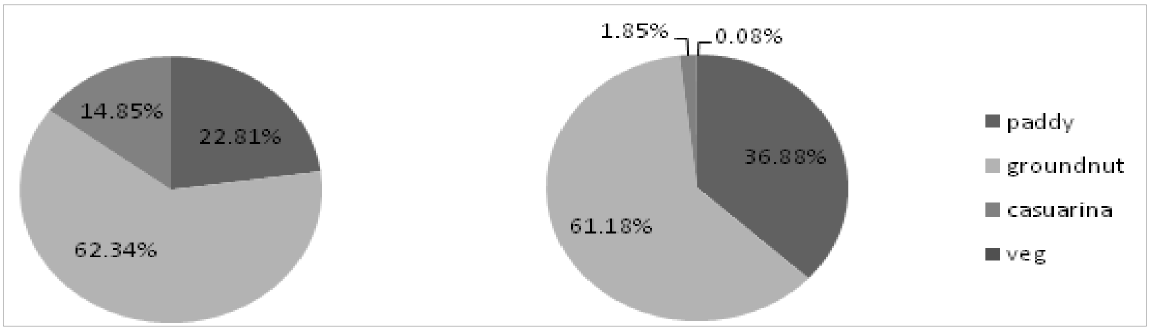

Figure 20 Distribution of crops at the cultivated area. Arapedu to the left and Tenpakkam to the right. Farming year 1996-1997.

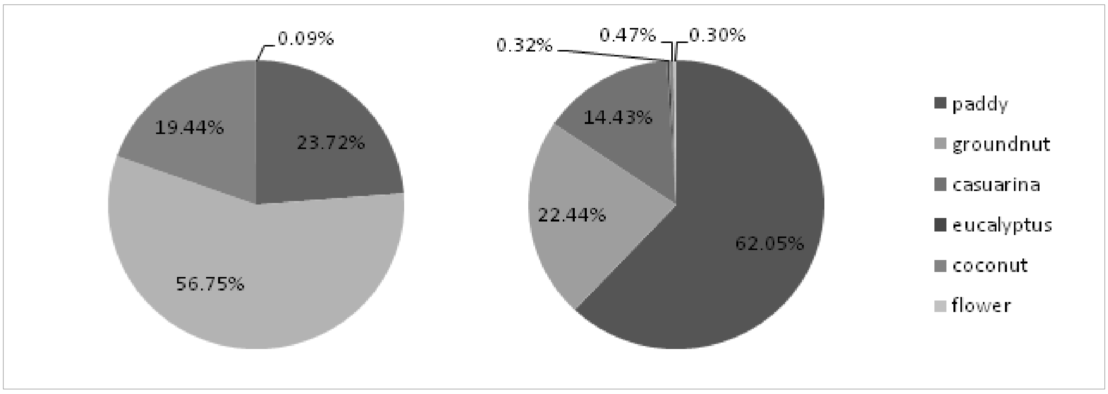

Figure 21 Distribution of crops at the cultivated area. Arapedu to the left and Tenpakkam to the right. Farming year 2001-2002.

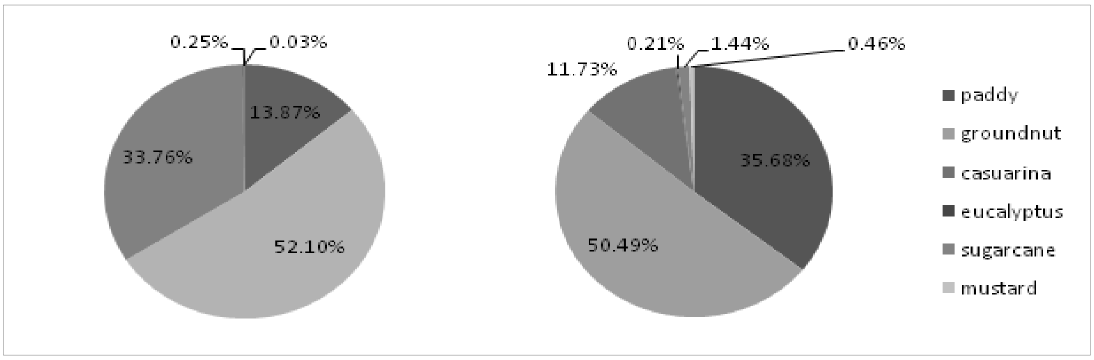

Figure 22 Distribution of crops at the cultivated area. Arapedu to the left and Tenpakkam to the right. Farming year 2006-2007.

In the village records parts of the cropping area were described as dry or wet land. The areas are shown and their classifications are shown in Figure 23.

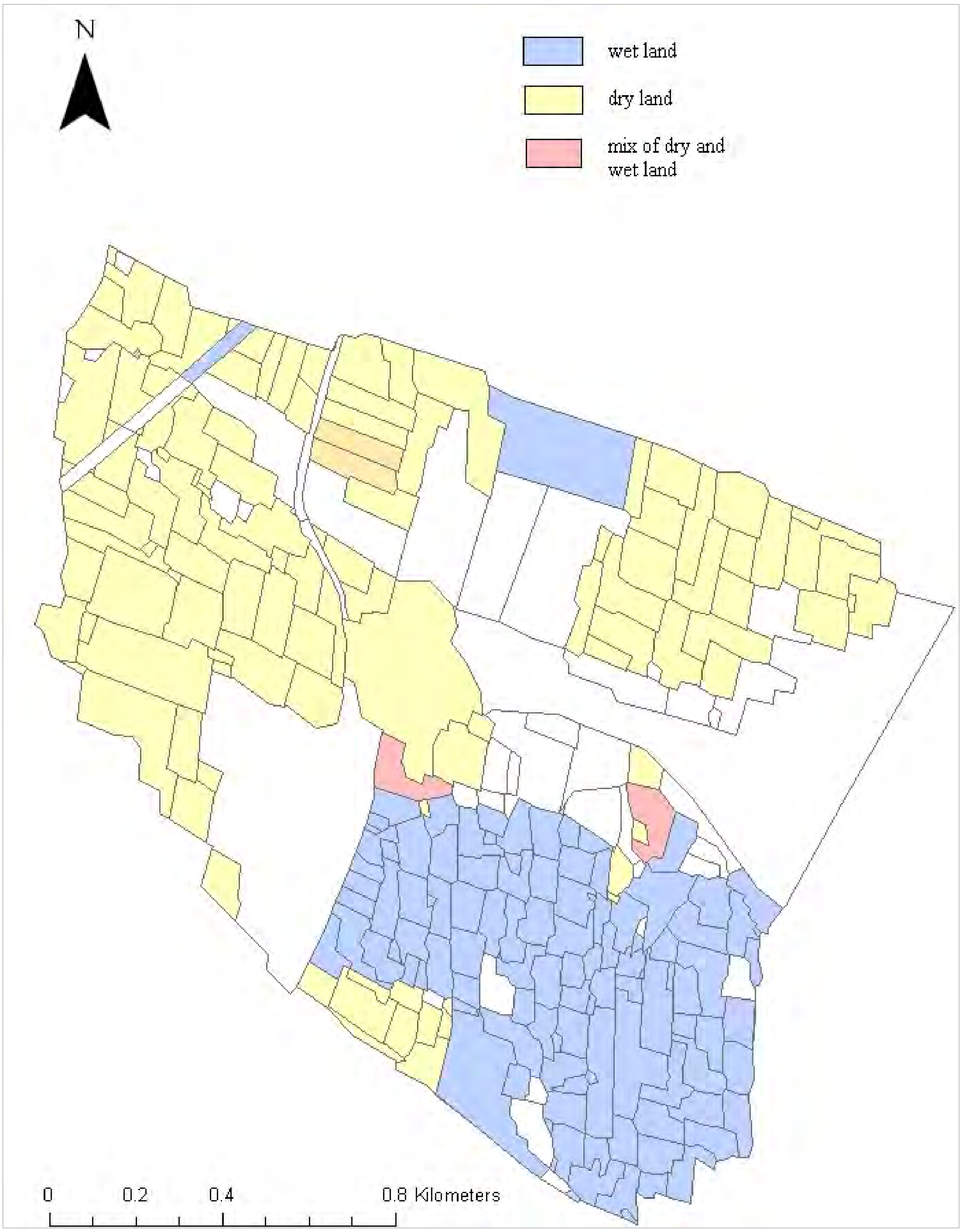

Figure 23 Dry and wet land. The area considered to be wet land is colored blue, the dry land yellow and the pink is partly wet, partly dry land. The non colored part was not classified.

At the area described as wet land mostly paddy and casuarina were grown. Groundnut was mainly grown at the area described as dry land. This can be seen in figure 24-25.

Note that the following maps do not give the exact picture since each plot in reality is divided into many sub-plots. This is also why some plots contain more than one crop.

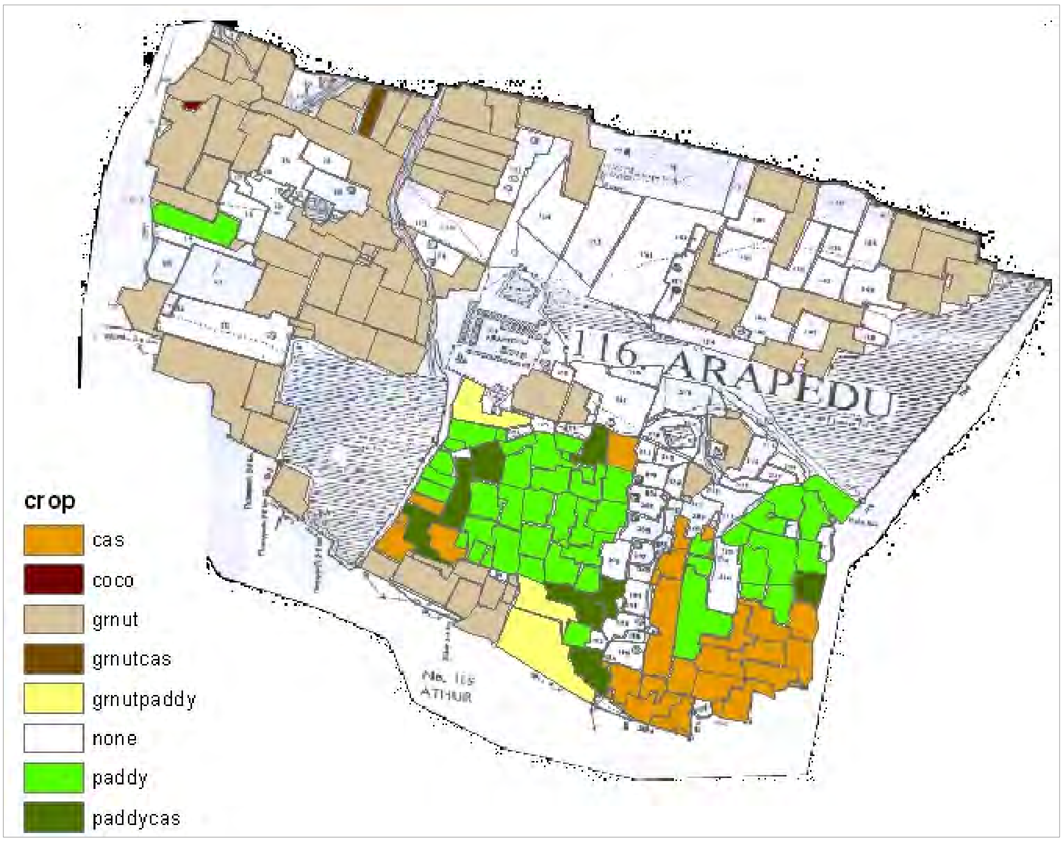

Figure 24 Map of Arapedu village and its agricultural area farming year 2001/2002. The crop names have been shortened; cas is casuarinas, grnut is groundnut, coco is coconut and eu is eucalyptus.

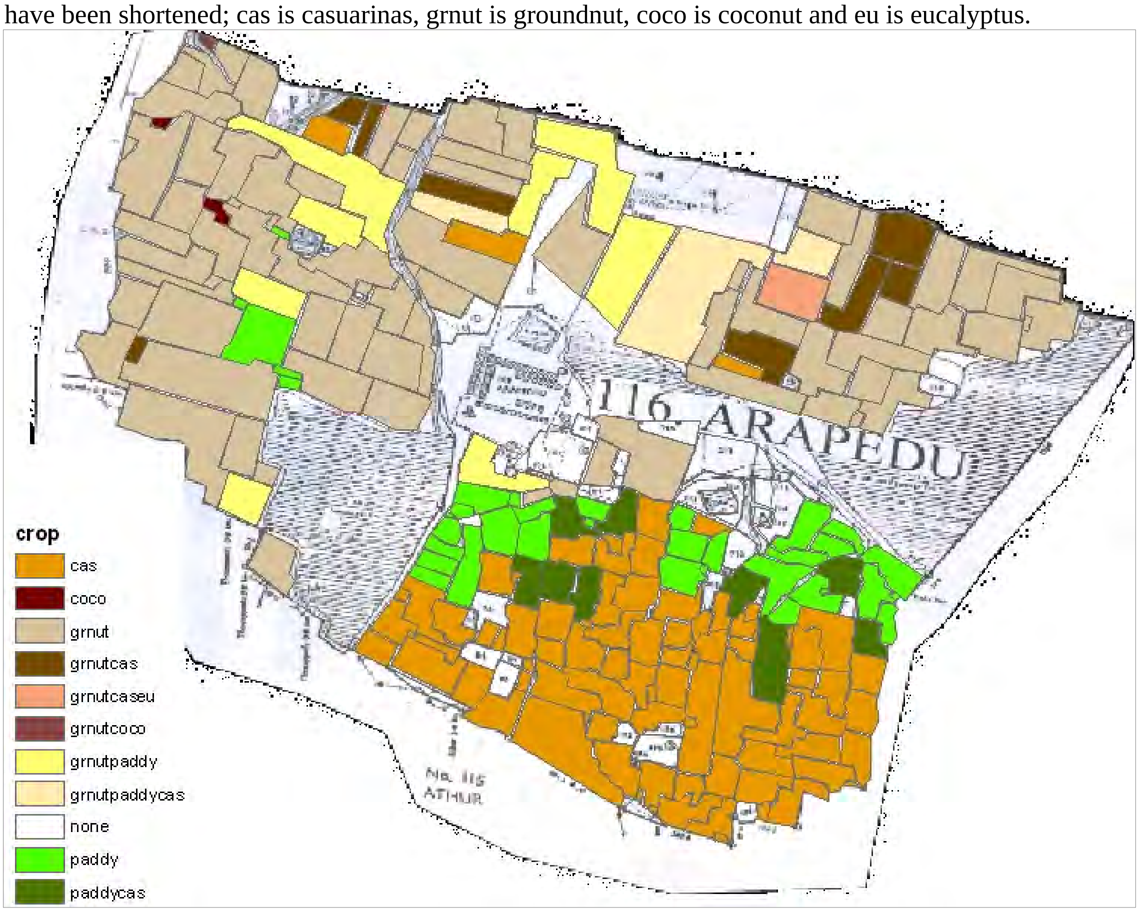

Figure 25 Map of Arapedu village and its agricultural area farming year 2006/2007.

4.2.7 Precipitation analysis

As mentioned earlier precipitation and number of rainy days for each month were available for a station 20 km south of Arapedu. The precipitation for each year and month is plotted in Figure 26.

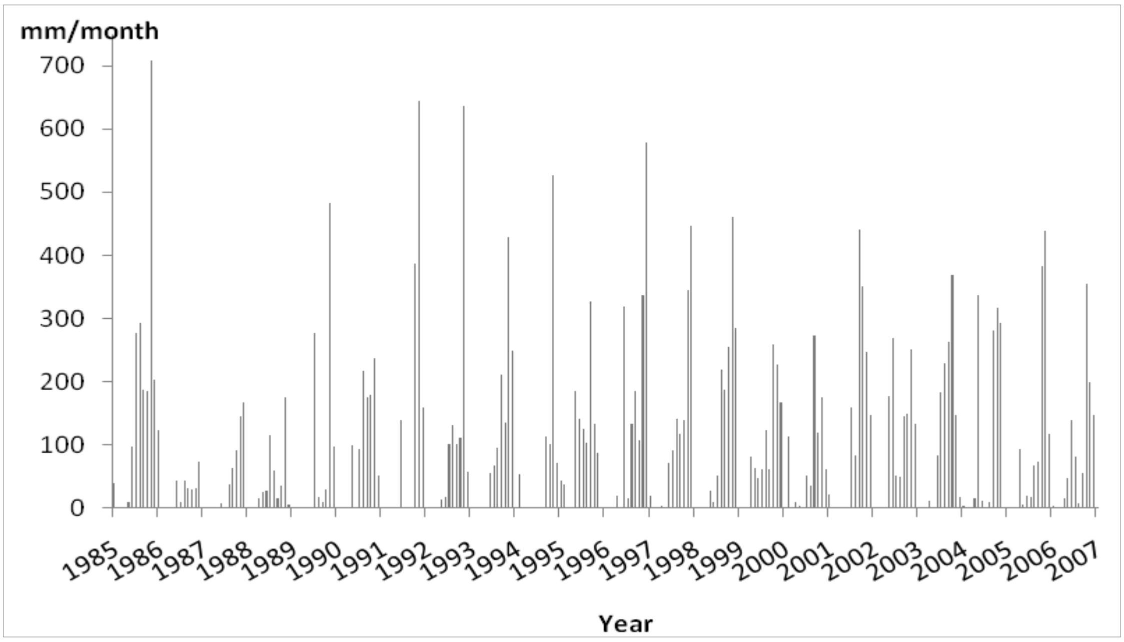

Figure 26 Monthly precipitation 1985-2007.

The amount of precipitation has a very small increasing trend and the intensity in mm/day seems to be decreasing, see Figure 27 and 28. The correlation for both amount of precipitation with time and its intensity with time is close to zero ($r^2 = 0.07$ respectively $r^2 = 0.09$); hence there are no signs of changes in yearly precipitation or intensity with time. As seen in Figure 29 the number of months per year that have rain has an increasing trend with a stronger, but still weak, correlation with time ($r^2 = 0.27$).

Statistical test in MATLAB gave correlation close to zero when looking at the correlation between time and: mean precipitation, total precipitation or monthly precipitation. No certain level was used. In other words there is no sign of change in time, mean, total or monthly precipitation.

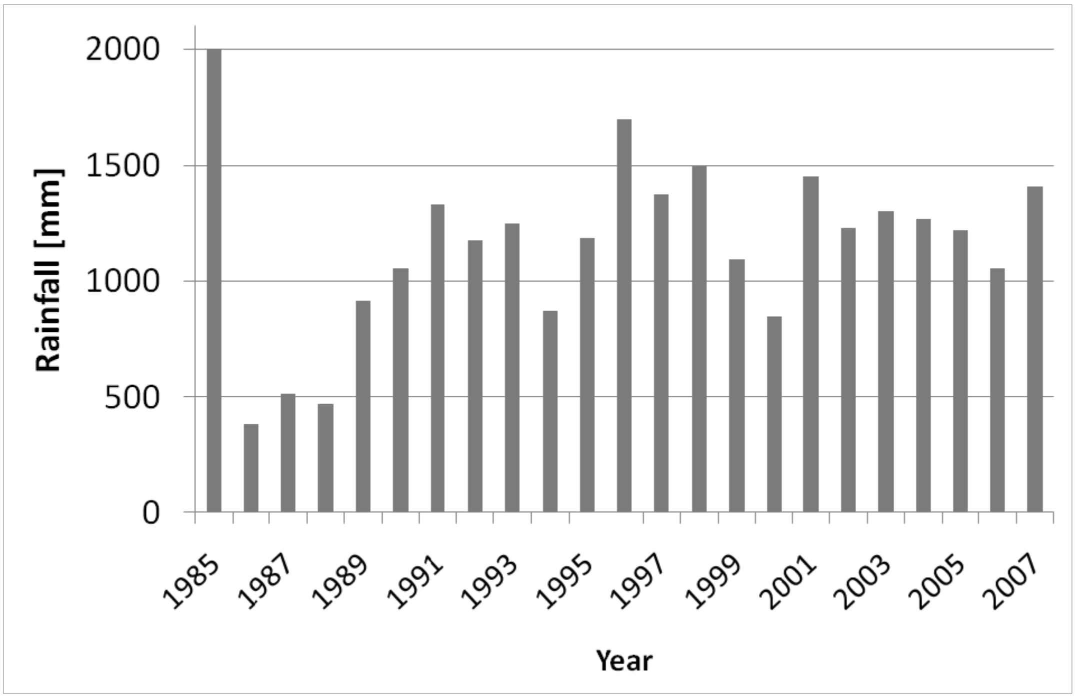

Figure 27 Amount of rainfall [mm/year] 1985-2008.

As can be seen in Figure 27 there are large interannual differences in precipitation. For example 1985 gave over 200 2mm of rain, but the following three years gave only 386 – 515 mm.

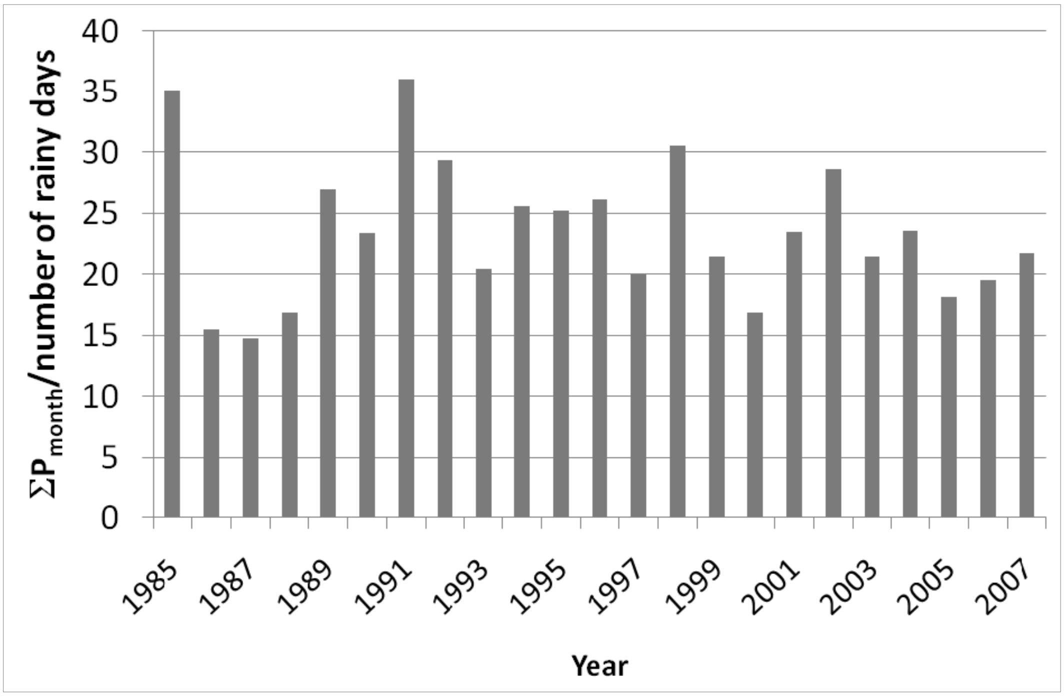

Figure 28 Average intensity of rainfall [mm/day] 1985-2008.

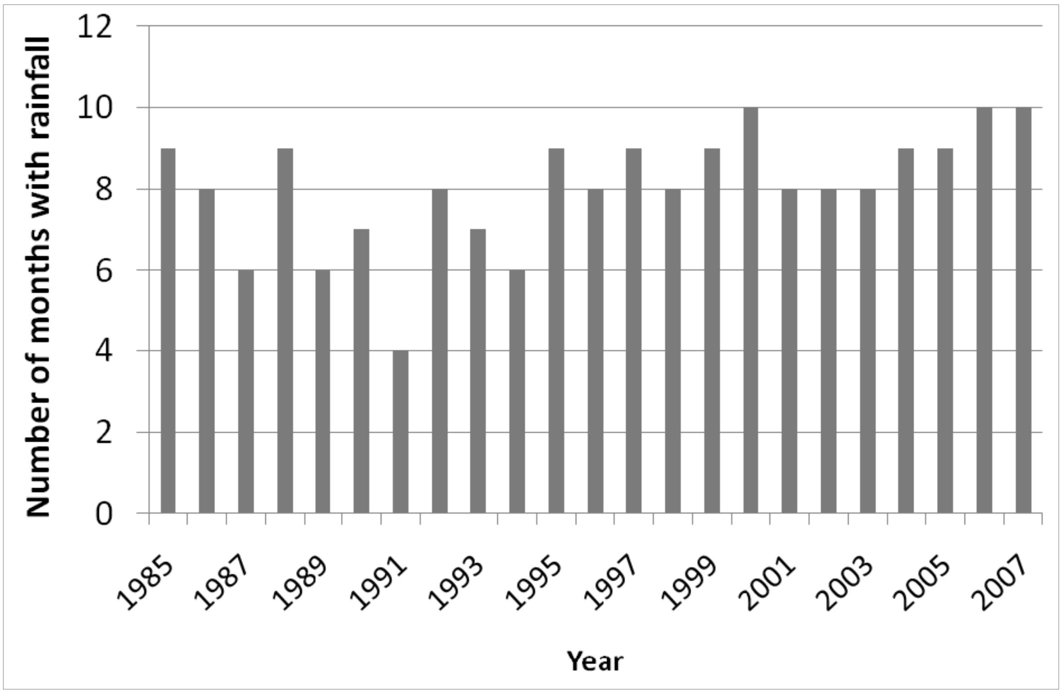

Figure 29 Number of months with rainfall 1985-2008.

Table 8 shows the heaviest rains and their intensity [$\sum P_{month}$/number of rainy days].

Table 8 Large rains and their intensities, sorted by year

Heavy rain (year, month) [mm]	Average intensity [mm/day] of heaviest rain	Average intensity the same year [mm/day] (most intense rain)
709 (1985, Nov)	59	35 (59)
483 (1989, Nov)	37	27 (37)
645 (1991, Nov)	40	36 (47)
636 (1992, Nov)	49	29 (49)
429 (1993, Nov)	29	20 (35)
527 (1994, Nov)	31	26 (38)
579 (1996, Dec)	53	26 (64)
447 (1997, Dec)	37	19 (37)
461 (1998, Nov)	46	31 (46)
441 (2000, Sep)	30	17 (30)
438 (2005, Nov)	31	18 (31)

The standard deviation for the monthly precipitation was large, sometimes larger than the average precipitation.

Table 9 shows the mean and median precipitation for each month during the period 1985-2007. The table also shows the calculated standard deviation and correlation with time. No trend correlation was proved.

Table 9 Statistics for monthly rainfall 1985-2007

Month	Mean precipitation (1985-2007) [mm]	Median precipitation (1985-2007) [mm]	Standard deviation [mm]	Correlation with time (r^2)
January	11	0	28	0.14
February	11	0	27	0.03
March	0	0	0	NaN
April	13	0	25	0.23
May	45	6	83	0.09
June	69	43	86	0.03
July	86	68	80	0.02
August	104	83	91	0
September	148	118	113	0.10
October	199	149	123	0.48
November	323	252	187	0.06
December	147	133	140	0

Frequency analysis for when it is likely that rain will fall can be seen in Table 10. The first column indicates the total number of days during the period 1985-2007 that had rain the valid month. The second column indicates the probability of rain a certain day of each month. For example for January this was 19/ (31*22) = 0.028. The last column shows the fraction of days with rain that occurred the valid month during the years between 1985 and 2007.

Table 10 Frequency analysis for rainfall 1985 - 2007

Month	Total number of rainy days	Probability of rain a certain day (%)	Fraction of the year's rainy days (%)
January	19	2.8	1.7
February	9	1.4	0.8
March	0	0	0
April	15	2.3	1.3
May	26	3.8	2.3
June	66	10	5.8
July	111	16.3	9.8
August	131	19.2	11.6
September	143	21.7	12.6
October	229	33.6	20.2
November	249	37.7	22.0
December	135	19.8	11.9

As shown in Table 10 and Figure 30 rain can be expected as often as every third day in October and November, while in March there is not much hope for any rain at all.

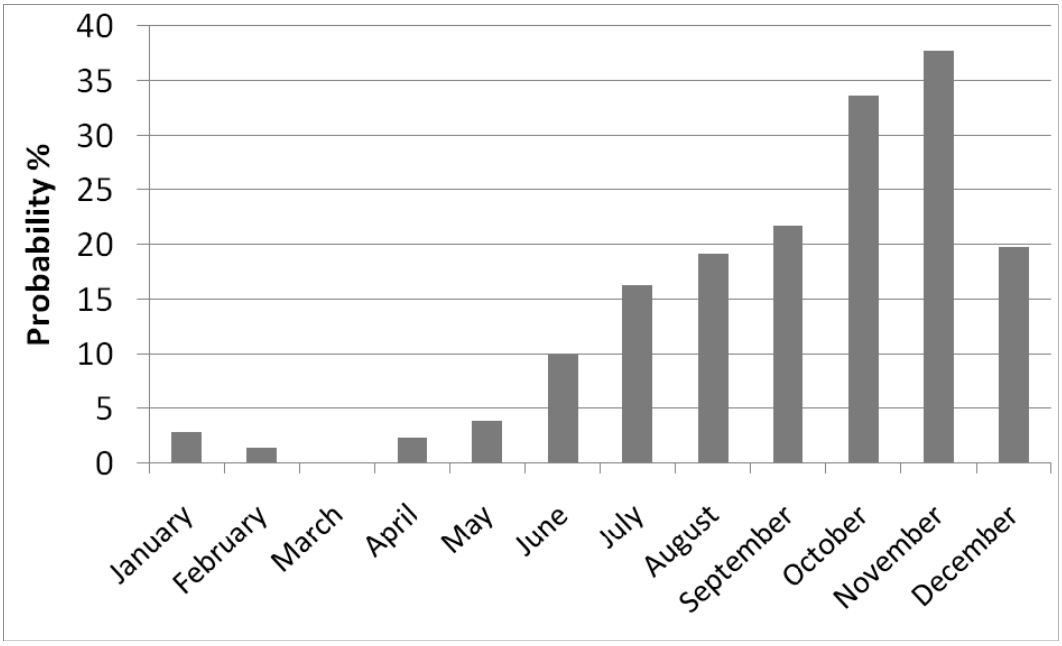

Figure 30 Probability of rain [%] a certain day each month.

4.3 Economy

In order to find out which crops were most profitable to grow the farmers were also asked about the costs and income from their crops. Some farmers actually did not gain any profit from their crops during any of the farming years asked about in the interviews. Some of the farmers might have been better off growing some other crops, but they kept cultivating the same. Some farmers seemed to have better skills than others in negotiating a good price for their products. Rice is an exception since it strictly follows market pricing.

5 DISCUSSION AND CONCLUSIONS

5.1 Effects of watershed management

The project in Arapedu started in March 2007 and had only been ongoing for 18 months when this study was conducted. One of the farm ponds was completed in September and cannot possibly have influenced the water levels in the farm wells that were analyzed here. The other two (one of the series one and the other single) were completed earlier and it is possible that they had given some benefits. Farmers that got their field bunds early might have had time to benefit more than those who got them later.

When it comes to evaluating the watershed project this study was a little premature. It should be seen as a primary evaluation and can be used as a base for future evaluations. The study of Tenpakkam can be useful when projects are going to start there, since it can be valuable to know the conditions in Tenpakkam before the start of the project. No such information was available for Arapedu. As Kerr (2002) pointed out, one complicated part in evaluating watershed projects is the lack of data before the project started.

Kerr (2002) stated that farmers most upstream in the watershed often do not benefit from the watershed management. Farmers most upstream in Arapedu village however had trenches upstream which they could benefit from. First and foremost they will probably suffer less from high speed excess runoff thanks to the watershed management.

A good sign for future management of the watershed was that almost all villagers joined the project in Arapedu and can work together for a common goal. An issue here could be that a farmer who did not take part regretted his choice when he saw the positive effects that other farmers experienced. All money was already spent when he had regrets and nothing could be done.

The agroforestry part of the project just had started during the fall 2008 and it will take years before the farmers can start to benefit from their fruit trees. Hence this part of the project cannot yet be evaluated.

5.2 Interviews

Some farmers said that they were able to grow crops in the spring season as well. This might not be due to the watershed management. In 2008 it rained more than usual for the early months of the year and it can be due to this fact that the farmers had more water in their wells and also were able to grow more crops. It is possible though that the different efforts to make improvements to the watershed actually helped keeping the soil moist and decrease the pace of the surface water flow.

There could be several reasons why the potential yield/hectare for paddy was exceeded in Arapedu: There are thousands of types of paddy and the information from Coimbatore may be an average. The sample size is small and if a couple of farmers remember wrongly this might have a large effect. Most interviews were conducted in groups and there was a risk that some might overestimate their yield to impress others.

The sample size for the villages is quite small, which leads to an uncertainty in the interview data. Even if aiming for a random choice of farmers to interview it is not an easy task in reality.

Since the whole interview group came from Hand in Hand, there was a risk that the answers from the farmers would not be objective if they were asked if they had experienced any change because of the watershed management. Hand in Hand gave support to their project villages in many fields, not only watershed management and this could make the farmers answering what they thought Hand in Hand would like them to say. Before the interviews one of the interpreters had gone through the questions and got help to clarify any indistinctness. In an effort to overcome certain subjectivity the questions were formulated in a way that made them possible to analyze quantitatively.

5.3 Well inventory

When comparing the water level data in the wells between 2007 and 2008 it was found that the water level seemed to have increased in most wells. Even if the water level increased, it is not possible to tell if it was due to the watershed management or due to the fact that it actually rained more the in early 2008 than in early 2007. Since May, June, July and August were the only months for which data was available for both years it was not possible to run any statistical tests. In a couple of years it will be possible to tell more assuming that Hand in Hand keeps monitoring the wells even after the management practices have been completed.

Why the water level in well 64 and 65 did not increase while the water level in wells around them did is not clear. The farmer that did not have field bunds might have had to use more water from his well (well 65) for irrigation. It could be some kind of geological aspect involved, but that has not been investigated in this study.

When measuring location with the GPS the error in measurement was between 2 and 4 meters. This did not make a big difference since the area was big. However, together with not being able to locate the center of the well and some of the wells being located close to each other, may make it appear like some wells are closer together or farther apart then they are in reality. When it comes to altitude the error of 2 – 4 meters is significant since there are small gradients on the ground water surface. The probably has a large effect when drawing the isolines for the groundwater surface.

The findings that the water levels in some wells did not sink during the dry period of the year could be due to their closeness to farm ponds. It could also be that the farmer did not draw any water from their well during the period.

There were a weak connection between a small distance to a farm pond and increase in water level in the wells, Figure 18. In most wells the water level had risen from 2007 to2008. The wells with the largest increase were found close to a farm pond. It should be noted that the first months of 2008 had significant more rain than the corresponding period 2007. Since there were no measurements in the wells from earlier years this makes the results hard to evaluate. The completed farm pond could have had effect, but more data is needed for validation. One of the farm ponds was completed in September and latest water level data were from August. It was not possible to show any difference in water levels in the wells depending on which the farm ponds they were closest to.

When trying to put the well locations together with maps of Arapedu village big methodological obstacles were encountered. The maps were in GCS Everest

Bangladesh projection and the wells in WGS 84 and conversion still could not make them fit together properly. Conversion was tried in both MATLAB and arcGIS, but none were successful. The geology map and the map showing the lots and their survey numbers did not agree with each other or with the GPS. The geology map did agree with maps from Google earth and ESRI in terms of location of the hill side when comparing visually. The main issue with the geology map was the unknown scale. After trying to make the geology and crop pattern maps together finally it was found where the crop pattern map fitted in with the geology map. If a proper GIS-projection of the geology map had been available the fitting would have been much more accurate. It was also found why the wells did not fit in the crop pattern map – the crop pattern map only partly covered the area where the wells were located. Much time was spent on trying to figure out how things fitted together. Since there is an uncertainty in the maps they should mainly be considered as a rough estimate of the reality. The approximate location of the farm ponds in Figure 11 (section 4.2.5) was estimated by looking at maps and pictures and comparing with the well locations. It was unfortunate that this part was hard to figure out and took time that could have been better spent. At least it was finally solved why only a few of the wells fitted in the crop pattern map – the wells were actually situated elsewhere.

5.4 Village records

As can be seen in Table 8, Tenpakkam seems to have been slightly cutting down their cropping area gradually since 1991. This could be due to increased number of inhabitants in the village, which may have led to increased need for using the land for building new homes, or farmers have shifted from cropping to keeping animals instead.

In Arapedu it was hard to find any pattern in the cropping records. Paddy seemed, however, to have decreased a little and instead have given space for increased cropping of casuarinas. Groundnut was the most grown crop during all investigated years.

The village records collected by local authorities did not always agree with the statements of the farmers. In the records for Arapedu there were no notes of the farmers growing ladyfingers, but when interviewed they stated differently. The village records did only cover a part of the well inventory area. Some crops that were noted in the village records were cultivated by none of the interviewed farmers. This was probably since the interviewed farmers also grew crops in the area not covered by the records kept by the local authorities.

To be able to see any clear pattern in cropping (or to determine that there is no pattern at all) maybe more years would be needed for investigation, but due to the vast quantity of data and the small amount of time it was not possible. Another possibility is that there actually was no pattern in the cropping records.

5.5 Precipitation

What was found after analyzing the precipitation data is different from other studies made in India (Bates et al., 2008). Earlier studies have found that rainstorms are less frequent, but have higher intensity. No sign of change in precipitation could be shown in this study. If the climate is getting warmer or not was not investigated in this study since there were no temperature measurements available. The inter-annual differences in precipitation make it however difficult for the farmers. For example the year 1985 gave 2002 mm of rain. When adding the yearly precipitation of 1986, 1987 and 1988 they got less precipitation together than the single year 1985.

The intensity of the rain could only be calculated as the monthly rainfall sum divided by number of rainy days for each month. This means that small low intense rainstorms and large high intense rainstorms got evened out in the calculation. There was no way of knowing how much it actually rained each day.

The three first months of 2008 gave together 302 mm of precipitation. This is the rainiest first three months during the record period 1985-2008. This fact may affect how the farmers experienced their ability to grow crops in the early season.

The large standard deviation for each month between different years, Table 9, makes it hard to predict the amount of rainfall. During the whole period analyzed it did not rain in March in a single year. However in March 2008 (not included in the analyses) 203 mm of rain fell in the area.

5.6 Hand in Hand

One of Hand in Hand´s strengths is that they not only practice watershed management in the village, but also include the other pillars in their five pillar programme (section 2.1). Hand in hand claims that their work does not end when the watershed management programme is completed; money is set aside for future maintenance costs. These are aspects that according to Kerr (2002) speak in favor for the project to be a success.

5.7 Conclusions

- The water level in most wells increased in May, June, July and August between 2007 and 2008, but it was not possible to determine the cause of this increase.
- The precipitation amount and intensity in the area does not seem to have changed over time during the analyzed period
- Each watershed is different and it will take more studies with longer time series in order to determine how well the project in the Arapedu watershed works.
- Hand in Hand seems to be doing a valuable work and they are aiming for the project to be sustainable.

5.8 Future suggestions

It is important that Hand in Hand keeps evaluating this project. First after at least two years it will be possible to tell whether the project is successful or not. When there are data from more years and especially years with the watershed management, it would be possible to tell if the practice worked or not.

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APPENDIX 1 Questionnaire

Questions

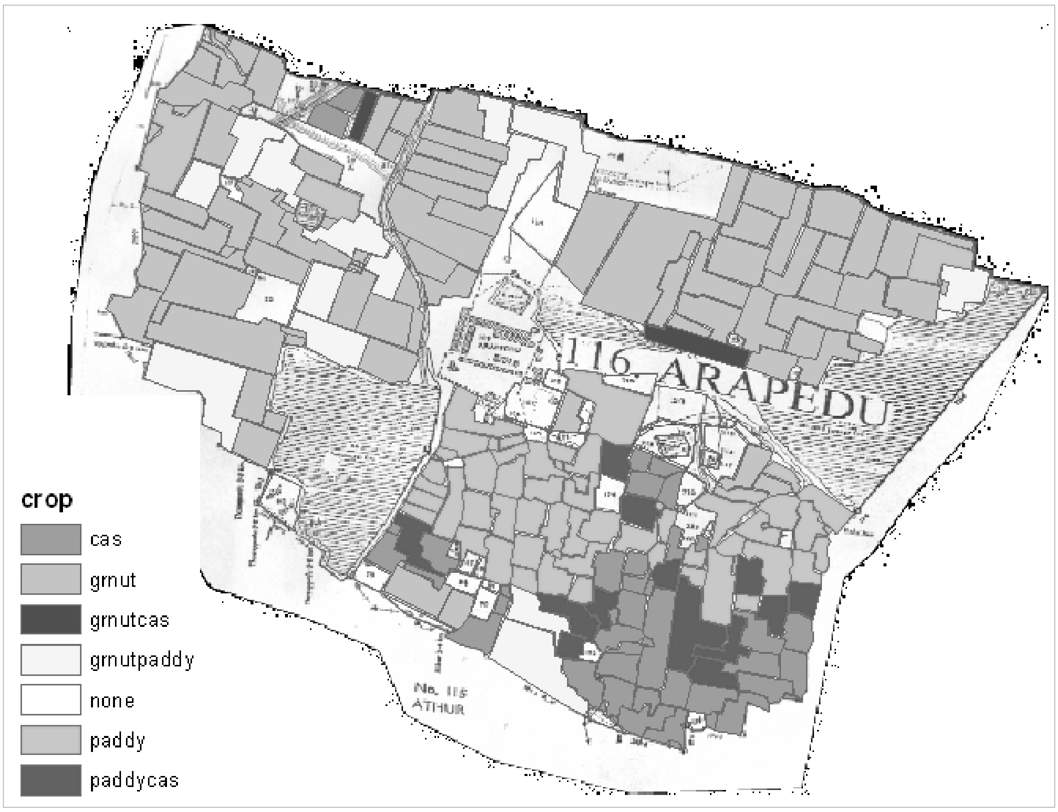
- Name?
- Age?
- Number of labour days? Contribution to watershed interventions?

Crops

- **How much irrigated land did you have 2007/08?**
  - What crops did you grow on this land?
  - How many seasons can you harvest this crop?
  - What was the size of each field?
  - What was your input cost for each crop?
  - What was your gross income?
- **How much dry land did you have 2007/08?**
  - What crops did you grow on this land?
  - How many seasons can you harvest this crop?
  - What was the size of each field?
  - What was your input cost for each crop?
  - What was your gross income?
- **How much irrigated land did you have 2006/07?**
  - What crops did you grow on this land?
  - How many seasons can you harvest this crop?
  - What was the size of each field?
  - What was your input cost for each crop?
  - What was your gross income?
- **How much dry land did you have 2006/07?**
  - What crops did you grow on this land?
  - How many seasons can you harvest this crop?
  - What was the size of each field?
  - What was your input cost for each crop?
  - What was your gross income?
- **How much irrigated land did you have 2001/02?**
  - What crops did you grow on this land?
  - How many seasons can you harvest this crop?
  - What was the size of each field?
  - What was your input cost for each crop?
  - What was your gross income?
- **How much dry land did you have 2001/02?**
  - What crops did you grow on this land?
  - How many seasons can you harvest this crop?
  - What was the size of each field?
  - What was your input cost for each crop?
  - What was your gross income?

Appendix 2village maps

Map of Arapedu village and its agricultural area farming year 1991/1992.



Map of Arapedu village and its agricultural area farming year 1996/1997.