A socio-economic and technical study of an irrigation scheme in the Kurunegala district, Sri Lanka

En samfunnsøkonomisk og teknisk studie av et vanndistribusjonssystem i Kurunegala distriktet, Sri Lanka

Kristoffer Sorkness and Paul Henrik Johnsen

Norwegian University of Life Sciences
Department of Institute of Mathematical Sciences and Technology

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A Socio-Economic and Technical Study of an Irrigation Scheme in the Kurunegala District, Sri Lanka

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Kristoffer Sorkness   Paul Henrik Johnsen

Abstract

This current study revolves around the Deduru Oya project in Sri Lanka and its interaction between old irrigation schemes and new-built ones. The right-bank canal or RB-canal, a 33 km long canal built in concrete is designed to distribute water from the new-built Deduru Oya reservoir to the older Inginimitiya reservoir, and to the smaller water tanks along the canal. The project is due operational in November 2013. The goal of the project is to meet the water requirements for the paddy fields in the Kurunegala district and to enable farmers to grow paddy (rice) two times a year instead of one, both in the wet *Maha* season, and in the dry *Yala* season. The *Maha* growing season is mostly dependent on precipitation, while the *Yala* season mostly is dependent on irrigation.

Through a series of structured interviews and simulations through the water resources program WEAP, the study looks deeper into the effects of the RB-canal and to what extent the expectations would answer to the reality. Several scenarios such as different canal flow, climate changes and irrigation improvement were implanted in the simulation program.

The results from the analysis show that the Deduru Oya project will have a positive effect on the paddy cultivation, increasing the yield. We see that the project will be able to supply enough water for the proposed paddy areas along the canal, as well as for the paddy areas downstream of the Inginimitiya reservoir. With scenarios regarding reduced precipitation, increased precipitation intensity and droughts expected to come with climate changes in this arid area, the reservoirs storage capacity will be crucial to store up and supply irrigation water throughout the year.

The people in the affected areas are well aware of chronic water diseases, but have little faith in the government and how they will handle this problem. Pipe born water in these areas are unusual and according to the National Water Supply and Drainage Board there is no existing plan of this being developed in the nearest future. Since the canal is not yet operational and the information from the government very limited, the people today live in uncertainty regarding how their future will develop with this project.

Acknowledgement

This study had not been possible without the kind assistance, advices and arrangements given by the following individuals.

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Table of context

Abbreviations

NWS&DB – National water supply and drainage board

OFC – Other Field Crops

RB-canal – Right bank canal

MT – Metric Tons

Paddy – Flooded parcel of arable land used for growing rice

IFAD – International Fund for Agricultural Department

MCM – Million Cubic Meters

CMS – Cubic Meter per Second

IWMI – International Water Management Institute

IPCC – Intergovernmental Panel on Climate Change

WEAP – Water Evaluation And Planning system

Rs – Sri Lankan Rupees

1 Introduction

1.1 Defining the task

Water management plays an important role everywhere in this world. Water is needed for irrigation purposes, for the industry, producing hydroelectric power or most importantly for human consumption. Global wise, we have more than enough fresh water to supply all the worlds' population, but the accessible fresh-water is unevenly distributed.

This also applies for Sri Lanka. Though in overall terms the country faces little or no water scarcity, there is a pronounced unequal temporal and spatial distribution due to different rainfall patterns. As in most Asian countries, agriculture is the largest water user in Sri Lanka accounting for about 90% of the total water use. Water has to be brought from wet areas to dry areas, or stored during the wet seasons for use in the dry seasons. As a result, numerous water tanks and irrigation structures have been constructed throughout the history of the country. (Samad 1999)

This present study will look into the Deduru Oya project and its right-bank irrigation canal from the Deduru Oya reservoir to the Inginimitiya reservoir. This is an ongoing project and expected finished at the end of 2013. Deduru Oya river is the 6^{th} largest river basin in Sri Lanka, originating from the Matale Hills, west of Kandy, and running for most of its length through the North Western Province.

The growing population, rising living standard and increasing competition from other water-use sectors suggest that water demand would continue to increase. Existing and future irrigation structures need to be supported with sustainable water supply in Sri Lanka.

This study will look deeper into the water requirements for the paddy fields in the Kurunegala district and around the Inginimitiya reservoir and in what extent the RB-canal will be able to distribute water from Deduru Oya to the areas it is supposed to. It will also look at the socio-economic picture and in what grade the Deduru Oya project will benefit the population.

The study is based on facts and some estimation due to limited data/information and opens for further research.

1.2 Background

"Let not even a single drop of water go to the sea without benefiting man"

- King Parakramabahu (1153–1186 CE)

1.2.1 Water and cultivation in Sri Lanka

These are the famous words of an old Sri Lankan king who ruled in the 12^{th} century. Water management has always been an integral part of Sri Lankan history and to understand the mindset of the Sri Lankan government it is important to look at the history of irrigation schemes in the country. The country is famous for its ancient hydraulic civilization.

The irrigation works in ancient Sri Lanka, the earliest dating from about 300 BC, in the reign of King Pandukabhaya and under continuous development for the next thousand years, were some of the most complex irrigation systems of the ancient world. In addition to constructing underground canals, the Sinhalese were among the first to build completely artificial reservoirs to store water. The systems was extensively restored and further extended during the reign of King Parakramabahu. The king was strongly advised by the Buddhist monks and the survival of the king greatly depended on how he chose to follow these advises. **(**Irrigationdepartment 2013)

"Throughout the centuries of native rule, rice cultivation was the principal concern of king and people and one of the noblest of callings. To build tanks and construct watercourses were regarded as the wisest and the beneficent acts of a good ruler. The extensive ruins scattered in profusion in the ancient kingdoms attest to the care of the kings and the expenditure of money and labor on the national industry." (Arunachalam 1901)

1.2.2 Deduru Oya project

One huge irrigation project that aims to solve some of the water scarcity problems in Kurunegala and Puttalam district is the Deduru Oya project. A whole new water reservoir which can hold 75 million cubic meters of water has been built to avoid runoff from Deduru Oya river to the ocean without benefiting man. Kurunegala and Puttalam district suffers from water scarcity in the *Yala s*eason and with the help of the Deduru Oya reservoir and two main conveyance canals it will be possible to distribute water to these areas.

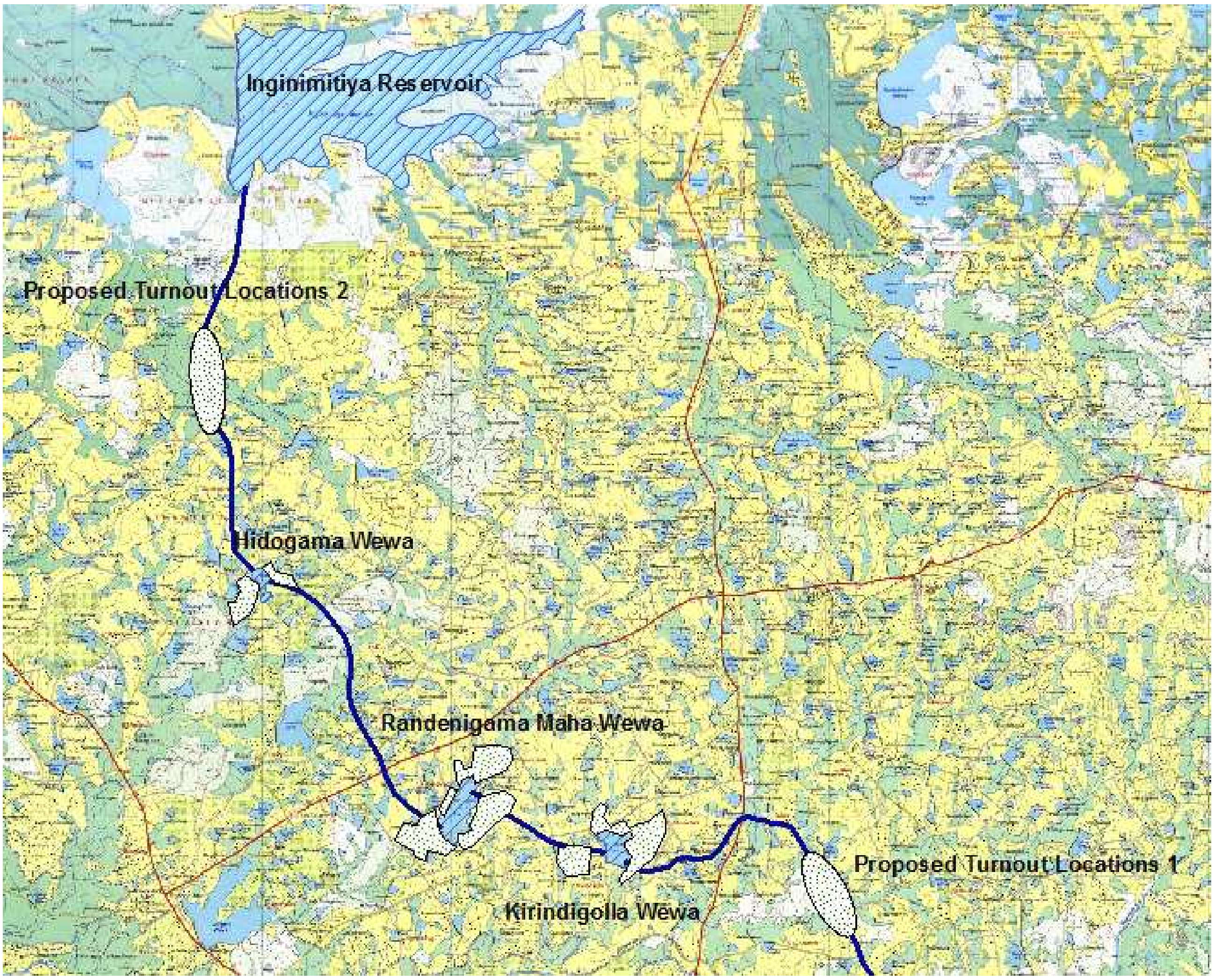


Figure 1 - The RB-canal stretches along the Kurunegala district. The Deduru Oya reservoir is down to the right, just outside the figure

There are currently many irrigation schemes within the district, one of them is the Inginimitiya Reservoir. This huge irrigation scheme was built 30 years ago, and its main purpose was to dam up the Mi Oya river, storing up enough water to be used as irrigation water for the paddy areas downstream of Inginimitiya. However, this project has not managed to fulfill the water demand, and therefore it was decided to build another reservoir, the Deduru Oya reservoir. Figure 2 shows the irrigation area below Inginimitiya reservoir. The reservoir has its own left- and right-bank canal.

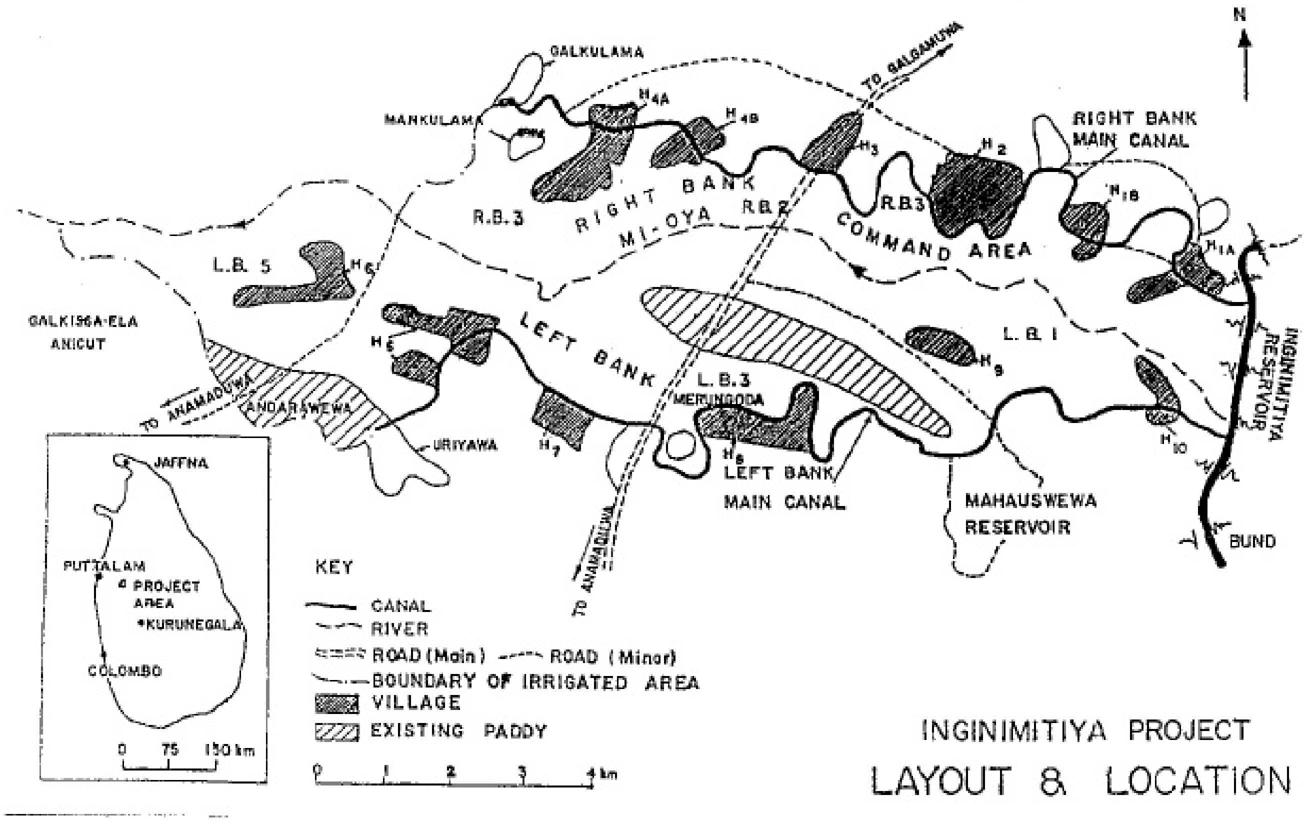


Figure 2 - Downstream Inginimitiya irrigation scheme. (HR Wallingford 1992)

Deduru Oya reservoir’s two canals are called Left-bank canal and Right-bank canal (or trans-basin canal). The 44 km long Left-bank canal will supply water to the paddy fields in the lowlands beneath Deduru Oya reservoir, while the 33 km long Right-bank canal will supply the areas between Deduru Oya and Inginimitiya, as well as supply Inginimitiya with the water it needs.

The Deduru Oya project is estimated to provide irrigation to 11 115 hectares of cultivated land, 1.5MW of hydropower generation and drinking water to 150, 000 families in the Puttalam and Kurunegala districts. During the months of heavy rainfall, the Deduru Oya reservoir is designed to store up water so that it can be distributed throughout the year to Inginimitiya reservoir with the RB- canal. The project is Sri Lanka's first modern reservoir built utilizing local engineering technology.

The project aims to distribute 90 MCM of freshwater from the Deduru Oya reservoir to the Inginimitiya Reservoir, using 30 MCM along the canal for supplementing irrigation. The RB-canal is a 33 km long soil canal with a bed slope of 0.0002 and bed width of 10.36 m (top width). The wide bund (floor width) is 1.82 m and side slopes are 1:2, both in concrete. The concrete layer is there to reduce soil erosion thus hindering the river from meander.

1.2.3 Paddy cultivation

The culture of paddy is strong in Sri Lanka, and as for every tradition that has been taught from one generation to another through many centuries, it is hard to interfere with these traditions.

"The beginning of Paddy Cultivation in Sri Lanka, traces its roots back to the proud history between 161 B.C. and 1017 A.D. The ideal climatic conditions in the country yielded a flourishing crop, which encouraged many Sri Lankans to make Paddy Cultivation their way of life. Thus it became a focal point of Sri Lankan lives, knitting a pattern including the society, culture and religious beliefs in the country. The governing Royal minds of Sri Lanka saw the enriching importance of rice cultivation that provoked them to build tanks of extraordinary size and numbers to irrigate the mass scale rice production." (Rice 2012)

Figure 3 - Paddy cultivation in Sri Lanka. Note the flooded fields. (archives.dailynews.lk 2009)

In Sri Lanka, the paddy fields are usually flooded with water. The reason for this is to protect the crops from being eaten by vermin and weeds. Rice does not need to be planted in flooded fields but you get a better crop if it is planted in this manner. Thus, the efficiency of the water used is not very high. The water used can be much more efficient if growing other things than rice, but the traditions with rice paddy fields in Sri Lanka as mentioned earlier goes back centuries and old habits are hard to change.

In most cases the farmer’s skill with growing paddy is significant better than growing other crops and this makes the change in agriculture even more challenging and the risk of losing money the first years after the change is high. For a farmer with limited resources, this is not a risk worth taking.

Rice is an important element of the Sri Lankan diet. It accounts for 45% of their average daily calorie intake, and the Sri Lankan Department of Agriculture’s figures show that about 70% of the cultivable land on the island is used for growing rice.

Just under 900 000 families in Sri Lanka are engaged in working paddy fields. (Moore 2011)

In 'Medieval Sinhalese Art', Dr. Ananda K. Coomaraswamy refers to the Sinhalese society as a community based on rice. *"Land was not the luxury of a few, but the daily occupation and livelihood of the majority; not to own land is still felt to be scarcely respectable. Every man from the King down had an immediate interest in the cultivation of the land; almost every man cultivated the soil with his own hands."*

Explaining the involvement of the community in paddy cultivation, he continues*: "Great chiefs were not ashamed to hold the plough in their hands. The majority of village folk were brought into close touch with the soil and with each other by working together in the fields; even the craftsmen did not as a body rely upon their craft as a direct means of livelihood, and used to lay aside their tools to do a share of field work when need was, as at sowing or harvest time.”* (Coomaraswamy 1908)

“Cultivated paddy has a higher sensitivity towards water shortages. They are in need of a steady supply of water, and it tends to immediately react by developing symptoms of water stress when the supply is disturbed and drop below the required. Therefore to ensure golden crop the cultivators should always maintain a sound water management system ensuring sufficient amounts of water reaches every rice plant from its birth to the final stage of its life.” (Moore 2011)

During the 1940´s the country produced only 45 per cent of the total requirement of rice with a population of 7 million. Today the country is close to reach self-sufficiency with a population of 20 million. (S.S.B.D.G Jayawardena 2003)

1.2.4 Access to irrigation water

Most of the farmers do not possess any individual rainwater harvesting method or alternative strategies if the season one year should be unusually dry. They are completely dependent on rainwater and irrigation for their crops to survive.

The majorities of the farmers possess wells, but lack the capital to build agro-wells if the crops need an emergency measure.

Agro-wells are large wells – typically 4.5 meters in diameter and 7-8 meters deep – and carefully constructed from blocks and concrete for durability. They last for many years with minimal maintenance. This is in contrast to traditional water wells that have to be repaired each year after the heavy monsoon rains.

IFAD *(International Fund for Agriculture Department)* says that farmers have increased crop rotation and can stabilize their crops in the dry season – with the agro-well providing irrigation water for periods when there is no rain according.

Some people discourages the digging of such wells, pointing out that the groundwater table is decreasing after being extracted, and this is going to have an impact on the moisture in the soil in the future. (D.M.K. Gamage 2008)

1.2.5 Alternative crops

Sri Lanka has a historical preference for growing rice. However, now days some officers and farmers leaders encourage the higher market values and less water-intensive characteristics of the dry crops, e.g. Mustard, Chili, Sesame and Maize to mention some.

Figure 4 - A farmer showing some of her Chili harvest. Chili is a typical dry crop.(2005, Habitat 2005)

What used to be called dry crops is now referred to as Other Field Crops (OFC). These crops constitute an important component in the food crop sector in Sri Lanka.

Dry farming is the profitable production of crops without irrigation on lands that receive annually a rainfall less than 20 inches. The dry farming, therefore, has been a major focus of agricultural research because of the facts that the reclamation of these lands remains a key issue for increasing the agricultural production in the world. Chili is the most cultivated dry crop in Sri Lanka. Gherkin is a relatively new dry crop in Sri Lanka and is proven to be a high cash earning crop that more and more farmers takes an interest in.

Sri Lanka has a goal of agricultural self-sufficiency both with paddy and OFC, and presently about 119,000 hectares are cultivated annually under OFCs. Nevertheless, the annual production of these crops does not meet the domestic requirement.

Therefore, about 42 percent of the annual requirement is imported to supplement the large shortfall of domestic production. According to *Dr. P.M. Wijeratne*, vast potential exist for dry farming in the dry zone of Sri Lanka. (Dr. P. M. Wijeratne Director 2011)

Paddy and OFC cultivation in Sri Lanka is dependent on irrigation canals and water reservoirs and with the country's goal of being self-sufficient with this, the development and expansions of paddy and OFC fields goes hand in hand with the development and expansions of irrigation and reservoirs.

2 Objectives

- How informed are the population in the rural areas regarding water-related diseases?

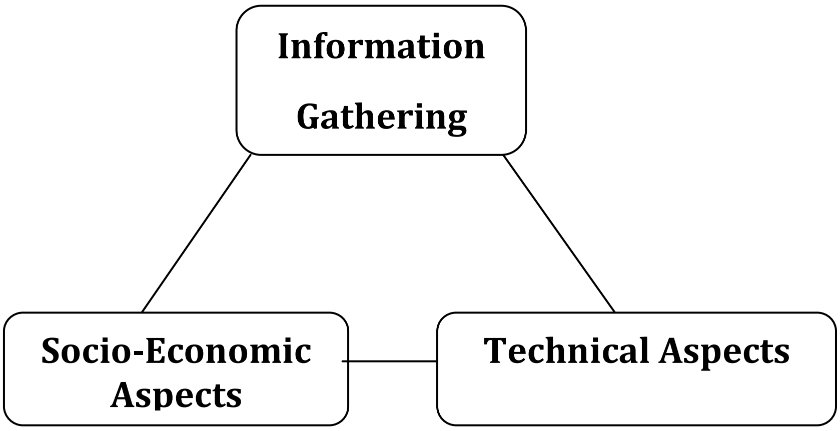
- In what grade will the expectations the population have towards this project be met?

- What are the challenges with simulating a scenario like this using WEAP?

- Is the project viable in the future, especially with regards to climate changes?

3 Methodology

Our assessment is divided into 3 parts. The sketch underneath shows the conceptual framework for our methodology.



All information gathered is used as a basis to understand the social and technical challenges. For this part we had to spend 7 weeks in Sri Lanka where we collected data from libraries, institutes, departments, professors, engineers and people living in the studied area.

To understand the socio-economic aspects of the project, we used the gathered information to prepare some questions for people in the affected area. It was carried out using structured interviews (survey), asking people living along the RB-canal. For this we had to use a translator.

For the technical part of this assessment, we made a hydrological model of the area. There are many ways of doing this, but we chose to use the simulation program called WEAP. The lack of technical data made the simulation a bit difficult, and assumptions had to be made.

In the final stage we will compare our results with the data gathered.

3.1 Survey in the fields

Because our time in Sri Lanka was limited, we chose to make a structured interview with a possibility for the interviewed objects to comment on each question if they had anything to add. We were dependent on a translator, and with a series of unstructured interviews that may had lasted for several hours each, the translation from Singhalese to English would have occupied too much of both ours and the translators time.

Definition on a structural interview: *The Structured Interview is a data-gathering methodology that involves a standard set of questions asked in the same manner and order. For example, when doing research, you may interview participants instead of asking them to fill out a questionnaire. This method usually results in a higher response rate. People are more likely to verbally answer interview questions rather than fill out a questionnaire that could be several pages long. (wikipedia 2013)*

The interviews were conducted based on the affected people's expectations to the project. A survey with 13 questions was handed out to 27 people total in the different areas.

The survey we undertook in the Kurunegala area took us three consecutive days and included a translator and a vehicle with a driver. We had the surveys printed out and went from door to door in different villages along the RB-canal within the Kurunegala district. To process this data we used Questback *(http://www.questback.com),* a fully integrated feedback solution system to make analysis of collected information. *(See the whole survey with answers, graphs and comments in the appendix)*

Even though we made the questions as little complicated as possible to save time, time passed by quickly. We had to explore the different areas to find people that were home during the daytime and we occasionally ended up knocking the doors of empty houses.

Figure 5 – Our translator Dinesh interviewing a mother and her child in the Girilla area

The questions of the survey as following:

1. Which area are you from?

2. What is your main profession?

3. All in all, are you positive or negative towards this project?

4. Have you or anyone you know got any work because of this project? For example with building the canal?

5. What kind of crops do you cultivate on your fields/land?

6. During the different seasons, do you and your family ever suffer from water scarcity?

7. Do you expect more, less or the same amount of freshwater after this project is finished?

8. If you get more fresh water as a result of this project, will you have the possibility to cultivate more on your land? Expand your fields?

9. During the last years, have you noticed any differences in the weather? Such as heavier rain, dryer seasons etc? Any form of climate changes?

10. How pleased are you with the information you have been given from the government about this project? Before and during the construction? (From a scale from 1-5, where 1 is very unhappy, and 5 is very happy)

11. If you felt very affected because of this project, do you feel that you got a reasonable compensation? For example if you had to move? (From a scale from 1-5, where 1 is very unhappy, and 5 is very happy)

12. How happy are you with the amount of freshwater on your fields/land? Is it enough? (From a scale from 1-5, where 1 is very unhappy, and 5 is very happy)

13. Do you know any water borne diseases?

14. Do you know of anyone who has gotten sick as a result of bad drinking water?

15. How high are your expectations for the future after this project is finished? Agricultural wise, economic wise, do you expect improved living conditions etc? (From a scale from 1-5, where 1 is very low, and 5 is very high)

3.1.1 Limitations

Due to limited time and resources in Sri Lanka it was only possible to spend three days in the field. The interview-survey could be handed out to more people and be a bit more in-depth, but this was not possible due to the limitations. 27 people is not a big sample, but we focused on finding the people that lived closest to the canal and tried to interview people at different locations so that the population sample would be as representative as possible along the different parts of the developed area.

It is important to understand that a comprehensive study of the power relationship and hidden inequity within the system in Sri Lanka is only achievable through in-depth anthropological study, which is neither the ambition of this study, or possible with the resources available. For example, although the system claims that women have equal rights to make important decisions in a typical Sri Lankan family, most of the women prefer to remain silent as they consider their husbands to be the head of the family and thus the ones who should make the big decisions, though they are involved equally, if not more, in daily activities such as farming.

The RB-canal is spread over a great area and it is noteworthy to point out that the sample size of 27 individuals is hardly representative of the heterogeneity in opinions of all the people along the RB-canal. The rumor mill and the “gossip-talk” amongst the people in the respective areas made the answers on the survey pretty much alike with some exceptions. All the interviewed people had a lot of opinions about the project, but it was obvious that the people in the respective areas had influenced each other.

The translation can also be seen as a limitation of the study. Not knowing the language is always a problem in a study where communication is one of the case topics. We were lucky to get a committed and reliable translator, though unprofessional. Without him we would have had big problems with going through with the interviews, but when you interview people through a survey like this, it is hard to capture the emotion of the interviewee. We opened for comments on each questions to get the interview as detailed as possible. Because the interviews were dependent of a translator, this was also a factor when we chose to make a survey in a check form.

The information can easily be “lost in translation” when an in-depth interview in Singhalese has to be translated to English without us being able to observe at all.

3.2 WEAP simulation

For the analytic part, we used WEAP - Water Evaluation and Planning, a simulation tool software developed by Stockholm Environment Institute’s U.S Center. In contrast from similar simulation program such as Mike Urban, WEAP is free of charge and used in a lot of under-developed countries. One of the reasons that Mike Urban is more frequently used in e.g. Norway is their excitable marketing in the western countries.

“WEAP is a software tool for integrated water resources planning that attempts to assist rather than substitute for the skilled planner. It provides a comprehensive, flexible and user-friendly framework for planning and policy analysis.” (WEAP 2013)

We used WEAP mainly as a hydrological tool. In order for it to run smoothly, it requires certain parameters which we have had some trouble collecting. Thus we had to make some simplifications and assumptions that are discussed later in the study.

To get the whole picture, we did multiple simulations with different scenarios, each with unique input. The main differences are the changes in water supply. We did scenario for half and full year round water supply from the RB-canal, as well as climate impact scenario with reduced rainfall.

The schematics for WEAP were made using ArcMap, a software to view, edit and analyze Geospatial data, constructing shapefiles and importing them into WEAP as vector layers.

Then we draw our model on top of those, adding catchments, rivers, water tanks, demand sites and transmission links. Thus we ended up with the model as seen in figure 6 below.

The schematics show the RB-canal with its three connected tanks Kirindigolla, Randenigama Maha and Hidogama and their connected paddy fields. The canal starts at Deduru Oya reservoir in south and ends up in Inginimitiya reservoir in the north.

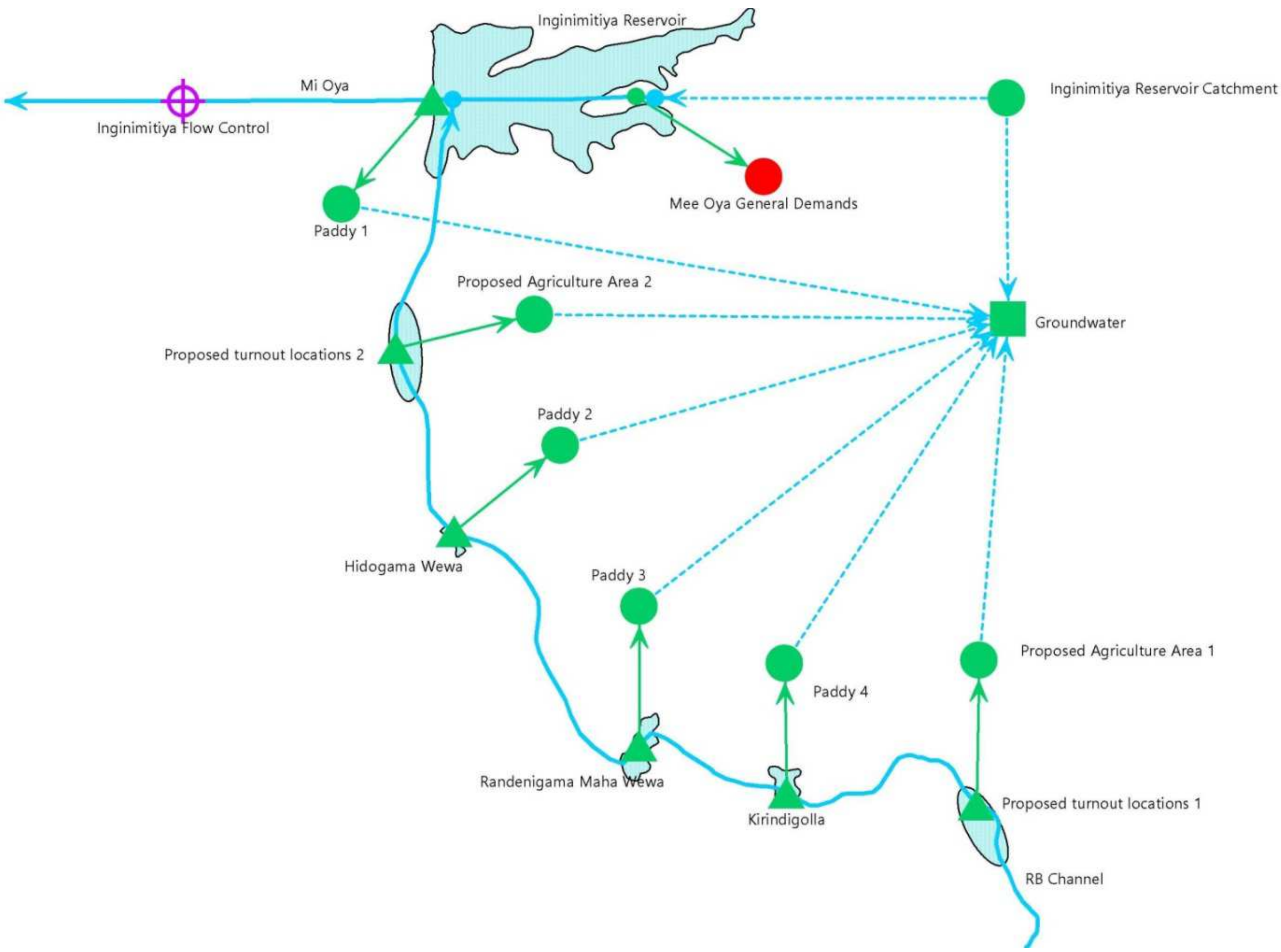


Figure 6 - Schematics of the WEAP model

The two proposed turnout locations is actually a set of many smaller tanks, located before and after these main tanks, which is not yet connected, and their proposed paddy areas *(see table 8 - Proposed turnout locations).* Paddy 1 shows the paddy areas distributed under the Inginimitiya Reservoir Scheme. A Mi Oya general demand is inserted to simulate necessary loss in order to optimize the model.

3.2.1 Limitations

WEAP made it difficult to maintain a steady yearly flow of 60 MCM through the channel, especially in the dryer years. It chose to fill up all the tanks along the RB-canal, and send whatever is left to the Inginimitiya reservoir. This is positive for the people living along the channel, as their tanks will be constantly filled up, but negative for Inginimitiya, which will suffer from bigger variations in storage volume. This will lower the water security for paddy areas under Inginimitiya reservoir scheme.

4 Results and Discussions

4.1 Research about the site conditions

The implementation process is important to emphasize in this report. One third of this study was used collecting information and through this collected information we based our surveys in the field and the WEAP simulation. One very time consuming part was to learn WEAP and build up the model without any guidance except for the WEAP Tutorial. Because of this we had to build the model up from start a couple of times before we got it right.

One source has been used frequently and is worth mentioning: the "Deduru Oya and Mi Oya Basins Development Project – Pre-feasibility report" made by the planning branch at the Irrigation Department, only found in hardcopy form. This report contains most of the necessary information regarding our project. We often refer to this report as the "pre-feasibility report".

4.2 Site of observation

The study site evolves along the RB-canal, starting at Deduru Oya reservoir and ends up at Inginimitiya reservoir (see figure 1). Along this path we chose to focus on three different areas. Two, of which had a nearby water tank and mostly grew paddy, and one area without any water tank and mostly dry crops like coconut and vegetables in their fields.

Girilla, Ballogalagama and the Siyambalewa area all lie in the Kurunegala district and are the areas we focused on collecting our samples. They are located near the tanks Hidogama Wewa, Randenigama Wewa and Kirindigolla Wewa.

The people in these areas have different experiences with access to water and different needs. Paddy fields require a lot more water than for example coconuts and the farmers in the areas may have different expectations to the project and what they hope to benefit from it.

4.2.1 Kurunegala

Kurunegala city is the capital of the North West Province (NWP) of Sri Lanka. It is situated 116 km from Colombo and 42 km from Kandy. The district covers an area of 4816 km2, consisting of 4624 km2 land area and 192 km2 water bodies. The district covers 7% of the total area of Sri Lanka. (Rashika Nishshanka 2007)

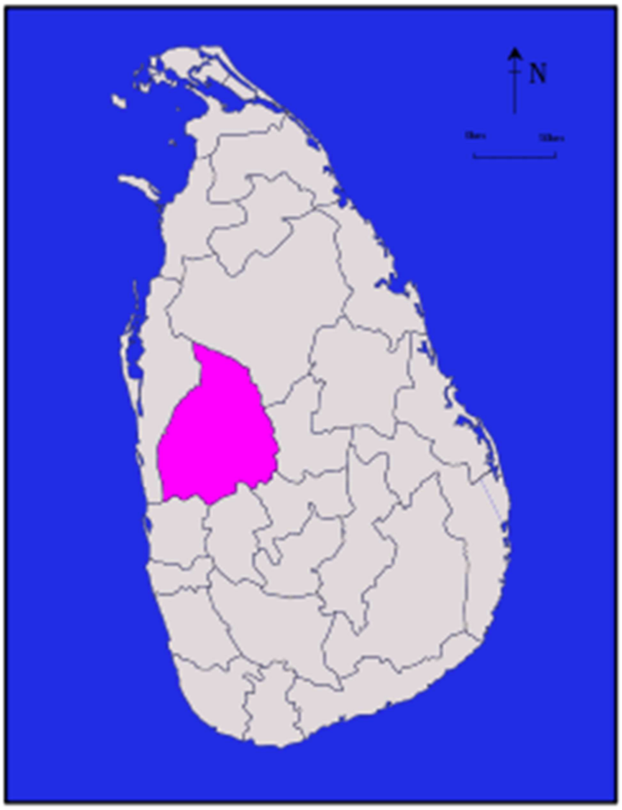


Figure 7 - Kurunegala district (Wikipedia 2012)

4.2.2 Land Utilization

According to the 2002 Agriculture Census there were about 272072 ha (2720 km2) of agriculture lands in Kurunegala District at that time. Of this the majority (1336 km2) was coconut and 625 km2 (23%) was paddy land. *(See Figure 7)* (Rashika Nishshanka 2007)

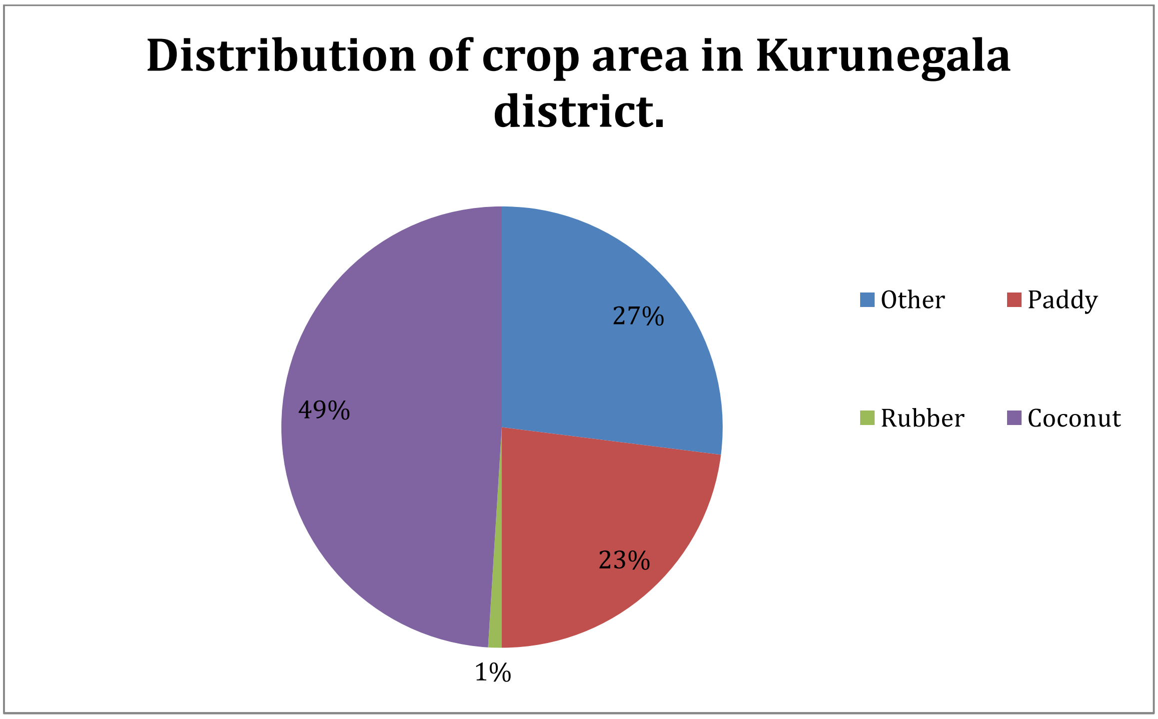


Figure 8 - Distribution of crop area in Kurunegala District (Rashika Nishshanka 2007)

Of the land area devoted to rice production in Kurunegala District, 39% was rainfed, 45% was under minor irrigation and the remainder was under major irrigation schemes in 2002/03 (FAO 2004). In Kurunegala DS Division, the proportion that is rainfed is much higher at 70% of the total paddy lands. These lands are cultivated with paddy in the *Maha* season and other field crops such as chilly, mungbeen and ginger, in the *Yala* season (Rashika Nishshanka 2007)

The total land area in Deduru Oya basin is approximately 262 000 Ha. At present lands of Deduru Oya basin are mostly fully developed and the land use pattern is well established. Therefore it is not possible to change the present land use due to new development. Under the circumstances, it is not possible to change the present land use in the Deduru Oya basin in a drastic matter, but it is possible to increase the productivity of existing agricultural lands by augmenting water into minor irrigation systems. (Planning branch 2011)

Discription	Percentage
Coconut lands	36%
Sparsely used crop lands	19%
Paddy lands	18%
Homesteads	13%
Water bodies, forest and range lands	14%

Table 1 - Land use in Deduru Oya (Hankuk Egnineering Consultants 2001)

According to the table above the major land use in the basin is coconut cultivation. The major land use for the low land soils is paddy especially during *Maha* season. Some of the paddy fields are abandoned or under upland annual crops especially during the dry *Yala* season, depending on the availability of water.

4.2.3 Demographics

The population in Kurunegala in 2009 was about 2 320 000, with a population density at 309/km^2 and a national population growth of 1.1%. This growth has been stable for the last 5 years.

In 2003/2004, almost 28.5 % of the population in the North Western province was employed in Agriculture, Forestry and Fishing sector. As water scarcity is a fact, many people in these sectors also need a secondary job when for instance when the crops fail or double cropping is impossible. The survey does not state how big this number is. But we know many farmers take up jobs as construction laborers. For the same time period, unemployment rate in North Western district was 8 %. If farmers are allowed to be full-time farmers, they can quit their secondary job, releasing jobs for the unemployed labor force.

In 2013 Sri Lanka ended up at no 60 in a total of 142 on the prosperity index. This index is based on factors like wealth, economic growth and quality of life. (index 2013) Population below the poverty line from 2000-2006 is 23 %, the same as other districts.

When it comes to education, In 2003/2004, only 6.7 % did not have any schooling, and the literacy rate is well over 90% for both females and males. (Department 2010)

4.2.3.1 Climate zones

Sri Lanka is divided in to three major climatological zones the Wet Zone, the Intermediate Zone and the Dry Zone. Kurunegala District covers part of the Dry Zone and the Intermediate Zone. The Dry Zone receives a mean annual rainfall of less than 1750mm and has a pronounced dry season. The Intermediate Zone receives a mean annual rainfall between 2500 to 1750mm. (Planning branch 2011)

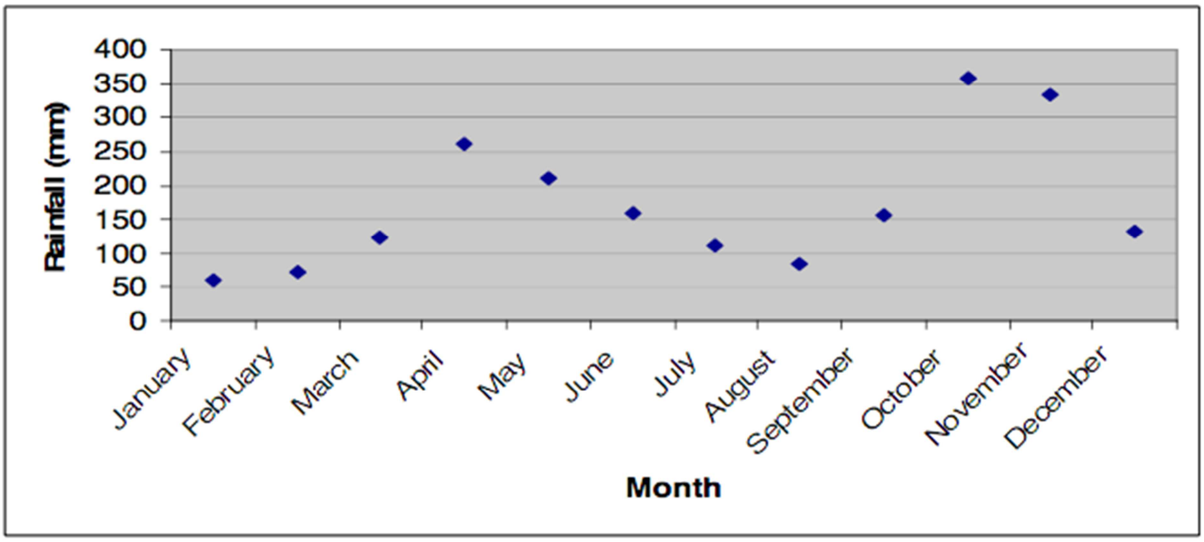


Figure 9 - Long term monthly average rainfall data for Kurunegala (1971-1998) (Department of Meteorology 2003)

4.2.3.2 Yala and Maha Season

There are 4 rainfall seasons in Sri Lanka.

March - April -- First Inter Monsoon (FIM) (*Yala*)
May - September -- South West Monsoon (SWM) (*Yala*)
October - November -- Second Inter Monsoon (SIM) (*Maha*)
November - February -- North East Monsoon (NEM) (*Maha*)

These seasons are called *Yala* and *Maha* season. They affect the country different, dividing the island into the 3 climatic zones. In the dry zone, only the South West Monsoon from May-September is effective. Because of this, it is not enough water to cultivate paddy in *Yala* season without irrigation water.

The *Maha* season, on the other hand, is a major growing season for the entire island. This usually allows for paddy cultivation in the dry zone. However, some years this season might be dryer than usual, making it impossible to cultivate all the available paddy fields in the dry zone without supplemental irrigation water. (Department 2006)

4.2.4 Rice-production in Kurunegala

Sri Lanka produces just over 4 million tons of rice each year. Rice is harvested twice a year if the amount of water allows for it. In Kurunegala, one crop is dependent on irrigation *(Yala season)* whilst the other on the monsoon rains *(Maha season).* As a result of water scarcity in the *Yala season*, farmers in Kurunegala district are often capable of producing rice only in *Maha*. (Nimal Sanderatne 2011)

Statistics available at the government states that Sri Lankas total rice production in 2012/2013 was 2,846,276 MT (metric tons) in the *Maha* season, and 1,128,984 MT in the *Yala* season of 2012.

The production of rice is constantly increasing, both due to population growth and knowledge amongst the farmers in how to get the crops as efficient as possible (Statistics-Division 2005). Out of this total production, the Kurunegala area accounted for 388 598 MT in the *Maha* season and 51 712 MT in the *Yala* season. This is about 14% and 5% of total rice production in Sri Lanka.

Cropping intensity is used as a measure of how much of total possible cropping is actually cropped. So if the cropping intensity for an area is 0.5, then it means that only 50% of the total agriculture area actually yields crop. In order to get this value to 1.0, more irrigation water will have to be supplied.

Today, Kurunegala district have a crop intensity of 0.5 in the *Maha* season and 0.3 in the *Yala* season (Hankuk Egnineering Consultants 2001). If the project is successful, the crop intensity will increases to 1.0 in both seasons.

4.3 WEAP parameters

In the next chapters we will show how we chose the parameters for our simulations in WEAP, and how we did the necessary calculations.

4.3.1 Scenarios in WEAP

One important part of WEAP is that it is possible to run a set of different scenarios where one can change input-values and compare it with other scenarios.

Thus we made a *"Reference"* scenario from 2002-2012 with a constant RB-canal flow. We also made two half year flow scenario called *"April-September flow"* and *"December-May flow"* to see what worked best with the system. A *"No RB-Flow"* scenario was also introduced to see what the effect would have been if the canal would not have been built.

Two climate change scenarios based on the *"Reference"* scenario was implemented.

For the last scenario we observed what would happen if irrigation efficiency was improved. This last scenario was based on both *"Reference"* and *"Climate changes Dry"* scenarios. The reason for this is to see if improving agricultural techniques will manage to maintain or improve paddy production in the future.

We have a total of 7 scenarios:

- April - September flow (Half-year flow)
- December - May flow (Half-year flow)
- No RB-flow
- Reference (Constant flow)

The 2 next scenarios are based on the Reference scenario:

- Climate change random
- Climate change Dry

The last scenario is based on both Reference and Climate change Dry scenario:

- With/without Improved application and conveyance efficiency

The tables under show the 3 different RB-canal flow pattern scenarios. They all share the same input data, the only difference is the flow pattern.

Reference Scenario

Headflow:		90000000	CM
Month	Percentage	CM/year	CMS
Jan	8.3	7500000	2.89
Feb	8.3	7500000	2.89
March	8.3	7500000	2.89
April	8.3	7500000	2.89
May	8.3	7500000	2.89
June	8.3	7500000	2.89
July	8.3	7500000	2.89
Aug	8.3	7500000	2.89
Sept	8.3	7500000	2.89
Oct	8.3	7500000	2.89
Nov	8.3	7500000	2.89
Dec	8.3	7500000	2.89
Sum	**100**	**90000000**	

Table 2 - Flow properties, Reference scenario

April-September flow

Headflow:		90000000	CM
Month	Percentage	CM/year	CMS
Jan	0	0	0.00
Feb	0	0	0.00
March	0	0	0.00
April	20	18000000	6.94
May	15	13500000	5.21
June	15	13500000	5.21
July	15	13500000	5.21
Aug	15	13500000	5.21
Sept	20	18000000	6.94
Oct	0	0	0.00
Nov	0	0	0.00
Dec	0	0	0.00
Sum	**100**	**90000000**	

Table 3 - Flow properties, April-September scenario

December-May flow

Headflow:		90000000	CM
Month	Percentage	CM/year	CMS
Jan	15	13500000	5.21
Feb	15	13500000	5.21
March	20	18000000	6.94
April	15	13500000	5.21
May	15	13500000	5.21
June	0	0	0.00
July	0	0	0.00
Aug	0	0	0.00
Sept	0	0	0.00
Oct	0	0	0.00
Nov	0	0	0.00
Dec	20	18000000	6.94
Sum	**100**	**90000000**	

Table 4 - Flow properties, December-May scenario

4.3.2 Hydrological data

4.3.2.1 Evaporation

Based on acquired pan evaporation data from Mahawa meteorology station (DD 7.824422, 80.277876), the correlation factor between pan evaporation data and lake evaporation is set to be 0.75. (wiki-evaporation) Tank net evaporation is calculated as the difference between precipitation and evaporation.

4.3.2.2 Evapotranspiration

We operate with two different sources of evapotranspiration, one for the paddy areas and one for the Inginimitiya catchment area.

Paddy area evapotranspiration

Penman-Monteith equations for determination of evapotranspiration were not used, as data were not available. Instead, the rainfall runoff (simplified coefficient method), which WEAP uses to calculate the crop water requirement, was used in its absence. The Reference Crop Evapotranspiration data, ET_0 and the Crop Factors, K_c, was taken from table 4.1 and table 4.2 (Planning branch 2011). The crop factors are given in table 5 underneath. Monthly Crop Factors was defined for lowland paddy 135 and 105 days in *Maha* and *Yala* respectively. K_c factors were defined for each month and weighted according to numbers of days in the month. For the other months, K_c was set to be 0.4.

Stages		Initial	Develop	Mid	Late	Total
Lowland paddy (135 days)	Days	30	40	45	20	135
	K_c	1	1.15	1.20	0.9	

Lowland paddy (135 days)	Days	20	30	30	25	105
	K_c	1.00	1.15	1.20	0.9	

Table 5 - Crop Factors, Table 4.2

Months		February	March	April	May		Total
Lowland paddy	Days	15	30	30	30		135
(135 days)	K_c	1	1.13	1.19	0.95		
Months		September	October	November	December	January	Total
Lowland paddy	Days	15	30	30	30	15	135
(105 days)	K_c	1	1.15	1.19	1.15	0.9	

Table 6 - Crop Factors for each cultivation month

Crop evapotranspiration calculations from pan evaporation data using the method described in FAO's *"Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56"* (Organization 1998) was also calculated to compare with the results above (see annex). When these calculations ended up being only half of those from the Pre-Feasibility Report, it was decided to use the latter.

Inginimitiya catchment area evapotranspiration

The Pre-Feasibility Report states that there are *"no sufficient data available in respect to the land use in Mi Oya basin and Inginimitiya command area" (Planning branch 2011)*

Kc factor for Inginimitiya reservoir catchment was calculated by looking at a map and dividing the catchment up in different vegetation areas. Gardens/short vegetation accounted for 50% of total area, 30 % was trees/palm and 20% is paddy and pasture.

In FAO's "Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56" (Organization 1998), kc values for different vegetation is given. We ended up with a kc around 1.

4.3.2.3 *Precipitation*

Daily precipitation data for 10 years was gathered from The Department of Hydrology in Colombo. The two stations used were Mahagalkadawal Galgamuwa (DD 7.992478, 80.295093) and Mediyawa Wewa (DD 7.878312, 80.289226). Average monthly and yearly data was calculated using Theisson weights 0.5 for both stations. In the calculations we called the stations North and South, respectively.

We noted big variations in precipitation from each year. Therefore we divided years into very dry, dry, normal, wet or very wet, with multipliers ranging from 0.6 to 1.4, although very wet never occurred. These multipliers were then used for the first 10 years of the *"Reference"* scenario, to see what impact dryer and wetter year would have on the system. We used both the *"WEAP Tutorial"* and personal experience as our reference for this weighting. It is worth noticing that these precipitation values may be too high, as they also conclude within the Pre-feasibility Report, 2.1.5.

4.3.2.4 Effective precipitation

Of total rainfall, only a certain percent can be used to cover the crop water needs. Some of it will cause runoff from the ground while some will percolate deep below the root zone. The Effective precipitation is what is stored in the root zone and readily available for the plant to use. We estimated our effective precipitation from the FAO's *report "Irrigation Water Management Irrigation Water Needs, Training Manual 3"* (FAO 1993)

4.3.2.5 Infiltration and loss

As groundwater data is non-existing for this area, we assume all infiltration lost to groundwater is lost from the system. This is not quite correct as we did witness some ground water feeding of the RB-canal.

Runoff from Inginimitiya Reservoir Catchment is calculated so that 70% of the runoff ends up as infiltration to the ground. This runoff factor was decided from “Natural Resource of Sri Lanka – Conditions and trends, 1991. page 141” (Department 1997) which states that only 31% of the precipitation ends up as runoff, while the Pre-feasibility Report, 2.1.5 states that the runoff factor is 30%. Runoff is understood as both infiltration to groundwater and runoff to rivers.

This means 70% is evapotranspiration and other use. There is to our knowledge no information regarding how much percent of runoff that is river runoff. All runoff from paddy fields were set to be lost to the groundwater.

4.3.2.6 Climate changes

Department of Meteorology together with IPCC states that dry areas will get drier with climate change, and that we can expect a 7% decrease in precipitation in the next 30 years. In addition, Kurunegala will have a high variability in annual rainfall. (Meteorology 2011)

For our climate changes scenario we mainly focused on changing precipitation. We introduced a function that returned random numbers ranging from 0.6 to 1.2, which simulates very dry to wet, and called this scenario *“Climate Change random”*. The problem is that these are numbers are uniformly distributed each month, which will not yield an entirely correct picture. We therefore made another climate change scenario where we manually put in the multipliers. This scenario called *“Climate Changes Dry”* will simulate several dry years, with some few, very wet years.

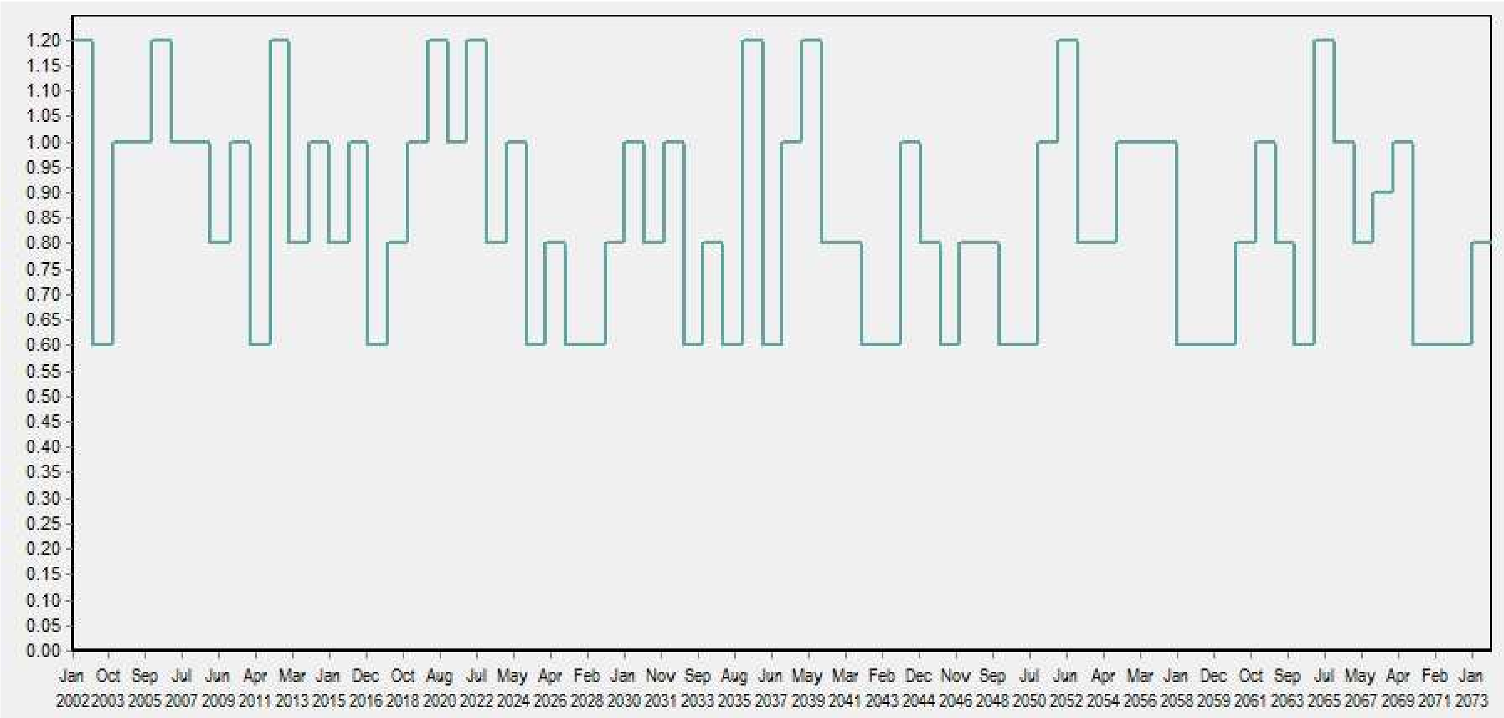


Figure 10 - Precipitation multipliers, Climate Changes Dry scenario

The figure above shows the multipliers we used. The average precipitation multiplier is 0.85 of normal. The 7% decrease in total rainfall over 30 years is not shown in the figure, but instead multiplied directly to the precipitation data.

The Department of Meteorology expects an increase in temperature between 2.5 and 2.9 degrees during the monsoon seasons by 2100, while the IPCC report (Cruz 2007) states an increase in temperature by 0.016 degrees per year. Increased temperature means higher evaporation. This might increase relative humidity, which again will lower evapotranspiration. In order to simplify the model, this has not been simulated for.

4.3.3 Right-bank canal

4.3.3.1 Canal flow

We never got the data for proposed canal flow. We therefore decided to run different scenarios which had their own flow pattern. Our *"Reference"* scenario was based on a full year operation, where 90 MCM is diverted along the RB-canal with a constant flow of 2.9 CMS throughout the year. Two other scenarios, both with 6 months operation, were also tried out to check the flexibility of the system, as well as a no-flow scenario.

4.3.3.2 Tanks

As seen below in table 7 (Planning branch 2011), a combined tank capacity of 6.5 MCM is required to cultivate 1000 ha under minor tank systems along the RB-canal. The total water spread area is 400 ha.

CAPACITY AT F.S.L	**MCM**	6.5	6.5	6.5	6.5	6.5	**6.5**
ELEVATION - (m) ABOVE	**MSL**	55.64	55.62	55.64	55.64	53.64	**55.64**
WATER SPREAD AREA	**Ha.**	400	396	400	400	400	**400**
PROPOSED EXTENT OF MAHA (PADDY)	**Ha.**	171	375	576	770	915	**1020**
PROPOSED EXTENT OF MAHA (O.F.C)	**Ha.**	0	0	0	0	0	**0**
PROPOSED EXTENT OF TALA (PADDY)	**Ha.**	171	375	576	770	915	**1020**
PROPOSED EXTENT OF YALA (O.F.C)	**Ha.**	0	0	0	0	0	**0**
PERCENTAGE OF SUCESS - MAHA		100%	100%	100%	100%	100%	**80%**
PERCENTAGE OF SUCESS - YALA		60%	60%	60%	60%	60%	**80%**
PERCENTAGE OF SUCESS - TOTAL		80%	80%	80%	80%	80%	**80%**
AV. ANNUAL INFLOW	**MCM**	0	0	0	0	0	**0**
AV. ANNUAL DIVERTED VOLUME	**MCM**	5	10	15	20	25	**30**
AV. ANNUAL DEMAND	**MCM**	8.3	8.3	12.7	17	20.2	**22.5**
AV. ANNUAL SPILLAGE	**MCM**	0	0	0	0.8	2.6	**4.9**
A. A SPILLAGE AS A % OF A.A RUNIFF		0%	0%	0%	4%	10%	**16%**

Table 7 - Proposed augmentation of minor tanks in RB-canal. "Result of the operation study for the proposed augmentation of minor tanks in trans-basin canal (option - 1)."

Our 3 main tanks were drawn from hard-copy map into ArcMap and ended up with a combined area of 200 Ha. Assuming a basic tank depth of 2 m, as given for medium tanks in IWMI's report no.13 (R.Sakthivadivel 1997), we ended up with a combined tank capacity of 4 MCM for the 3 main tanks. Looking at a topography map, we managed to decide the volume-elevation curve. The two proposed turnout locations then needed a combined tank capacity of 2.5 MCM, covering 100 ha each.

4.3.3.3 Paddy areas along the canal

When looking at a map for possible paddy cultivation sites along these 3 main tanks, it was found that 615 ha of land could be cultivated. This was done by comparing unoccupied land areas around the tanks, by using Google maps shown in figure 11, and drawing them into ArcMap, which calculating the total agriculture area. The turnout locations then need to be assigned to the 385 ha of paddy that is not accounted for.

Figure 11 - Kirindigalle Wewa and its surroundings, from Google maps

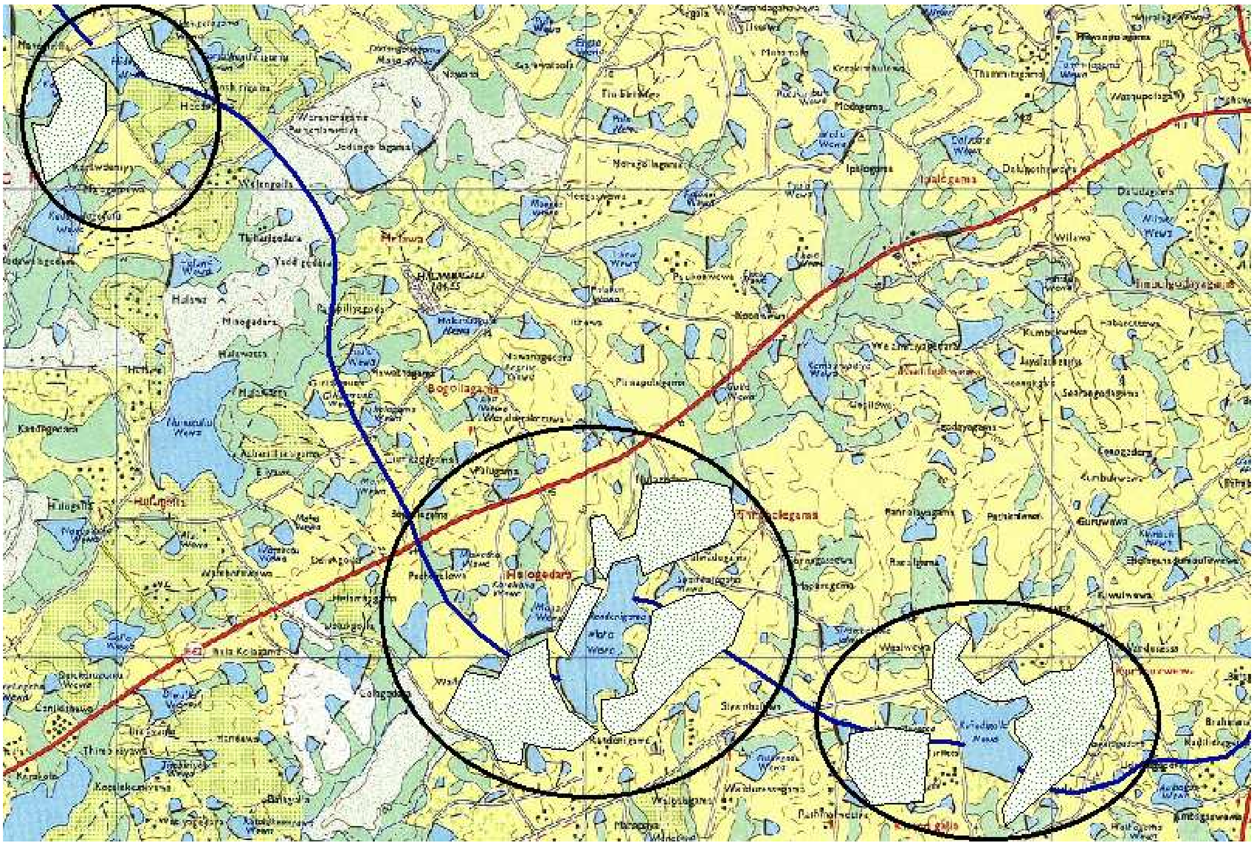


Figure 12 – Main tanks with possible paddy land and the areas were we focused on collecting our survey-sample. Respective Girilla, Ballogalagama and the Siyambalewa area

In the simulation program we have called these paddy areas for paddy 2, 3, 4. The proposed agriculture area 1 and 2 is not seen in figure 12 but lies before and after these three areas.

4.3.3.4 Proposed turnout locations

The engineers plan to develop additional paddy areas along the canal. However, the locations have yet not been decided. The proposed turnout locations are shown in the table below.

“Location” describes where along the canal the proposed turnout location is situated. This is given in kilometers away from start, which is the Deduru Oya reservoir. The “Direction” shows which side of the canal we can find it.

Location	Direction	Expected Acre of paddy field	Proposed area to supply water
0 + 450	Left	150	Katuwannawa, Existing Katuwannawa Tank & D/S of main bund
1 + 20	Right	20	Adjacent paddy field
	Left	40	
1 + 434	Right	10	Adjacent paddy field
	Left	80	
2 + 500	Left	70	Pothuwewa/Dikwewa
3 + 575	Left	100	Walpuluwa Tank
4 + 495	Left	60	Babi Estate
4 + 915	Right	70	To Panwewa Tank paddy field
5 + 828	Right	30	Benmullegama Tank
	Left	50	
6 + 140	Right	60	Amunukole Tank
6 + 160	Left	40	Brahmanayagama & Balagollagama Tank
7 + 400	Left	15	
8 + 175	Left	40	
8 + 610	Left	60	Ambagas Tank
9 + 225	Left	20	Ambagas Tank
Kirindigolla Tank	Left	70	Ranbanda Tank, Muthubanda Tank, Rabewa Tank, Kubukgaha Tank, Malhami Tank
13 + 200	Left	70	Wasi Tank, Siyabalagaha Tank, Gonamanthiniya Tank, Konoththe Tank, Manapana Tank
Randenigama Tank (RB sluice)	Left	50	Lakahettiya Tank, Karunagaga Tank, Meekandewa Tank
18 + 100	Left	70	Ihalakolagama Tank, Kankani Tank, Mallapana Tank, Galagedara Tank, Maiyagama Tank
20 + 850	Left	60	Giridamuna Tank, Ihalagama Tank, Pahala Tank
22 + 90	Left	200	Hulugalla Tank, Nugampola Tank
22 + 100	Left	80	Kadurukola Tank
23 + 50	Left	50	Hulawa Tank, Palugaswewa Tank, Bogahayaya Tank
24 + 25	Left	40	Nalagamuwa Tank, Kappati Pokuna Tank

Table 8 - Proposed turnout locations

4.3.4 Inginimitiya reservoir catchment area

4.3.4.1 Mi Oya inflow

There are no inflow data from Mi Oya into the Inginimitiya reservoir. A monthly water balance for Inginimitiya reservoir catchment has been performed in the period 1985-2000 to decide average inflow. The results are shown in the Pre-feasibility Report, Table 4.4. However, we lack the necessary precipitation data for that period to decide the percentage of rainfall that ends up in Mi Oya. Average yearly inflow is calculated to be 61 MCM, with variations from 19-109 MCM.

When our calculated inflow data ended up being over twice this amount, it was necessary to make some corrections. We solved this by constructing “Mi Oya General Demands”, which calculates annual water use rate depending on precipitation times a multiplication factor we chose as 0.7. This number was derived after several trials where we compared the Pre-feasibility reports calculated inflow with our inflow results. A demand area like this is plausible as there are several rain fed paddy lands within Inginimitiya reservoir catchment area which might divert some of the water to local tanks and paddy fields.

4.3.4.2 Reservoir

Data from the irrigation department (Irrigation Department 2013) states that Inginimitiya Reservoir has a catchment area of 55 642 ha and a capacity of 72.36 MCM.

4.3.4.3 Paddy areas under Inginimitiya reservoir scheme

Pre-feasibility Report, table 7.8 shows that 2640 Ha agriculture lands are available under Inginimitiya Reservoir Scheme. Only half of this is available for paddy under *Yala* season, but in order to simplify the model, we assume double cropping of 2640 Ha paddy, as OFC needs less water. Figure 2 shows the layout of what we have called “Paddy 1” in the program.

4.3.4.4 Inginimitiya discharge

Inginimitiya operation design discharge is set to be 1 cusec for all field canals (HR Wallingford 1992), but it does not state how many canals there are under the Inginimitiya reservoir scheme, nor the flow downstream of the paddy areas. However, it does state that this operational design discharge has not been followed. Since our information was limited, we chose a discharge of 40 MCM per annum, which is almost 1.3 CMS. There is no specific reason why we chose 40 MCM except that we wanted to add a flow for environmental purposes and further possible irrigation downstream.

4.3.5 Other data

4.3.5.1 Land preparation

Pre-feasibility Report, 4.9 states that paddy in clayey soils need 15 days of land soaking and land tilling prior to sowing, with a total of 178 mm water (7 inches) to be applied. In the dry season, this has to be irrigated. In our model, this has not been accounted for. With a total agriculture area of almost 3600 Ha, additional irrigation water of 1.8 MCM in the RB-canal and 4.6 MCM under Inginimitiya reservoir scheme has to be applied.

4.3.5.2 Irrigation efficiency

FAO's *"Irrigation Water Management: Irrigation Scheduling - Training manual no. 4"* (FAO 1993) calculates the scheme irrigation efficiency by multiplying the Field application efficiency with Conveyance efficiency. These are in the Pre-feasibility Report, 4.10 and 4.11 given as 60% and 70%, which yields 0.6*0.7 = 0.42.

FAO's *"Small scale Irrigation for Arid Zones, Principles and options, Chapter 3, Improving Water-Use efficiency"* (Department 1997) states that the loss is close to 50 %, which, when we look at our land class inflows and outflows for paddy fields, is close to our calculations.

In one of the scenarios we wanted to see what happened if we improved the irrigation efficiency so that less water is lost. We changed the application efficiency from 60 % to 75 % with sprinkler irrigation, and the conveyance efficiency from 70 % to 95 % with lined canal, and ended up with an irrigation efficiency of 71.25 %. (FAO 1989)

4.4 Socio-economic analysis

People in these interviewed areas have lived in uncertainty since the 1960s when the idea of this project was first submitted. As a result, some of the people have deliberately postponed the construction and development of their houses in fear of eventually end up losing it.

Now, at the end of the project development in 2013 the people knew a lot more compared to the 1960s, but the majority of the interviewed people were still not happy with the information the government had provided them during the development.

Listed is an excerpt from the survey with the most relevant questions.

14. Do you know of anyone who has gotten sick as a result of bad drinking water?

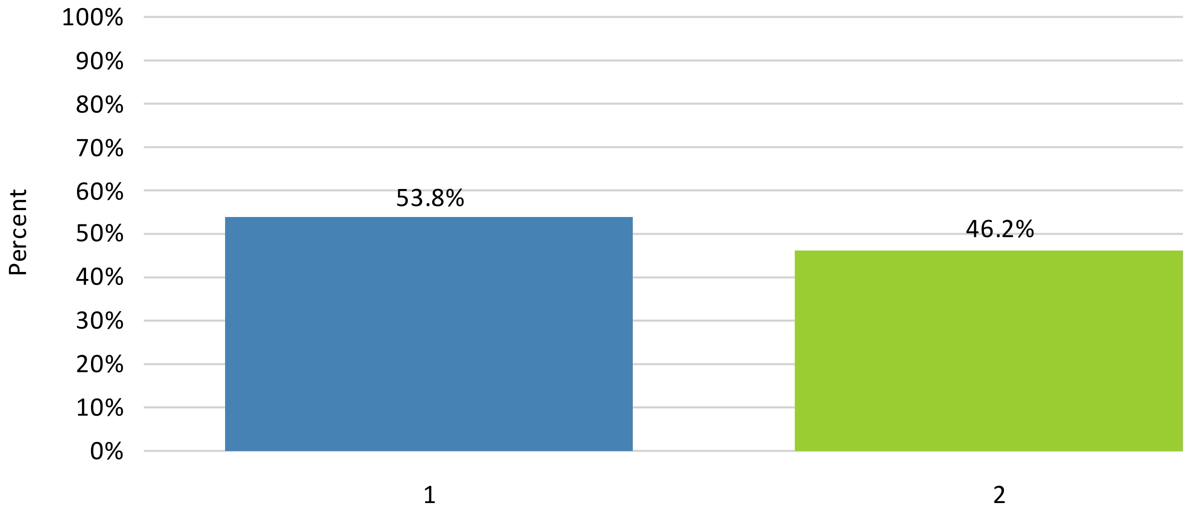


Figure 13 - Question 14 from the survey

	Name
1	Yes
2	No

A bit over 50 % know anyone affected of water borne diseases. This was a following up question after we asked if they knew of any water borne diseases.

Most of the people knew about diarrhea, kidney cancer, cholera, kidney stone and teeth problems (tooth decay, fluorosis). Especially kidney cancer was common knowledge. In these areas kidney cancer can almost be seen as a national disease. Especially in Girilla, an area in the Kurunegala district, kidney cancer or renal failure is a big problem.

As the results from the survey also states, the "Feasibility Study for Deduru Oya"-report (Hankuk Egnineering Consultants 2001) mentions Kidney stone and Fluorosis as regularly reported diseases in the Kurunegala district.

4.4.1 Water Supply Facilities

In Kurunegala District 43% of households have protected wells within their premises, 35% have protected wells outside their premises and 13% have unprotected wells: only 4% have mainline water supplies (Rashika Nishshanka 2007). Some of these wells are constructed close to paddy fields, and most of the groundwater quality is not acceptable due to high content of Fluoride, Manganese, Iron, conductivity and hardness. The surface water in local water tanks and streams that consist with drainage water running off through the paddy fields could be contaminated with pesticides and heavy metals (e.g. Cadmium). *(Hankuk Egnineering Consultants 2001)*

Hundreds of patients are reported with serious, fatal illnesses in this area. Chronic Kidney Diseases is a big problem, and numbers of deaths have been reported as a result.

The World Health Organisation (WHO) launched a research project several years ago but has been unable to definitely identify the disease's causes. Last year, the WHO stated that multiple causes, including exposure to arsenic and cadmium, might be responsible. Approximately 88 percent of CKD patients had arsenic and/or cadmium in their urine. The water sources used by the patients were 99 percent hard. Hardness of water is known to reflect heavy metal toxicity. (Medis 2013)

The District Medical Officer of Polpithigama DS division, (Polpithigama is an area near the studied RB-canal) indicates that most of the small irrigation tanks available in the vicinity of his administrative area are contaminated with agro-chemicals used by farmers living in the catchments of those tanks.

The fact that Chronic Kidney Diseases almost can be seen as a national disease in this area is a critical situation and the need for safe, fresh drinking water is the basic and the most prominent need of the people in this part of Sri Lanka. Not for the luxury of their lives, but for saving of their lives. (Hankuk Egnineering Consultants 2001)

6. During the different seasons, do you and your family ever suffer from water scarcity?

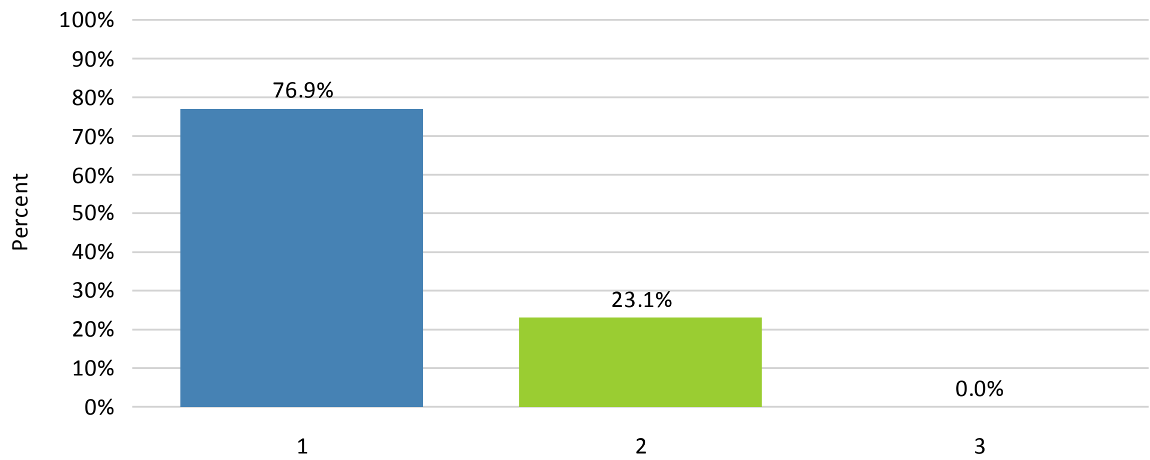


Figure 14 - Question 6 from the survey

	Name
1	Yes
2	No
3	Sometimes

As expected, if the people ever suffered from water scarcity there would be in the dry seasons. People mentioned January- March and July- September as the worst months. During our stay in the field, the area had not seen rain for two straight months.

Most people had enough drinking water all year around, but not enough water for the crops. This made it in most cases impossible to cultivate two times a year. The 23.1 % that didn't suffer from water scarcity at all were workers that did not have any land to cultivate. These people were mostly living in "urban" areas with pipe water and were pleased with their amount of drinking water.

2. What is your main profession?

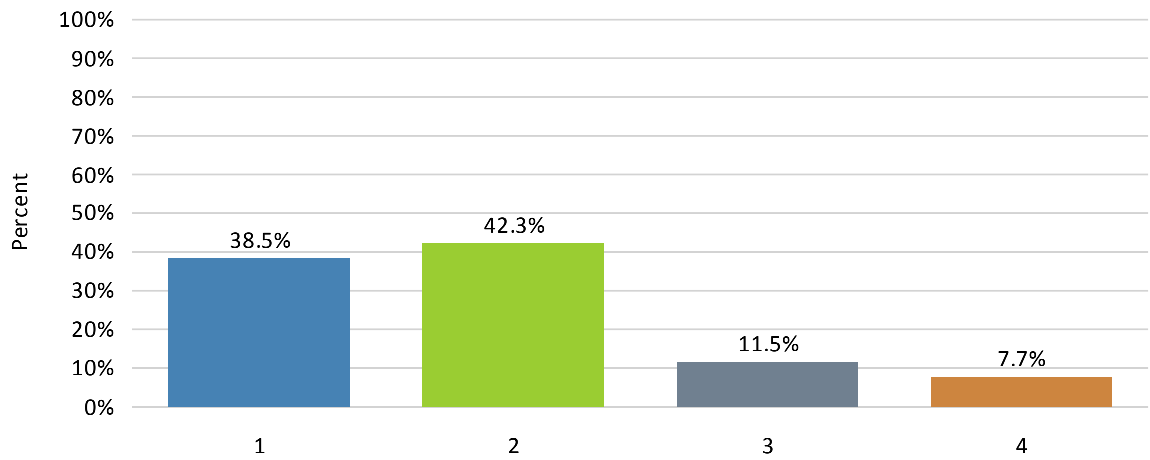


Figure 15 - Question 2 from the survey

	Name
1	Worker
2	Farmer
3	Higher educated
4	Without work

Most of the people were both workers and farmers. Police officers, three wheel drivers, teachers, military officers, laborers etc. Almost everyone had a spot where they grew things, but only the minority worked as full time farmers. The reason for this is because the water scarcity is too big of a problem and the profitability with farming was not sufficient enough.

Figure 16 - A small-scale farmer who also worked as a three wheel driver and a musician

15. How high are your expectations for the future after this project is finished? Agricultural wise, economic wise, do you expect improved living conditions etc? (From a scale from 1-5, where 1 is very low, and 5 is very high)

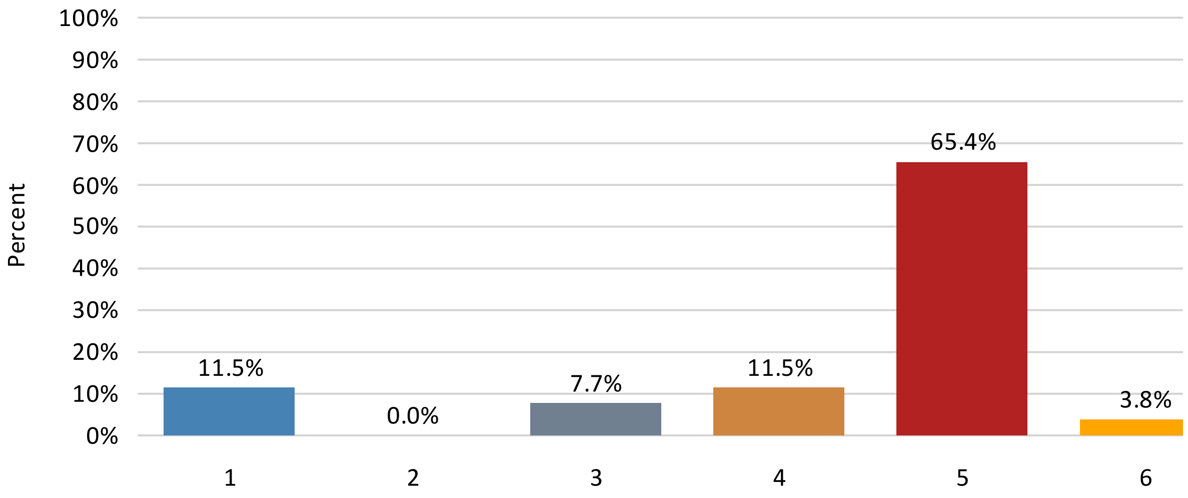


Figure 17 - Question 15 from the survey

	Name
1	1
2	2
3	3
4	4
5	5
6	I don't know

Generally, people have high expectations towards this project. Even though they have been affected in a bad way, they were still positive to the project and the effect it can have on future generations and other people. It seemed like the majority of the people asked focused on the big picture and not necessarily on themselves when asked this question, but many also answered that they expect more water, more blooming crops and more money which in the end would result in improved living conditions. People mentioned new cars, bigger house, and water on tap etc.

How their economy would increase in line with their expectations was not very clear amongst the interviewed, but the expectations were definitely there.

After studying the irrigation canal and the government's plan, the RB-canal is basically designed to bring water from the Deduru Oya reservoir to the Inginimitiya reservoir. It will affect the people in the rural areas around the Inginimitiya reservoir with more irrigated water throughout the year, but in what grade the RB-canal will affect the people along the canal is more uncertain.

Mr. Deepthi Sumanasekara, Deputy General Manager at the NWS&DB told that the government did not yet have any plan for the branch lines along the canal or where these would be located.

During the interviews we were informed that there's been some episodes were the relationship between farmers and officials has resulted in impaired trust between the two parts. One *Yala* season, the officials instructed the farmers in an area near the Mahaweli-river to cultivate more based on a rainfall project were more water would be available. The season unexpectedly became the driest season in a long time, resulting in severe water scarcity and crop failure in the area.

4.4.1 The Deduru Oya project effects on the population

According to the “Environmental impact assessment report” from 1999 the biggest problem affecting the people in the area appeared to be misinformation about the project. They lacked a spokesperson they could get correct information from and in several cases the people have obtained wrong opinions about the project. The media has also contributed with a lot of misinformation about the project.

The people who will be affected by the reservoir and the irrigation canal are mostly Sinhalese Buddhists. Economically, the majority of villagers fall into the poor category. The amount of people who have permanent employment in the state or private sector is very small and almost everyone is directly or indirectly dependent on the land and water resources by engaging in agriculture or providing labor to agriculture.

The compensation from the government is difficult to calculate, considering all the energy and the hour’s people have spent in building the different houses. A survey carried out in 1998, interviewing the people about the compensation and the possibility of losing their homes, the overwhelming response was that they should be paid adequate compensation to rebuild a similar house. A detailed socioeconomic survey carried out by the EIA team has received some information on the value of the houses but it was felt unreliable. For example, for houses identical in structure and size, the compensation ranging from Rs. 200.000.00 to Rs. 1.200.000.00.

Along the constructed RB-canal, some houses will have to be sacrificed due to the construction, but it is the inundation area from the reservoir where this will affect most people. The numbers of lost houses due to the RB-canal is not yet known because they still haven’t finished the canal. About 1150 acres of paddy will also be lost, which again will lead to full or partial unemployment to over 300 people in the paddy sector. For this sector alone, the loss of income is estimated to be about Rs. 54 300 000.
(Centre of environmental studies 2003)

A negative effect of the relocation is the inevitable break-up of the long established communities who have evolved complex and intricate social, economic and kinship relations. The affected villages are traditional communities, which provided the people with social and economic insurance and safety nets. A person removed from the community would thus become vulnerable at least until the person develops similar relations at the new location. A calculated compensation for this scenario does not exist and is often not taken into account at all. (Centre of environmental studies 2003)

Figure 18 - A family uncertain about the future of their house

A total amount of 335 people will be unemployed as a result of this inundation. This number strains from an environmental report from 2003, and the amount of people are most probably higher in 2013, when the reservoir and the RB-canal is near completion. (Centre of environmental studies 2003)

"Almost all the construction work has been done on private lands. Hence the resistance of the landowners, and the land acquisition process resulted delay in payment of compensation to the affected people." (Irrigation Solution 2013)

This interview of an angry citizen was printed in the Sri Lankan version of the Sunday Times in 2007:

"Secretary, Organisation of the Displaced People of the Deduru Oya project, H.M. Senerviratne said that officials and politicians promised compensation and land before laying the foundation stone. We were fools to believe them, and now we are beginning to doubt their words. Hence, it is natural for people to be angry. Their anger is justified. Today, we live in fear. That is the truth. Speculation is rife that the villagers are to be arrested. We dont know what is happening. We are not criminals, just innocent villagers, with no intention of assaulting or hurting anyone, Seneviratne said." (Diversion to disaster 2007).

"In these areas, the government has no plans for installing pipe water, because the population density is so low" - Mr. Deepthi Sumanasekara, Deputy General Manager at the NWS&DB.

4.4.2 Stealing water

Politicians in control of the Deduru Oya project are several times accused of committing favoritism towards some farmers in the area. Some of the downstream farmers feel unfairly treated and claims that upstream farmers are going to be able to allocate more water than them self. This result in different timing of water received to the crops, and the opinions for a lot of the farmers, this timing of water received is crucial for the quality of the crops. There is an assumption that the condition of the crops might be better if they are able to access water with the right timing.

Although farmers are allowed to discuss and decide their own cultivation plan, the officials often alter the cultivation plan to what they think is the most "reasonable". This is especially if it revolves around a dry season like *Yala*.

According to a research published in the report (The International Irrigation Management Institute 1992), they analyzed the amount of dissatisfied farmers and their actions towards what they felt as unfairness. The study was based on sample surveys and participant observations of 60 farmers. This example strains from a canal downstream from the Inginimitiya reservoir and one can imagine what will happen along the RB-canal when this becomes operational. It is impossible to make everybody along the canal happy, and some of the people will experience unfairness.

The only data we found on this particularly topic was a survey from 1992. At that time, opening of the gates was the most frequently used method to achieve water. As seen in table 5, almost 18 % answered that this was frequently done.

Frequency of occurrence of illicit activities

Activity	**% Farmers Reporting**		
	Often	**Sometimes**	**Never**
Unauthorized opening of gates	18	33	49
Making illegal inlets to field	12	33	56
Obstruction channels	20	22	46
Threatening other farmers to get extra water	11	28	61
Threatening officials go get extra water	2	13	86
Interference through politicians to get extra water	2	17	82

Table 9 - Actions done by the farmers to achieve more water to their fields and lands. (The International Irrigation Management Institute 1992)

During our time in the field we witnessed a few homemade pipes that went from the main canal and out to the cultivated fields. This was a primitive pump stationed near the main canal which pumped water from the canal and out to the fields.

Figure 19 - Sluices that easily can be opened with a simple tool

Figure 20 – On the right side, one can see a pipe leading from a private farmer to the main canal "stealing" water for use on the crops

4.5 WEAP analysis

We try to divide the simulation up in parts to get a better picture. We are looking at the RB-canal and the Inginimitiya reservoir separately. Only then can we know where things are being affected the most. The areas of interest are paddy field hydrology, the Inginimitiya reservoir catchment hydrology, stream flow, storage volume and coverage.

4.5.1 Right-bank canal

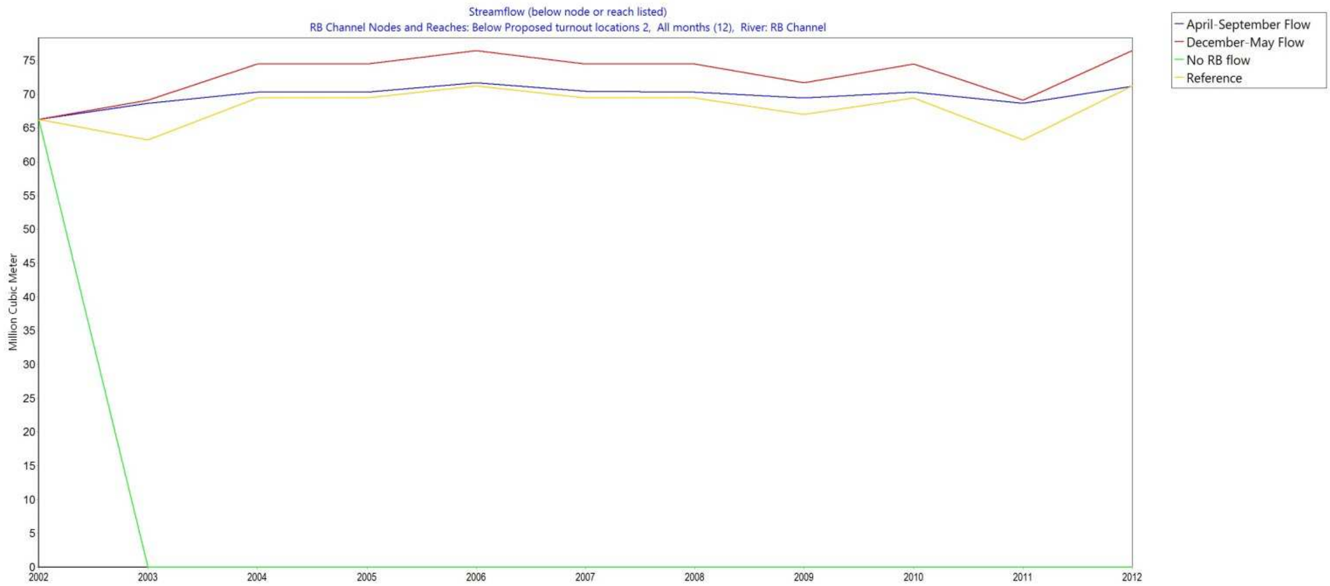


Figure 21 – Yearly streamflow into Inginimitiya Reservoir from the RB-canal, Different scenarios

The graph above shows the yearly discharge into Inginimitiya by 4 different stream flows through the RB-canal. Two of them, the *"April-September"* and the *"December-May"* scenarios, discharge all 90 MCM during 6 months. The *"Reference"* scenario keeps a steady flow throughout the year, and is the option closest to our goal, which is a discharge of 60 MCM.

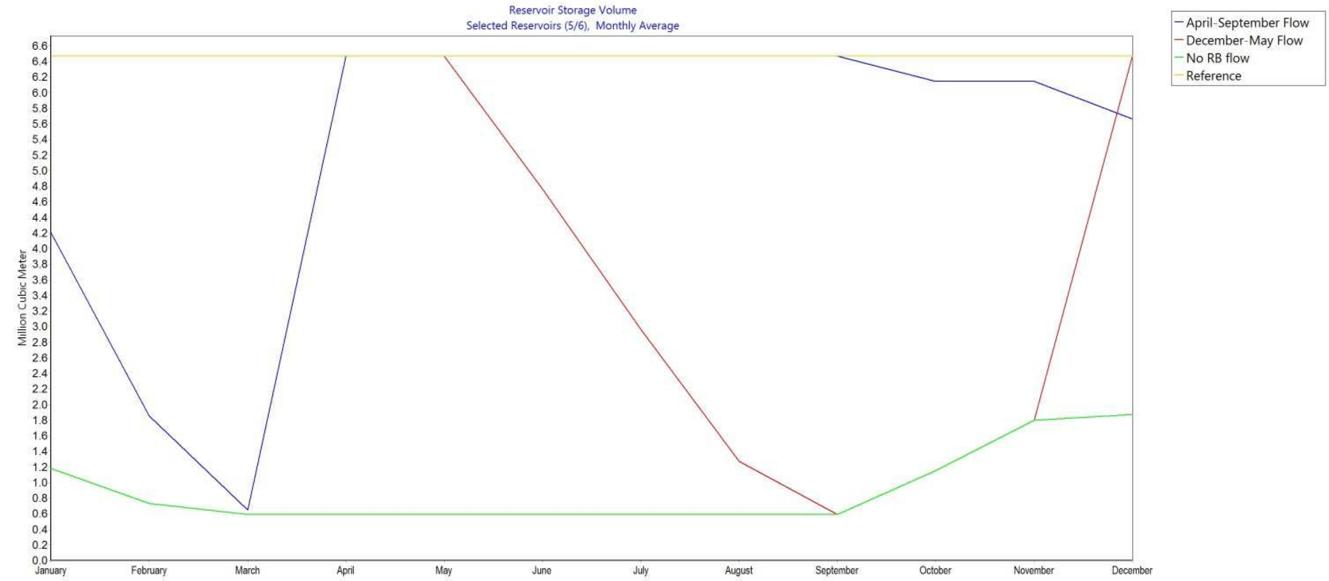


Figure 22 – Monthly total tank storage along the RB-canal, Different scenarios

The importance of choosing the right flow pattern is clearly shown in this graph above, where tank storage volume changes dramatically depending on scenario. When storages are full, one is less exposed to droughts. In addition, inland fishing from tank can be maintained throughout the year. Remember, that this graph shows the total storage capacity for all the tanks along the RB-canal. So a total storage of 1 MCM for all the tanks, which is the case for the *"No RB-flow"* scenario, might make for an unlivable habitat for fish.

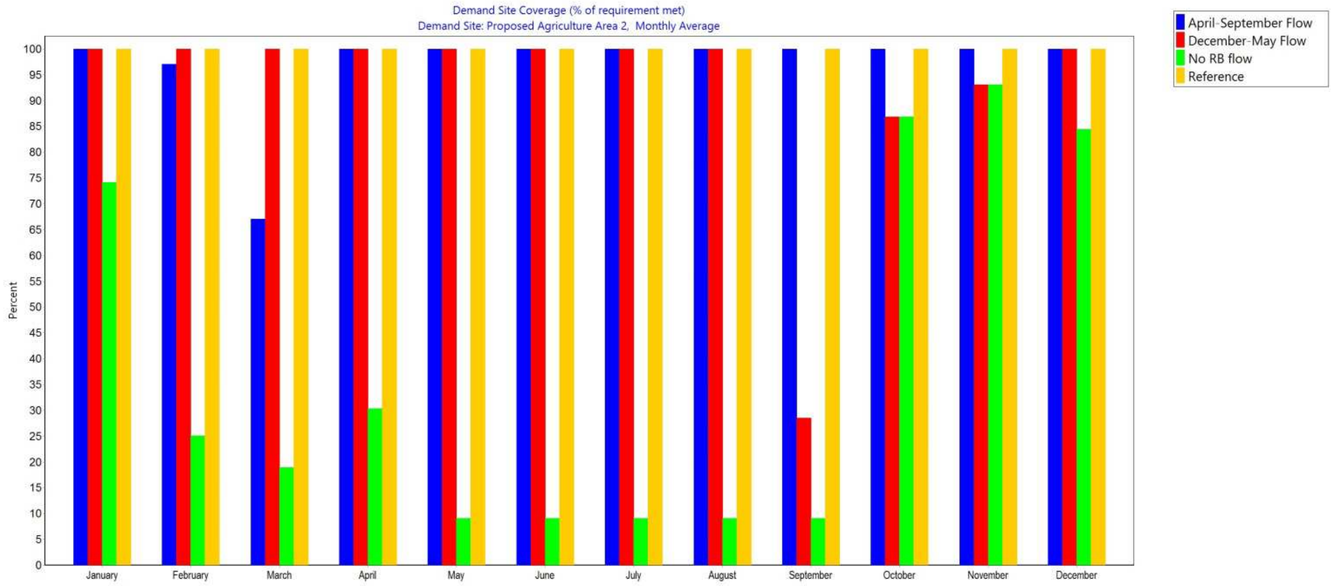


Figure 23 - Monthly demand site coverage for paddy fields along the RB-canal, Different scenarios

This graph shown water coverage for one of the paddy sites along the canal, but the trend is the same for all of them. Even though the same amount of water is transferred along the canal, only the flow in the *"Reference"* scenario can maintain full demand site coverage. The flow pattern in the *"April-September"* scenario is the second best scenario with almost 100% coverage, except in March where it drops to 65%.

Rice is very dependent of water. If the coverage drops to 65% in March, then the cropping intensity for that season will be 0.65. For double cropping of 1000 ha with cropping intensity of 1, constant flow is therefore advised.

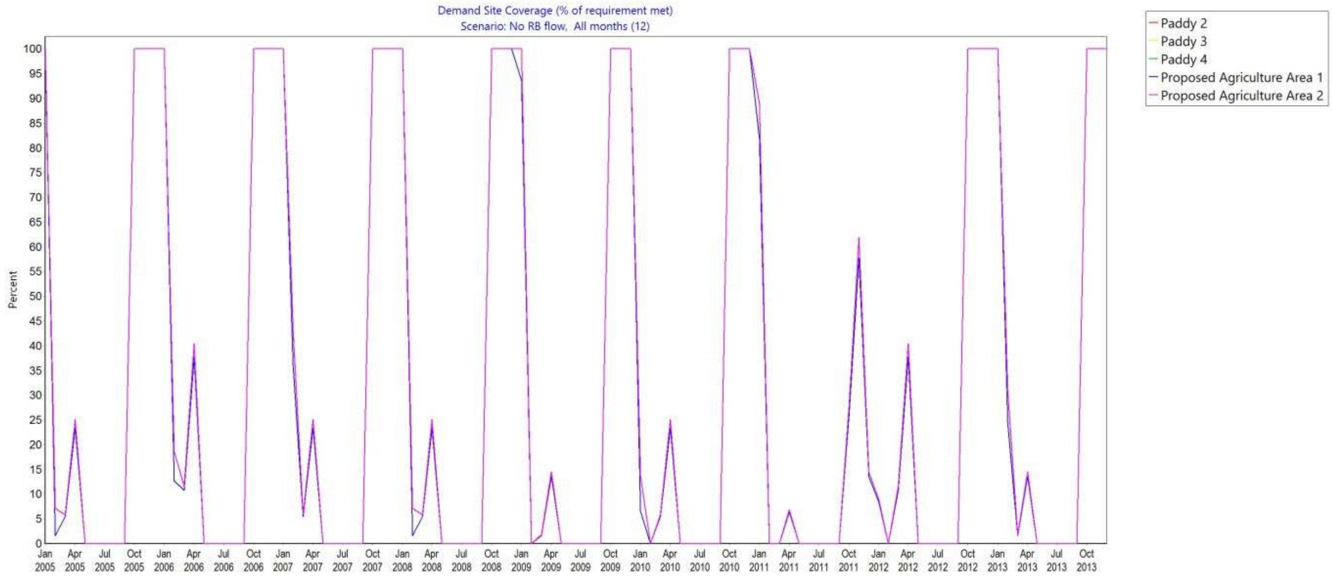


Figure 24 - Yearly demand site coverage for paddy fields along the RB-canal, No RB-flow Scenario

One of the problems related to this lack of data is that we do not know how close to reality our model is. Therefore we have to look at our results and compare it with those empirical data we might have, and then draw some conclusions.

We already know from the Pre-Feasibility Report that the cropping intensities for *Maha* and *Yala* season, before the canal was made, were calculated to be 0.5 and 0.3. Compared to our results given in the figure above, which shows the *"No RB-flow"* scenario, we see that our *Maha* and *Yala* season is closer to 1 and 0.2. Either we have too much precipitation, or our crop water needs are lower than in reality.

4.5.2 Inginimitiya reservoir catchment area

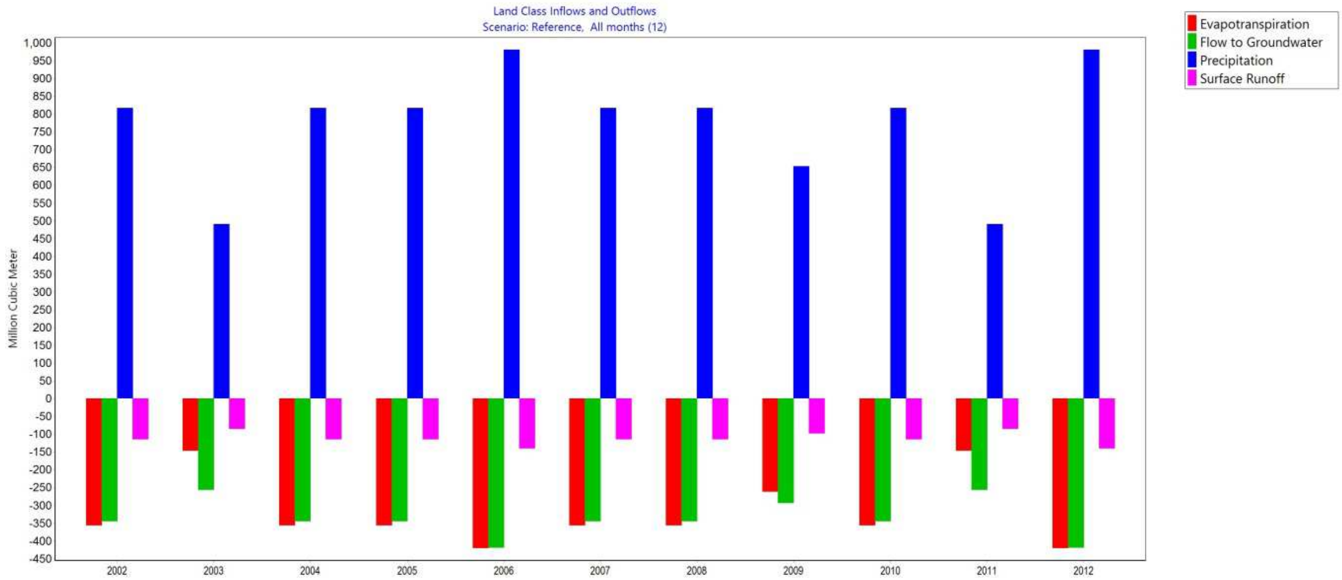


Figure 25 – Yearly inflows and outflows from Inginimitiya Reservoir Catchment, Reference scenario

From figure 25 (above) we observe that the runoff is almost 50% of precipitation, and that surface runoff is 1/3 of groundwater infiltration. If all this surface water had flowed into Inginimitiya, we would end up having much more water than what is really the case.

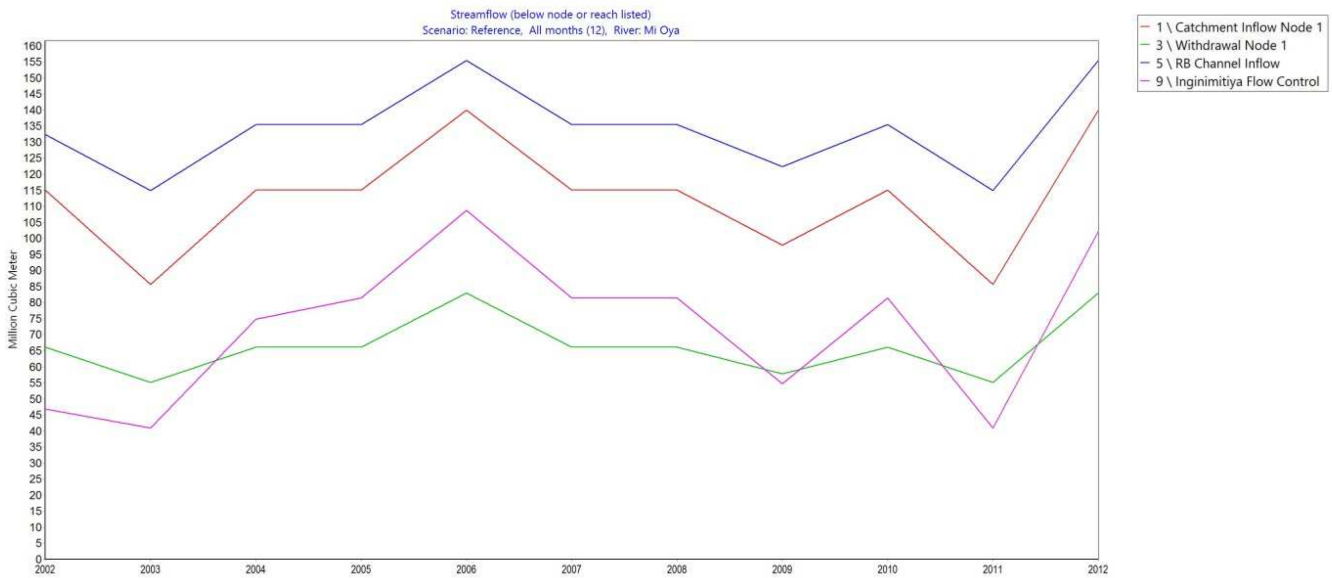


Figure 26 – Yearly streamflow at different places along Mi Oya, Reference scenario

The difference between Catchment inflow node 1 and Withdrawal node 1, seen in figure 26 (above), is the loss we added to make our model more similar to the inflow data computed in table 4.4 in the pre-feasibility report. Inflow to the Inginimitiya reservoir is therefore the sum of Withdrawal Node 1 and the flow from RB-canal in the *"Reference"* scenario. This sum is shown as RB canal inflow.

The difference between RB canal inflow and Inginimitiya Flow Control shows water use for Paddy 1, the paddy areas under Inginimitiya Reservoir Scheme. The graph shows that the system can manage our environmental flow design discharge of 40 MCM.

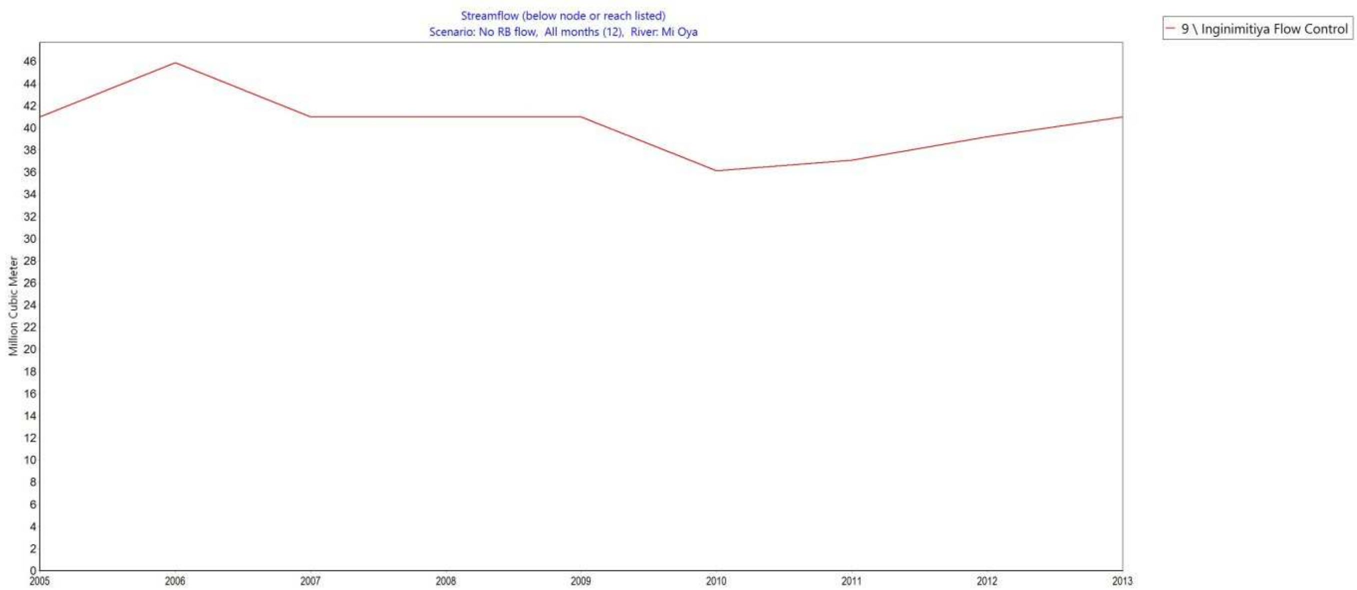


Figure 27 - Streamflow after Inginimitiya flow control, No RB-flow scenario

From figure 27, we see that the "No RB-flow" scenario cannot maintain the environmental flow design discharge of 40 MCM.

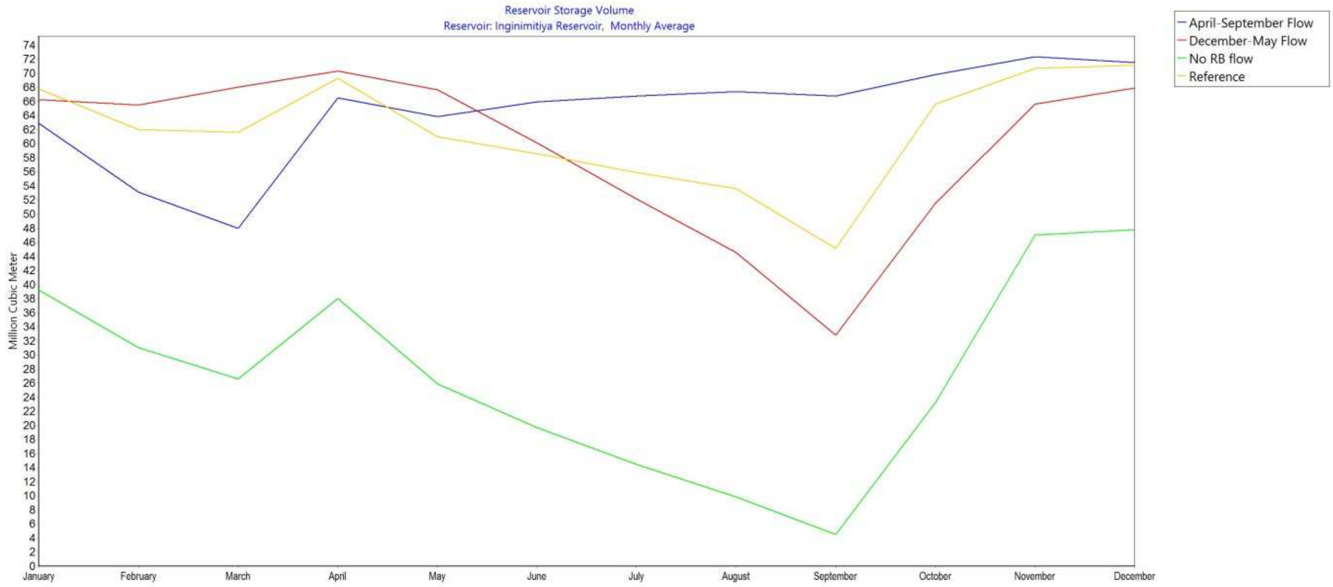


Figure 28 –Monthly storage volume for Inginimitiya reservoir, Different scenarios

In Figure 28 shown above, we can see that the Inginimitiya reservoir is at the lowest storage level in September, just before the rain season. Notice the low September-storage level in the *"No RB-flow"* scenario. According to this figure, the *"No RB-flow"* scenario never manages to fill up the reservoir. However, as shown in Figure 29 below, the Inginimitiya reservoir can be filled up even without the RB-canal. But the flexibility of the system is not upheld, as seen in the dry years of 2011 when the reservoir is completely empty.

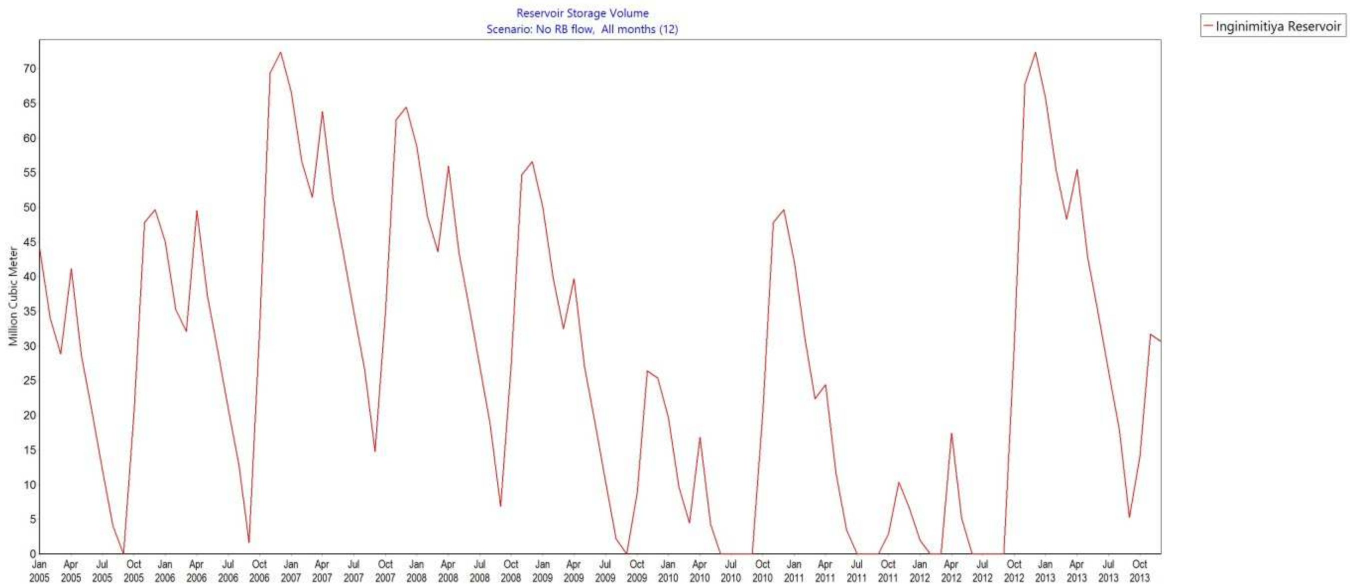


Figure 29 - Yearly storage volume at Inginimitiya Reservoir, No RB-flow scenario

We see that figure 29 (above) and 30 (below) are dependent on each other. Whenever the reservoir empties, demand site coverage is sharply reduced.

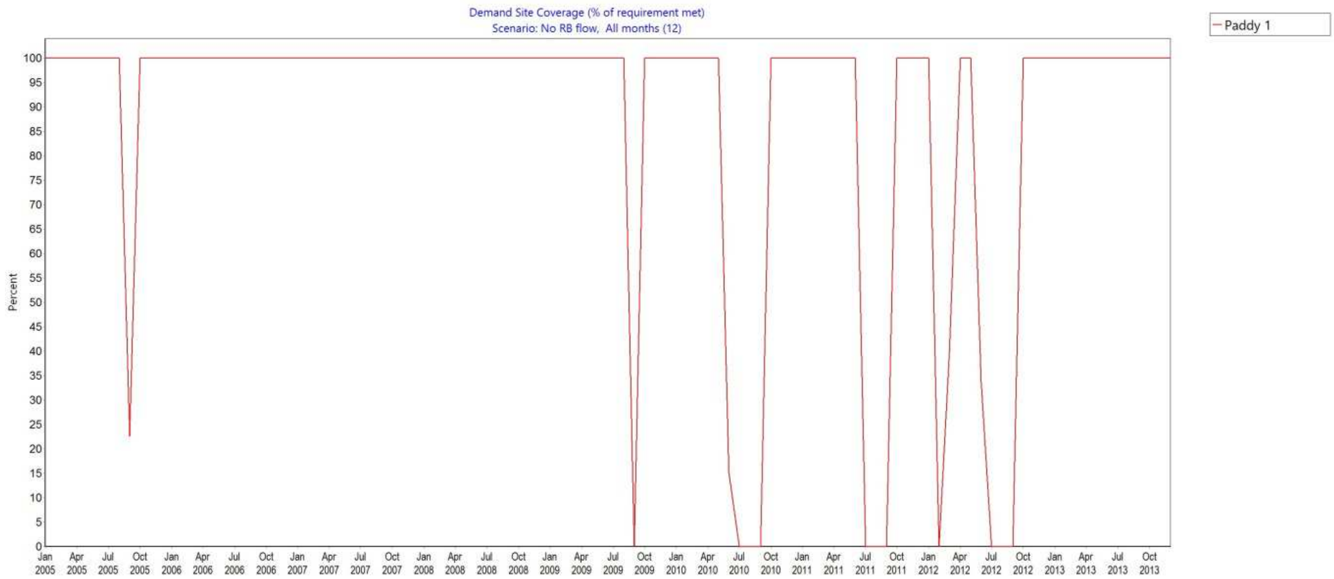


Figure 30 - Demand site coverage for paddy fields under Inginimitiya Reservoir Scheme, No RB-flow Scenario

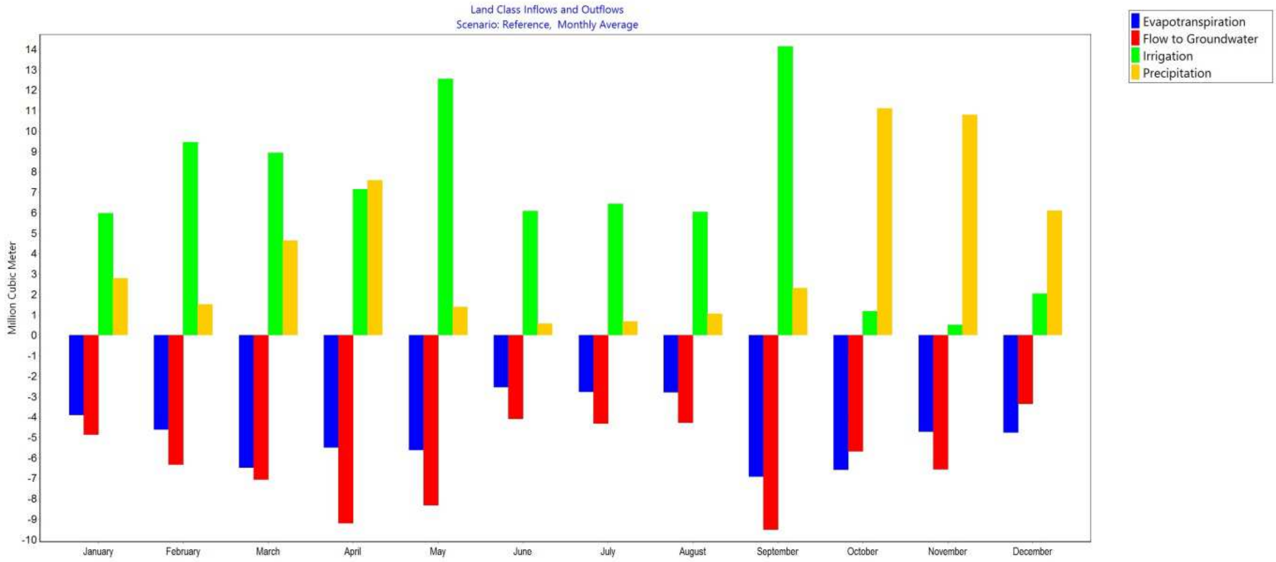


Figure 31 - Monthly inflows and outflows from paddy fields under Inginimitiya Reservoir Scheme, Reference scenario

The figure above shows the *"Reference"* scenarios' monthly water balance for all the paddy fields under Inginimitiya Reservoir Scheme. One thing that should be noticed is the water use for June, July and august, a period when there are no agricultural activity. The reason for this consumption of 6-7 MCM in these months is because WEAP calculates demand based on Kc factor. This makes our model less correct, as water will not and should not be used to irrigate grasslands between paddy seasons.

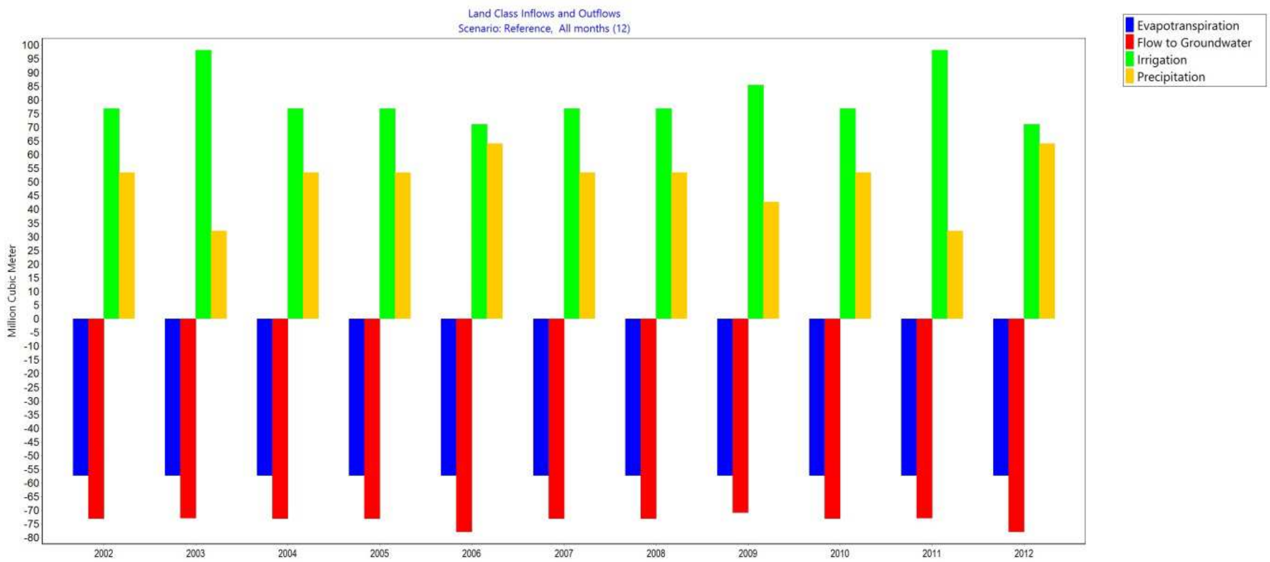


Figure 32 - Yearly inflows and outflows from paddy fields under Inginimitiya Reservoir Scheme, Reference scenario

Nevertheless, when we look at the model as a whole, we see that the errors do not disturb our conclusions. We end up with a RB-canal canal that needs 25-30 MCM for irrigation and keeping the tank volume, and paddy areas under Inginimitiya Reservoir Scheme that require 60-70 MCM. This can be observed in the yearly water balance graph above.

4.5.3 Climate change scenario

For the climate change scenario, we run scenarios up to year 2070. We compared the two results with our *"Reference"* scenario. Since we are to check the flexibility of the system, we will mainly focus on the *"Climate Change Dry"* scenario, which has the most irregular precipitation.

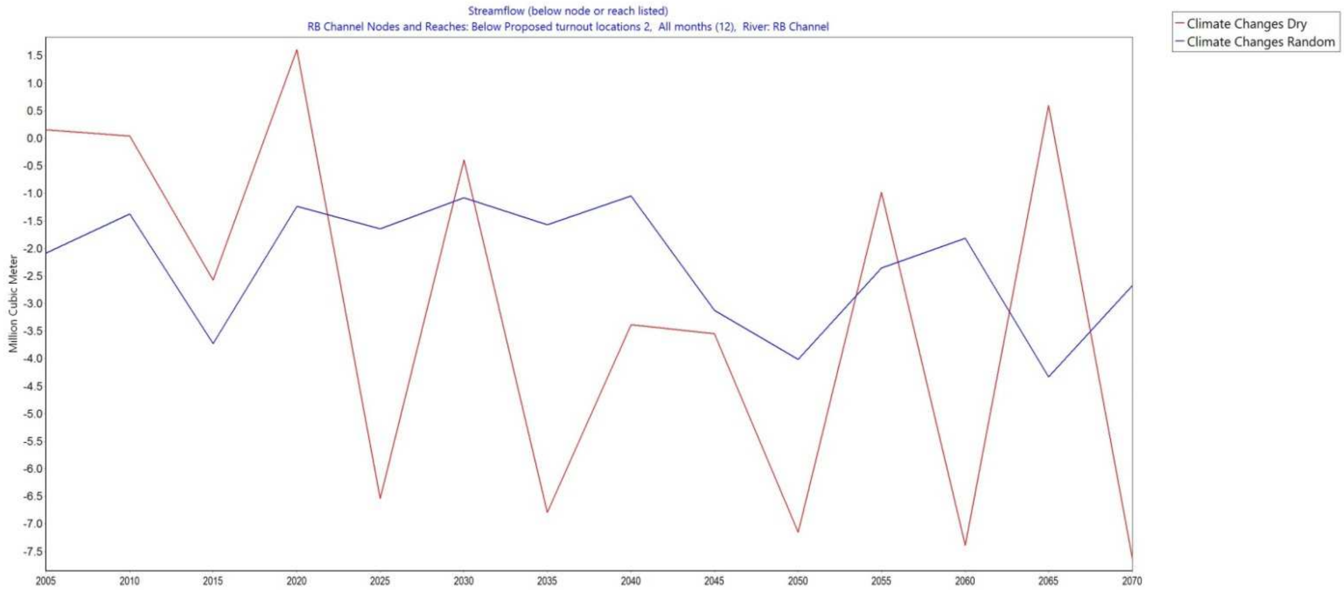


Figure 33 –Yearly streamflow into Inginimitiya Reservoir from the RB-canal relative to Reference scenario, Different Climate Change scenarios

As expected, with the decreased rainfall, irrigation water demand will be higher, and less water will flow out of the RB-canal and into the Inginimitiya reservoir. Some few wet years will manage to maintain the same flow as in our *"Reference"* scenario. But for most of the years this will be lower. There will be no change in tank water levels, as WEAP priorities to keep them full and rather reduce volume flow.

This might have both positive and negative impacts on the system as a whole. Positive because it will have a higher water security for those areas along the RB-canal and negative because it will reduce the Inginimitiya reservoir water level.

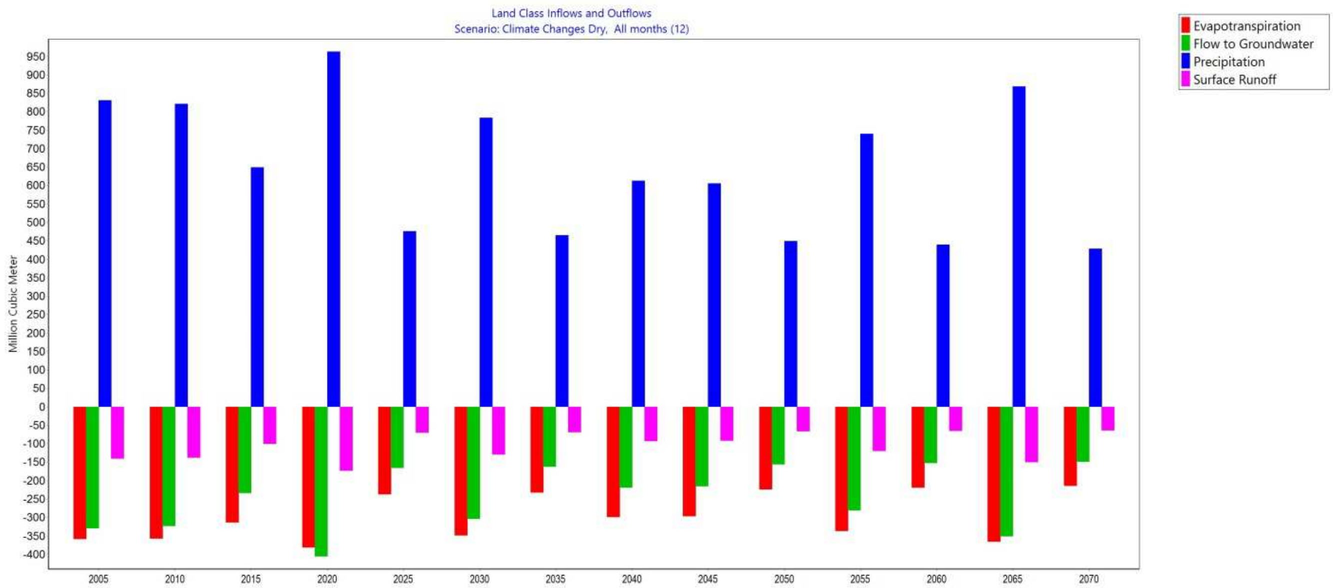


Figure 34 – Yearly inflows and outflows from Inginimitiya Reservoir Catchment, Climate Change Dry scenario

The graph above shows the decreased precipitation over the Inginimitiya reservoir catchment for the dry climate change scenario. If we compare it to the *"Reference"* scenario as seen in figure 34, we get a grasp of how big the difference is. For the dryer years, we can thus anticipate 340-380 MCM less precipitation.

WEAP has some flaws that make the results look different from what they really are. The land class inflows and outflows graph is calculated with precipitation as positive, and evaporation, groundwater flow and surface runoff as negative, all to end up in zero. If in one scenario surface runoff is 100 MCM yearly and another one is 50 MCM yearly, and if they are compared relative to each other in a graph, the 50 MCM will show up as having a bigger runoff. That is because -50 is bigger than -100. For this reason, we will not show catchment hydrology relative to the *"Reference"* scenario.

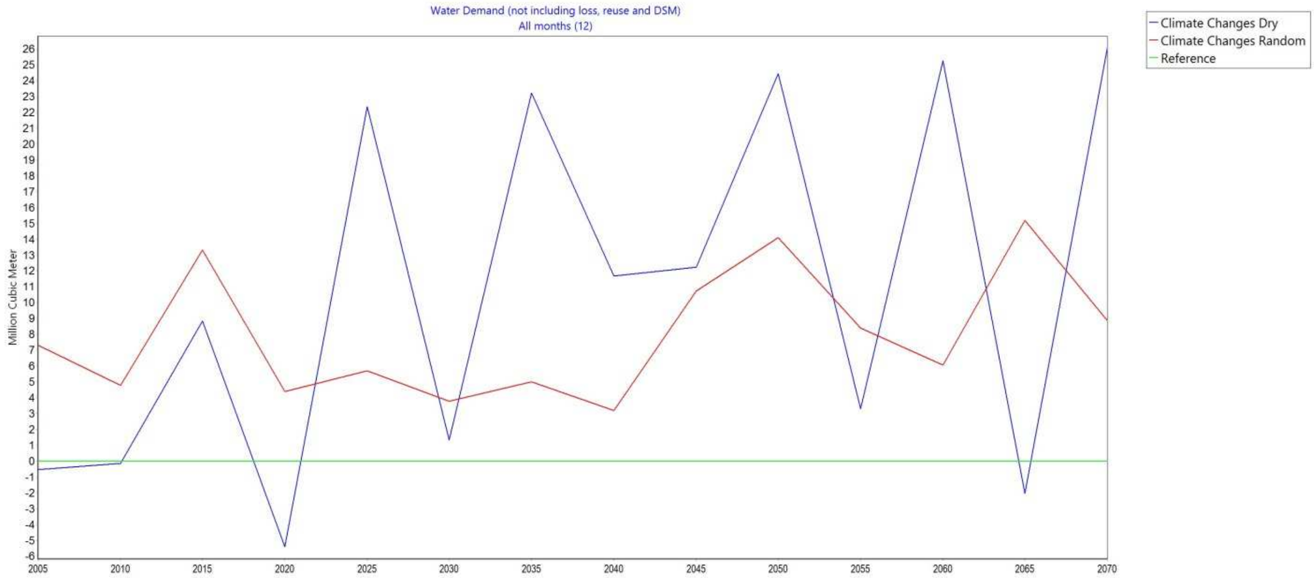


Figure 35 –Difference in total irrigation demand for all paddy fields relative to Reference scenario, Different climate change scenarios

The graph above shows irrigation water demand relative to the *"Reference"* scenario. As predicted, irrigation water demand will increase with decreased precipitation. Water demand in 2070 for the dry scenario is 6-26 MCM higher than today.

However, the project will manage to keep up full coverage for all those years.

Although coverage is 100 % for all years, the impact on reservoir volume for the Inginimitiya reservoir is heavily influenced by the dry years around 2060.

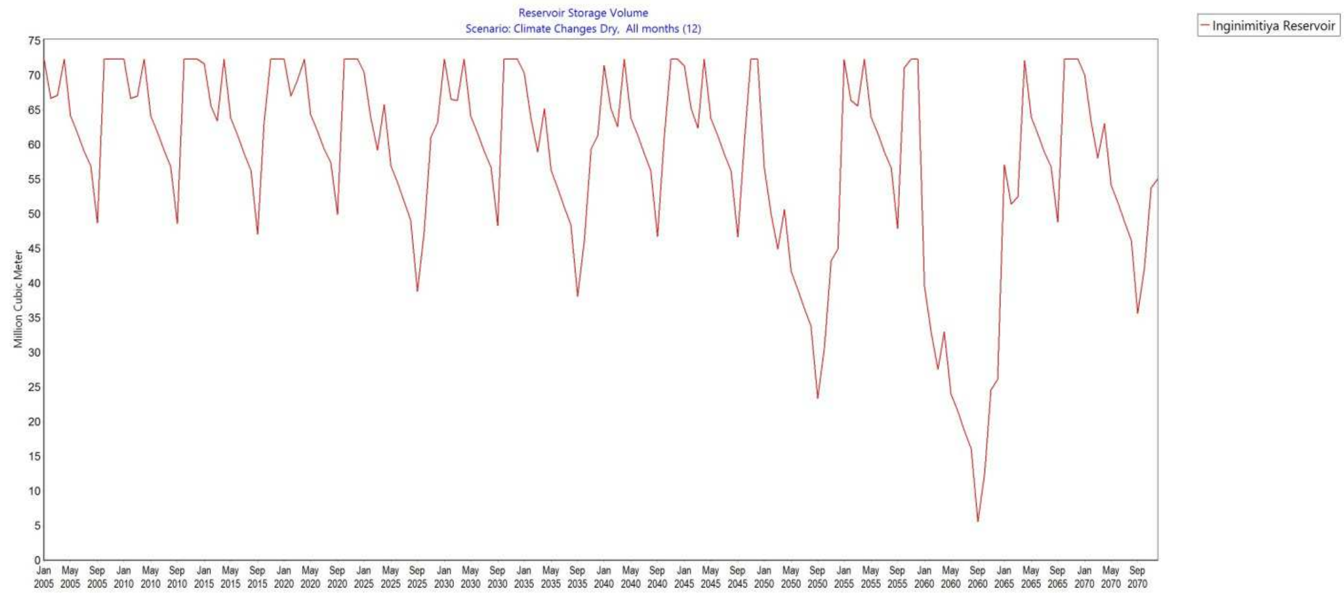


Figure 36 – Yearly change in storage for Inginimitiya Reservoir, Climate Change Dry scenario

The main reason the reservoir is emptying is because of the environmental flow, shown below. Even though precipitation is lower, the flow still has to be maintained.

If we compare figure 35 and 36 with 37 and 38, we see that improving the irrigation efficiency is a good way for reducing water use. The improved irrigation efficiency will lower water demand with more than 30 MCM a year. In order to maintain double cropping of all the areas and develop more paddy areas in the future, this should be considered.

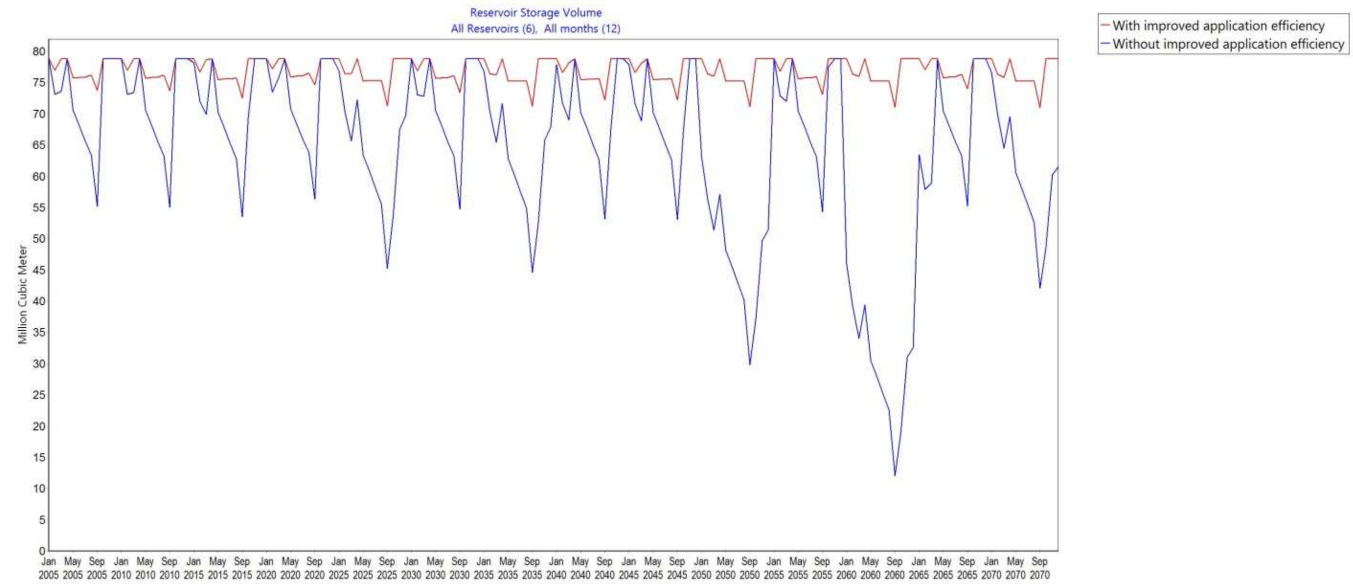


Figure 37 - Yearly change in storage for Inginimitiya Reservoir, Irrigation Efficiency Scenarios

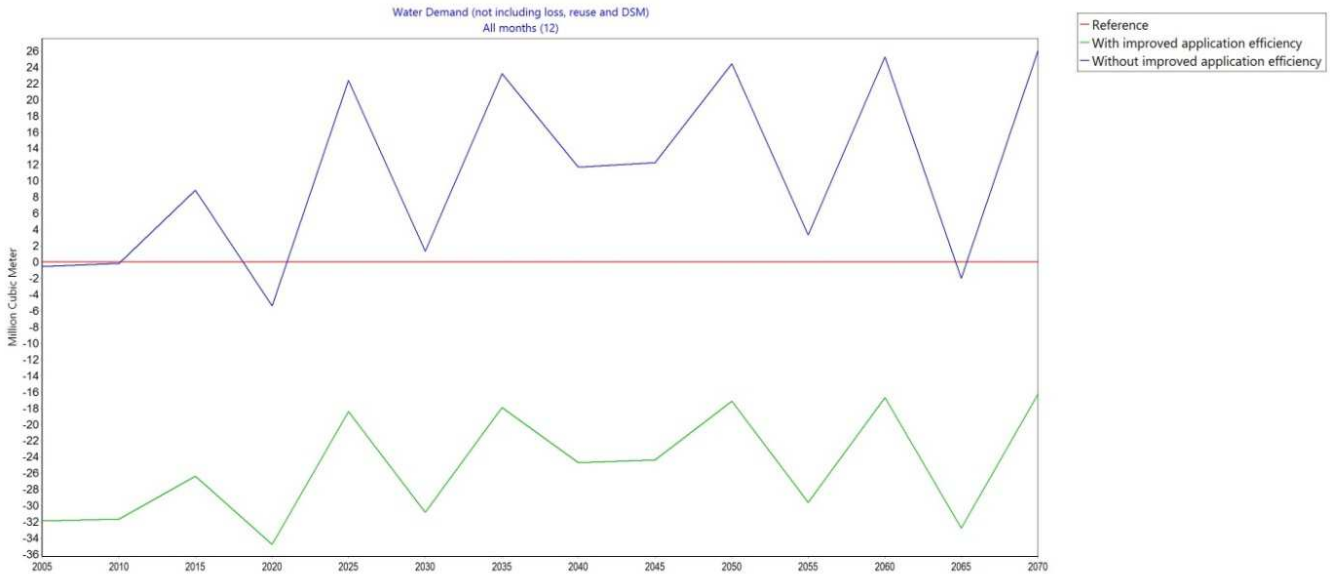


Figure 38 - Yearly total water demand relative to Reference, Irrigation Efficiency Scenarios

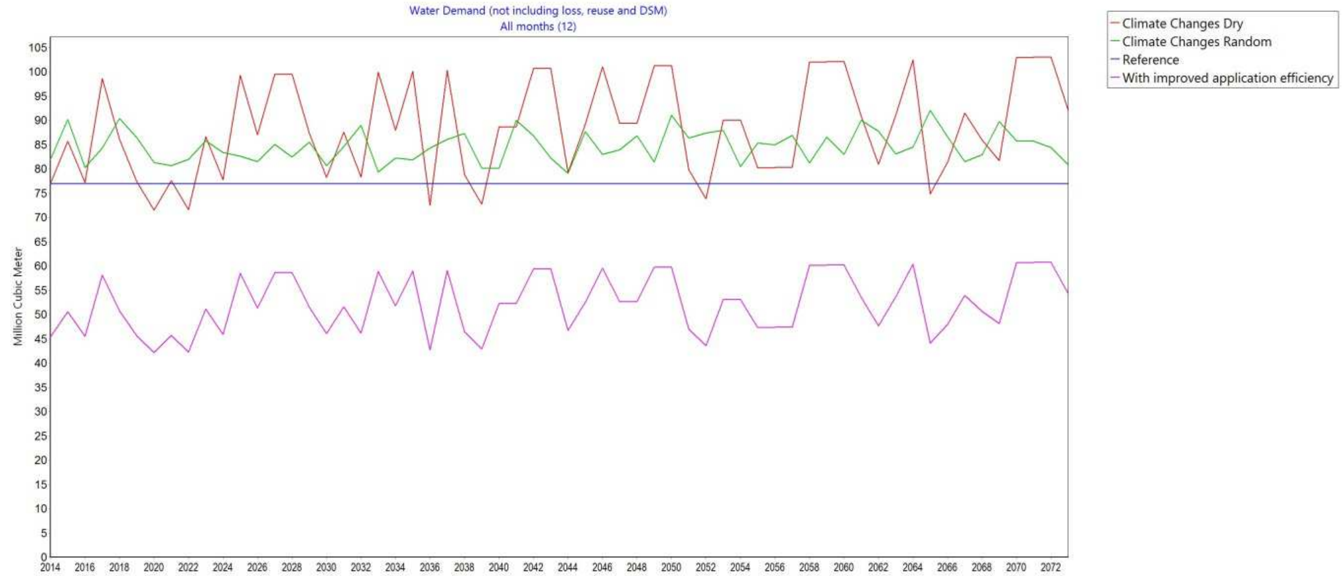


Figure 39 - Total irrigation water demand, various scenarios

As the table above shows, water demand will be higher in the future with climate changes. If the irrigation efficiency increases however, we see that we can decrease water demand with almost 40%.

5 Conclusions

We have below summarized our findings to the questions we have initially formulated in the study:

- **How informed are the population in the rural areas regarding water-related diseases?**

As the results from the survey shows, the general information amongst the people is good when it comes to diseases related to water. They are well aware about the problems with the “hard” groundwater from their wells but have little alternatives to this water source. Kidney disease is a widespread problem in these rural areas, but without the resources to bring the water supply to a safe level, the faith of the people lies with the government and the hope for a pipeline system with healthy, drinkable freshwater.

- **In what grade will the expectations the population have towards this project be met?**

The survey points out that even though the Deduru Oya project will benefit the population in Sri Lanka in a good way and that people generally are positive towards the project *(See question 3 in the survey),* the people negatively affected can easily be forgotten. There are many individual sacrifices involved in a project like this, and the compensation to these people was according to the interviewees delayed and it was not clear how much they would end up receiving. The admirable about what seems to be the mindset of an average Sri Lankan is as Spock says in Star Trek II:

“The need for the many outweighs the need of the few”

Even though the people we interviewed risked losing their house, they thought of the benefit of the many and how this was a wise decision considering the long term.

The impression was that people in the area were living in uncertainty, but almost everyone was positive towards that things were going to change to the better. More water to the fields, more economic growth and a more comfortable way of life was mentioned as consequences of this development. Exactly how this would happen was not as obvious as the people's expectations for a change for the better were.

Due to lack of information regarding how the Deduru Oya project will operate when it is completed it is hard to say in what grade this project will meet the expectations to the people. What we do know is that the RB-canal will result in more water to the Inginimitiya reservoir and to the smaller water tanks along the RB-canal. This will benefit the people and their crops to some extent, but exactly how much water that will benefit the people directly remains to be seen. With the increase in water supply, the fields and the amount of crops will also increase. This again will result in more pesticides being spread over the crops and this can affect the groundwater by making it more poisonous. With this development, the water-related diseases and the kidney cancer problem that these rural areas already struggle with can become even more severe.

Based on our assumptions, and according to the results from the WEAP simulations, there is proof to say this project will have a positive effect in the community. Without the RB-canal, double cropping of the paddy areas between Deduru Oya and Mi Oya, and those under Inginimitiya reservoir, would not be possible. Even though it is hard to give exact numbers due to all the uncertainties linked to the lack of data, we can draw some conclusions from our results.

It is worth commenting on the amount of water we have in our simulated system, and especially in our tanks and reservoir. Empirical data for the past years shows that the Inginimitiya reservoir water level has been down to around 15 MCM, and that it never fills up. When we compare the empirical data with our results, we understand that we might have overestimated the precipitation or underestimated the water losses. Either way, our simulation gives us more water than we believe will be the case in the reality.

- **What are the challenges with simulating a scenario like this using WEAP?**

Given that all the necessary data is available, WEAP can be used to get a good overview of an area and its water management. It is a useful supplemental tool, but conclusions should not be based strictly on the results from the simulations. Its user-friendly interface may sometimes be too simple, which often leads us to wonder where to insert other water losses not specified in the tabs. It would be nice to see how WEAP actually calculates everything, and what kinds of equations are being used.

Our biggest challenge was the total lack of hydrological data. It is not advised to make a hydrological model if you lack information regarding groundwater, infiltration, runoff, evapotranspiration and land use.

- **Is the project viable in the future, especially with regards to climate changes?**

Although we do not know exactly what will happen with the climate in the future, some predictions given by the IPCC seems likely. When taking these factors into account, we end up with the conclusion that the project is in fact viable.

Our climate change scenario runs up to year 2070. During that interval, the RB-canal distributes sufficient amount of water to The Inginimitiya reservoir, even though the demand is 6-26 MCM more than today as a result of drought. The climatic factors that IPCC predicts are higher evaporation due to temperature increase, a decrease in yearly precipitation, and some wetter months/years leading to flooding. With the reservoir, this floodwater can be collected and put to good use during the dryer periods. And with the RB-canal constantly supplying the reservoir with almost the same amount of water as the average yearly inflow from Mi Oya, 61 MCM, there is no reason to believe this project is not viable for the future.

When looking further into the future, taking into account the population growth, possible drinking water extraction from the reservoir, increase in personal water demand and the need to produce more rice etc., water scarcity will be an even bigger issue. In order to counter this, some options are available.

The first solution will most likely be to minimize the operational environmental flow downstream of Inginimitiya reservoir. If this is done, it will have a negative effect on the aquatic ecology, destroying habitats. But unfortunately, economy is usually prioritized over ecology. One other solution may be to increase the application efficiency by modernizing the traditional farming technique, and decrease the loss from the canal by increasing conveyance efficiency by lining the canal. Looking at the results from the scenario simulation, we conclude that this is a better option and should be considered.

5.1 Recommendations

This study opens for further research, both with this particularly project and generally with other irrigation schemes in Sri Lanka using WEAP as a simulation program. WEAP is not a well-known program in Norway and people with unique expertise are always attractive, so further studies and working with WEAP is considered applicable for the future.

- Based on this study, a possibility could be to interview people in the same areas after the Deduru Oya scheme has been operational for a few years to obtain a picture on how the development has been and if the results of this project have somehow answered to the expectations. Exact numbers on how many people that got affected at the end of the project is yet not known since the project is currently not finished. Some people in a negative way, some people in a positive way. How much water will benefit the people along the RB-canal directly?

- The project will result in more paddy fields, and more grown paddy results in more pesticides that will be spread over these fields and eventually into the groundwater. Will the increase in paddy fields result in an increase in heavy metal toxicity in the groundwater? Making the water “harder” and increasing the already existing kidney cancer problem?

- To optimize the WEAP-model, there should be additional hydrological research on the Inginimitiya catchment area. Only then one can know exactly how big the percentage of precipitation that ends up as surface flow is. For the RB-canal, one should simulate with changes in tank water levels. A study on how the Inginimitiya reservoir scheme will look in the future. Will there be a growth of water demanding industries? Perhaps withdrawing freshwater for use as drinking water? Development of new agricultural lands above the Inginimitiya reservoir that will draw more water from its catchment, reducing the volume flow into Mi Oya and the reservoir?

Writing a master thesis in a foreign country has been an interesting journey filled with learning, both academic and social wise. Two months is not enough time to really get to know a country, but during our stay we experienced staying in a country without being there on vacation. We got the chance to be part of a university-society and to live in an apartment in a Sri Lankan neighborhood. Without exceptions, every local we met in Sri Lanka was positive and did what they could to help us. Even though we experienced a lot of waiting e.g. collecting data, Visa-approval etc. compared to what we are used to in Norway. This is a difference in culture and need to be expected. Norwegian people as a whole have a lot to learn when it comes to hospitality and to be forthcoming towards complete strangers.

The politics and the culture in Sri Lanka are very different from how things work and are run in Norway, the democracy, the rights of the people, and the fact that Norway is a highly developed country, while Sri Lanka is a developing country who went from being a under-developed country as late as in year 2010. (Herrald 2010) Some of the interviewees called the government a dictatorship where the president and his family run everything. It's the president's voice that is heard. Not the peoples.

We traveled down to Sri Lanka with great expectations hoping to receive much more information and produce much more than the reality proved we would be doing.

As Prof Harsha said when we came back to our university in Norway: “ If you get to do half of what you planned to do in twice as much time in a country like Sri Lanka, you should be very pleased. “

Considering this, we are pleased with the results of our work and deeply recommend future students to write a master thesis, which involves getting to know a different culture than your own.

5.2 The collaboration

Since we chose to pair up and write our master thesis together we had to be structured and plan how the process was going to be from the beginning. Working as close together as we have done can be challenging. Not only did we work together during the daytime, but we lived together for two months in a foreign country were neither of us had any friends or other social connections. We got to know each other's inequalities and learned both each other and ourselves to know in a different way.

When working as close for a longer period of time it is important to be adaptive and open for other opinions then the one you think is the right one. This is something that has value ahead in life and in every setting where teamwork and collaboration is of great importance.

Leaving Norway we knew very little of what awaited us in Sri Lanka. Most people in Norway can somehow relate to e.g. India. They've watched a movie that origins from India, they have relatives or friends that's been in India on vacation etc. This does not apply to Sri Lanka the same way, so our information of what we could expect was limited.

After the civil war ended in 2009, the country has just recently started building up its tourism and facilitate the country for this industry. More and more people add Sri Lanka to their travel list and in 2013 the Lonely Planet ranked the country on top over best travel destination. (Planet 2013)

From early on we had decided that Kristoffer Sorkness should immerse in the simulation program WEAP, while Paul Henrik Johnsen was going to look at the more socio-economic affects by making a survey and interview people in the rural areas.

The simulation in WEAP was more time consuming than first expected, so while Kristoffer continued on the simulation process, Paul Henrik has been working on the theory and the layout of this paper. One can hardly see all the hours behind the results of the WEAP-simulation without mentioning it here.

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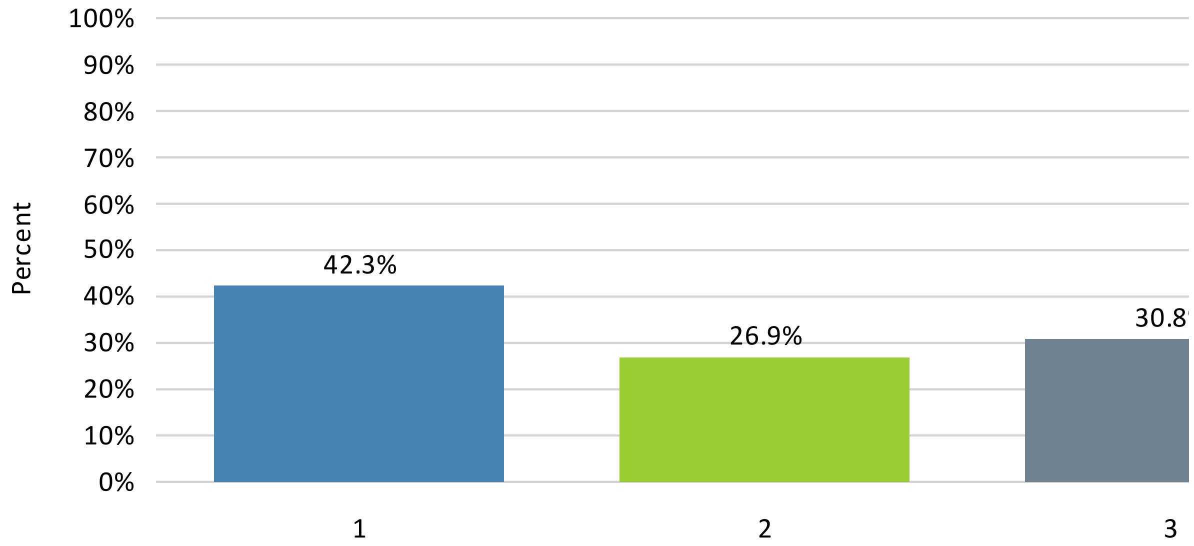
6 Appendix

6.1 Deduru Oya survey

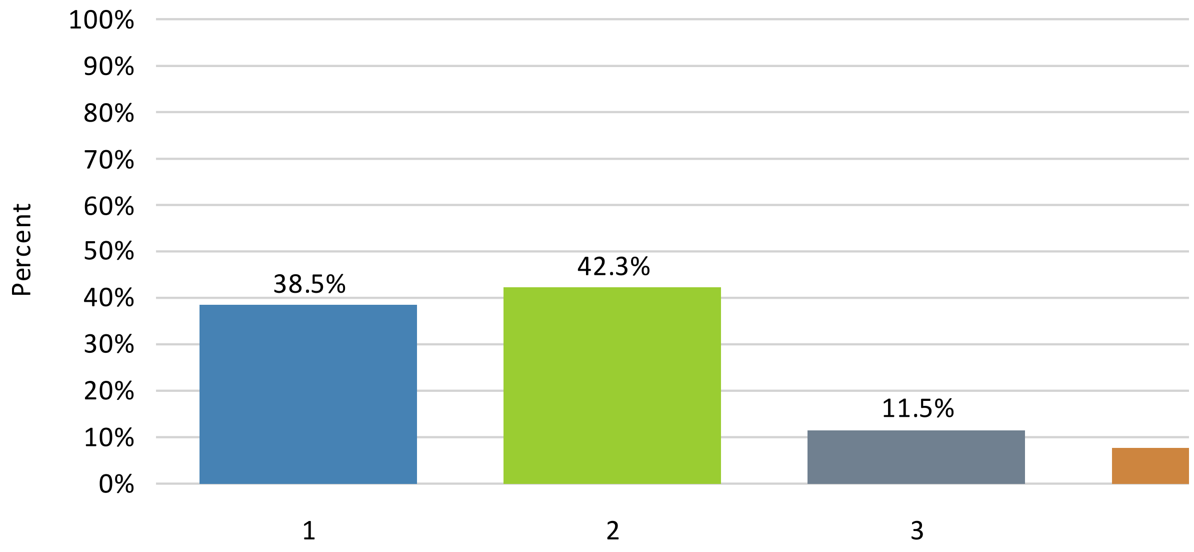
Applied Analyses with short comments

1. Wich area are you from?



	Name
1	Area 1 (Girilla)
2	Area 2 (Siyambalewa)
3	Area 3 (Ballogalagama)

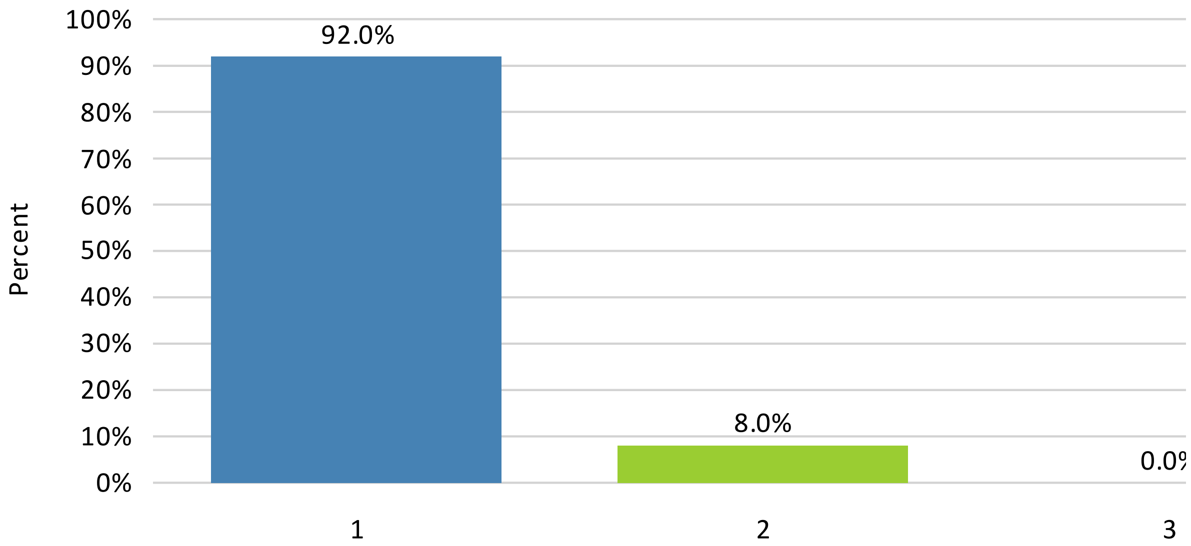
2. What is your main profession?



- Most of the people were both workers and farmers. Police officers, three wheel drivers, retired teachers, military officers, labourers etc. Almost everyone had a spot were they grew things.

	Name
1	Worker
2	Farmer
3	Higher educated
4	Without work

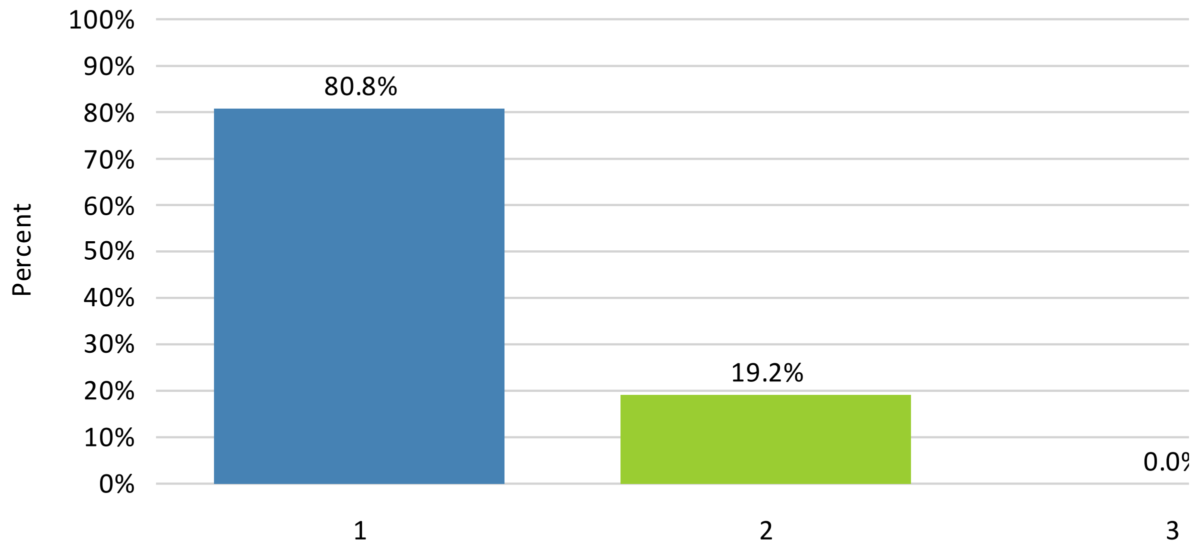
3. All in all, are you positive or negative towards this project?



	Name
1	Positive
2	Negative
3	I don't know

- Most of the people were positve even though they had to sacrifice their own land, crops. Even their own house. It was the big picture that counted. As long as the community would benefit of this project they were happy. Admirable!

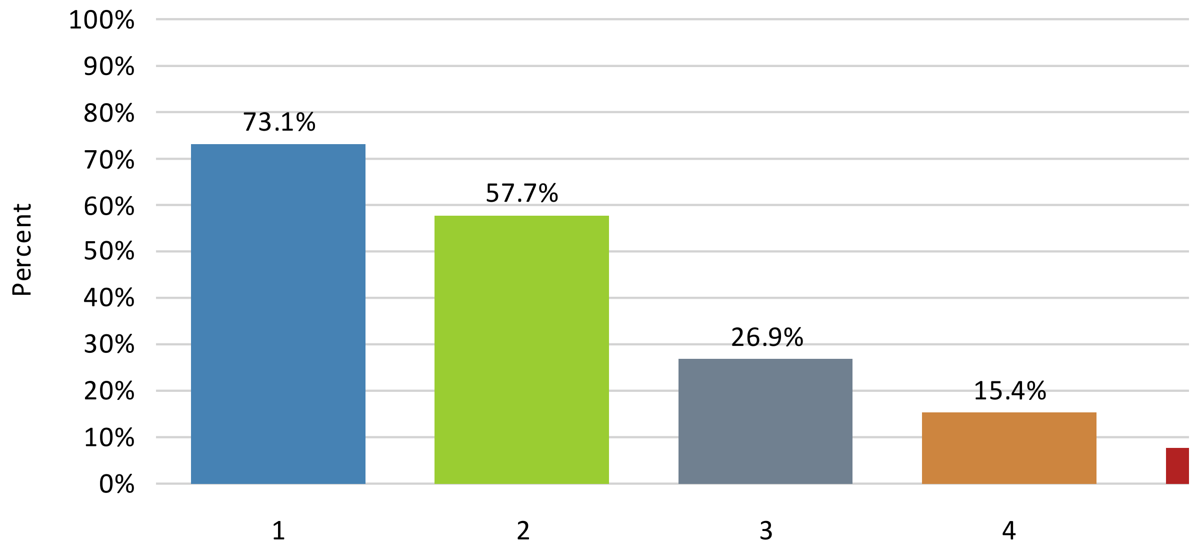
4. Have you or anyone you know got any work because of this project? For example with building the canal?



- The areas we were interviewing were very close to the irrigation canal, and most of the people knew somebody that has gotten work with the project. Just temporary though. Drivers, construction (help with cementmixing and so on.) People were happy with this opportunity.

	Name
1	Yes
2	No
3	I don't know

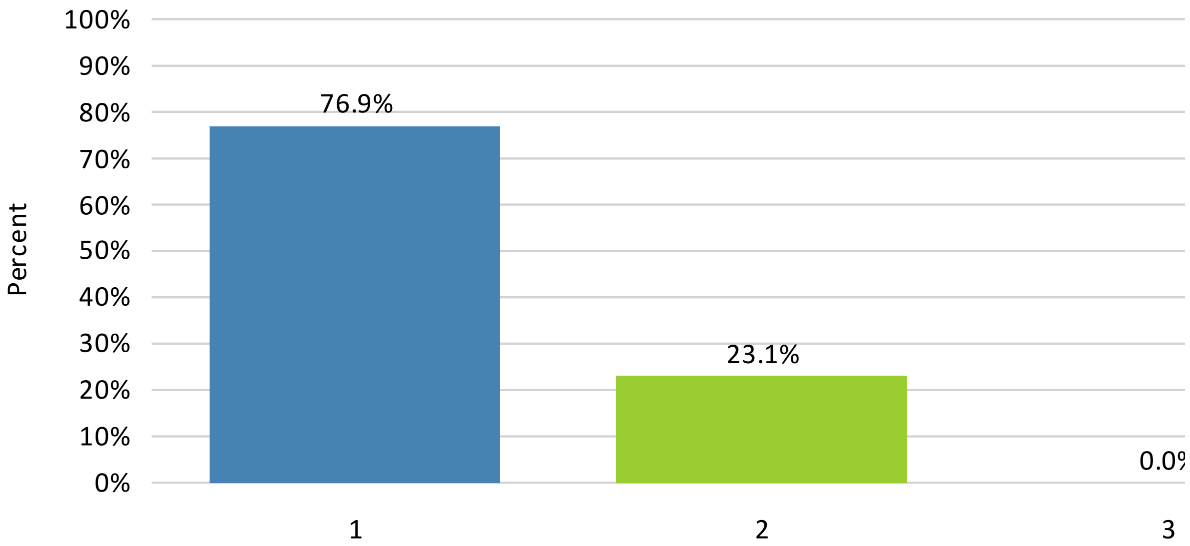
5. What kind of crops do you cultivate on your fields/land?



	Name
1	Paddy
2	Coconut
3	Vegetables
4	Other
5	I don´t grow anything

- This was a multiple choice were u could check more than one answer. Most people grew paddy, but a lot of them also grew coconut. Mostly on a small scale, but some had plantations.

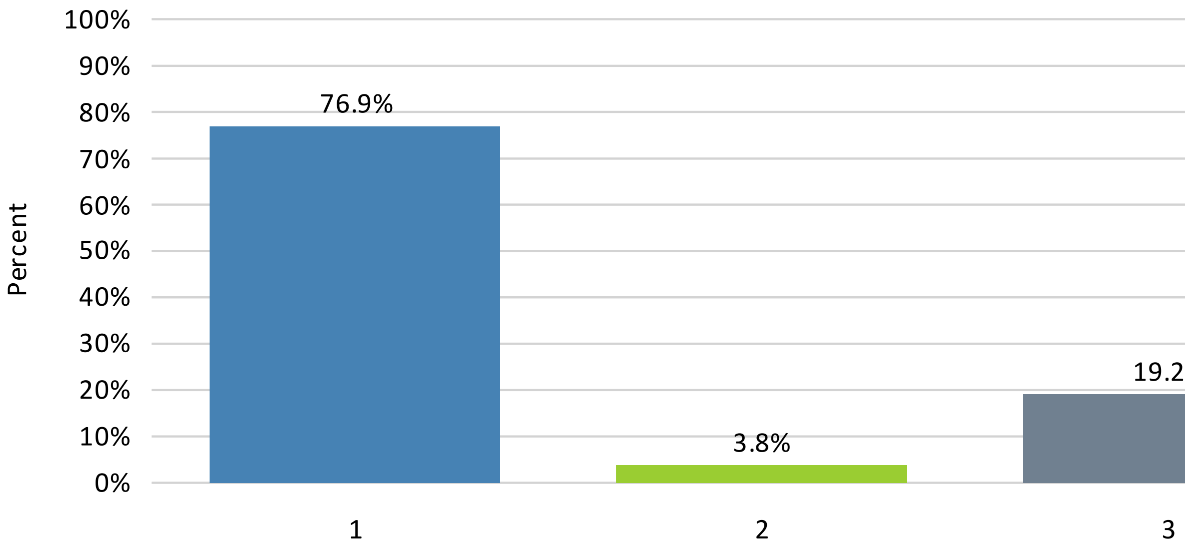
6. During the different seasons, do you and your family ever suffer from water scarcity?



	Name
1	Yes
2	No
3	Sometimes

- As expected, if the people ever suffered from water scarcity there would be in the dry season. Most people had enough drinking water all year around, but not enough water for the crops. This made it in most cases impossible to cultivate two times a year. The 23.1 % that didn´t suffer from water scarcity at all, were workers that did not have land to cultivate.

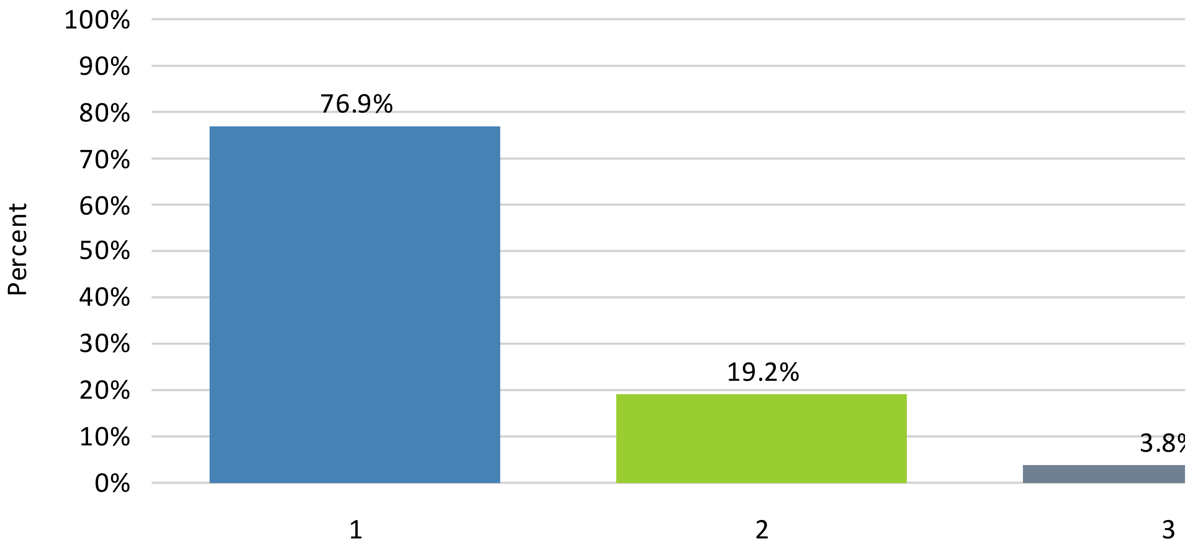
7. Do you expect more, less or the same amount of freshwater after this project is finished?



	Name
1	More
2	Less
3	I don't know

- The expectations amongst the people were unambiguously with this question. Nobody had got any information about this from the government, but the expectations were high.

8. If you get more fresh water as a result of this project, will you have the possibility to cultivate more on your land? Expand your fields?

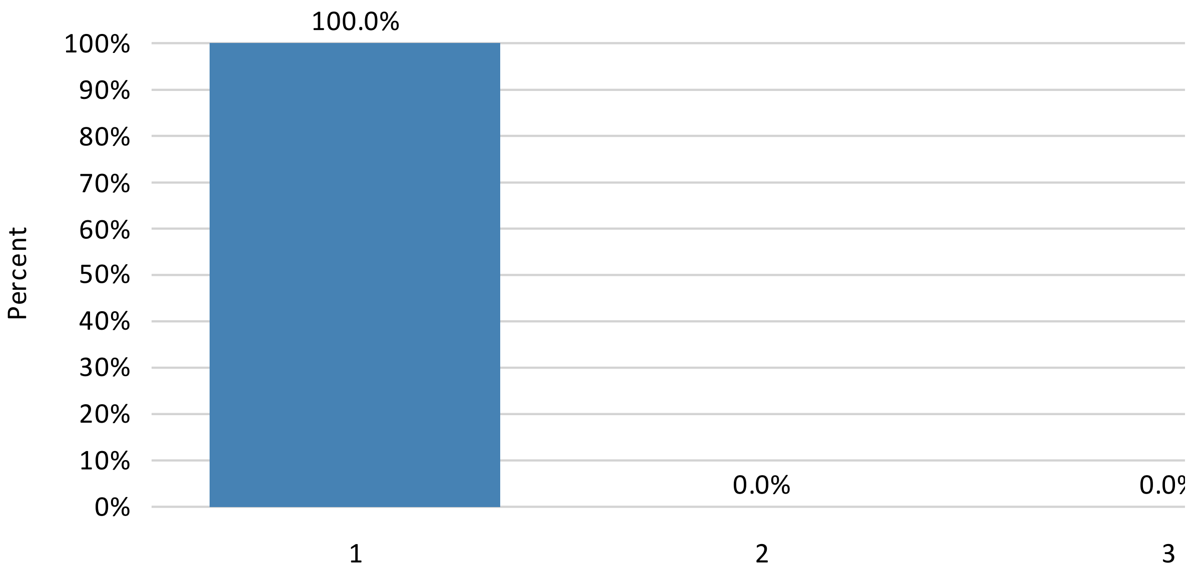


	Name
1	Yes
2	No
3	I don't know

- The majority of the people had the possibility to cultivate more and expand their fields on their land, but they lack water. The people that answered no to this question were people who had lost much of their land due to the irrigation canal, or the people that only had a garden with some coconut trees and did not cultivate on a big scale.

A common problem for the farmers is that the nearby tank is located higher than the irrigation canal and the result is that the reservoar actually feeds the irrigation canal instead of the other way around. We talked to one farmer that experienced that the groundwater in his well had sunked with 27 feet after the irrigation canal arrived just outside his house.

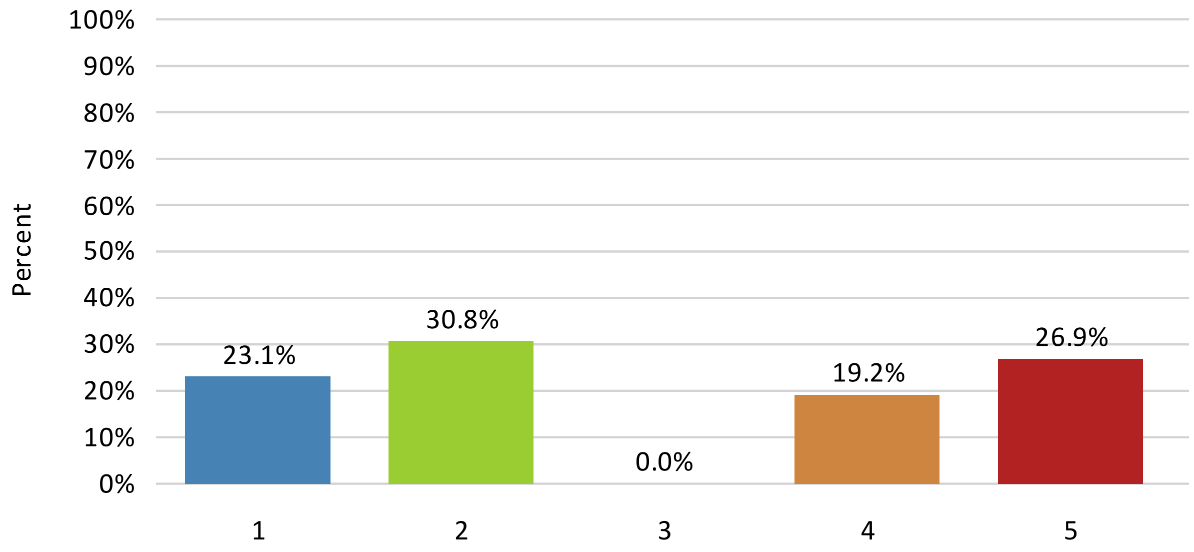
9. During the last years, have you noticed any differences in the weather? Such as heavier rain, dryer seasons etc? Any form of climate changes?



	Name
1	Yes
2	No
3	I don't know

- Climate changes are happening all over the world, and the people had got to feel this on their body and their land. The dry seasons lasts a lot longer, and unexpected heavy rainfall. An example is that the heavy rainfall usually doesn´t come until October, but while we were out interviewing we were struck by a very heavy rainfall and had to seek cover in the car. This was early September. This makes the paddy harvesting difficult. A problem with the long dry seasons is that the crown of the coconut trees dryes out and the tree dies.

10. How pleased are you with the information you have been given from the government about this project? Before and during the construction? (From a scale from 1-5, where 1 is very unhappy, and 5 is very happy)

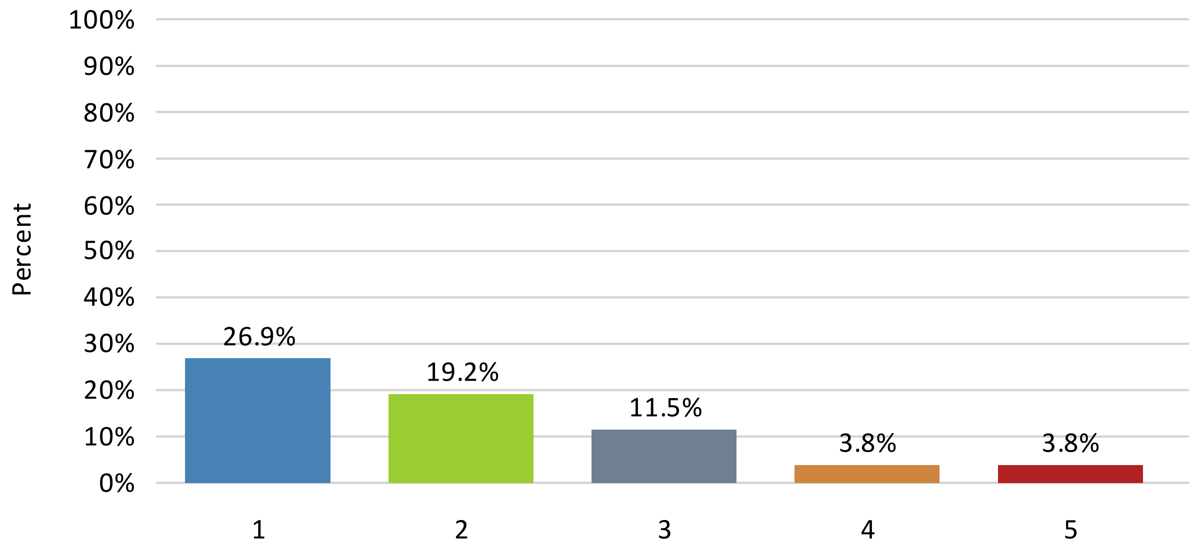


	Name
1	1
2	2
3	3
4	4
5	5
6	No opinion

- This is the question in the survey were we got the biggest gaps between the answers.

During the interviews we met some people that had lost lot of their land because of the canal. These people felt well informed by the government, while the people who didn´t get directly affected (f. example with losing their land) felt overlooked by the government and had to base their information on the rumor mill. Also, the few people we met that lived in more "urban" areas, besides the highway for example also felt well informed.

11. If you felt very affected because of this project, do you feel that you got a reasonable compensation? For example if you had to move? (From a scale from 1-5, where 1 is very unhappy, and 5 is very happy)

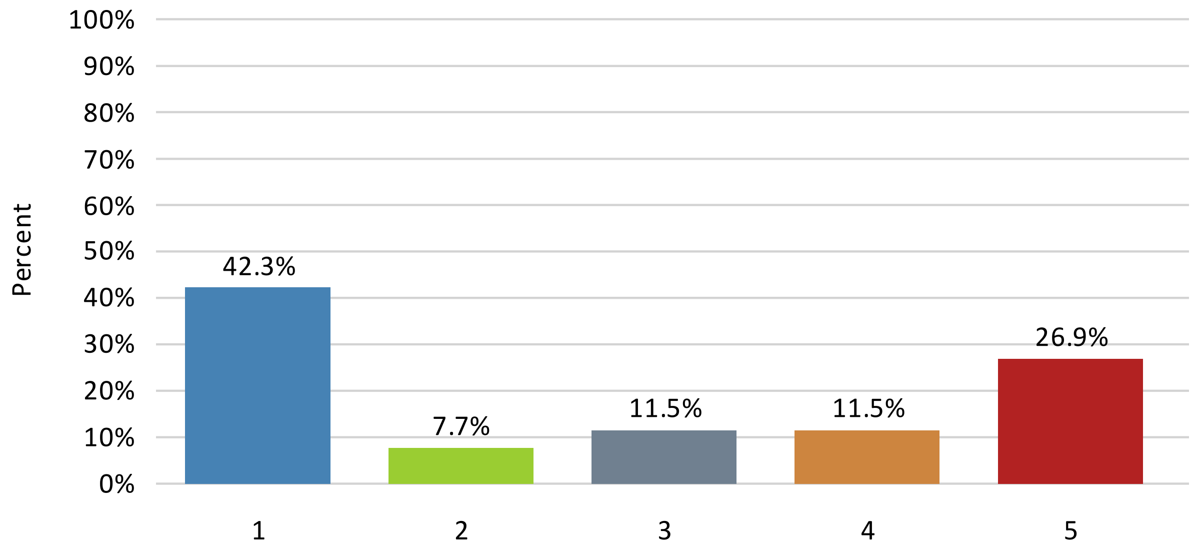


	Name
1	1
2	2
3	3
4	4
5	5
6	I don´t feel affected

- This shows the dissatisfaction amongst the affected people with how the government has played its role. Most of the people say that the government has promised them money for the lost land, but nobody we talked to had received any money yet. They didn´t know how much they were going to get, but some people had trust and were certain that the government would keep its promise. Also, they have heard rumors that the people affected from the Left Bank Canal got their compensation after a while.

Mostly, the people that had to give up their house had already got new lands someplace else, but very few people are pleased with losing their house no matter what kind of land they are promised as a replacement.

12. How happy are you with the amount of freshwater on your fields/land? Is it enough? (From a scale from 1-5, where 1 is very unhappy, and 5 is very happy)

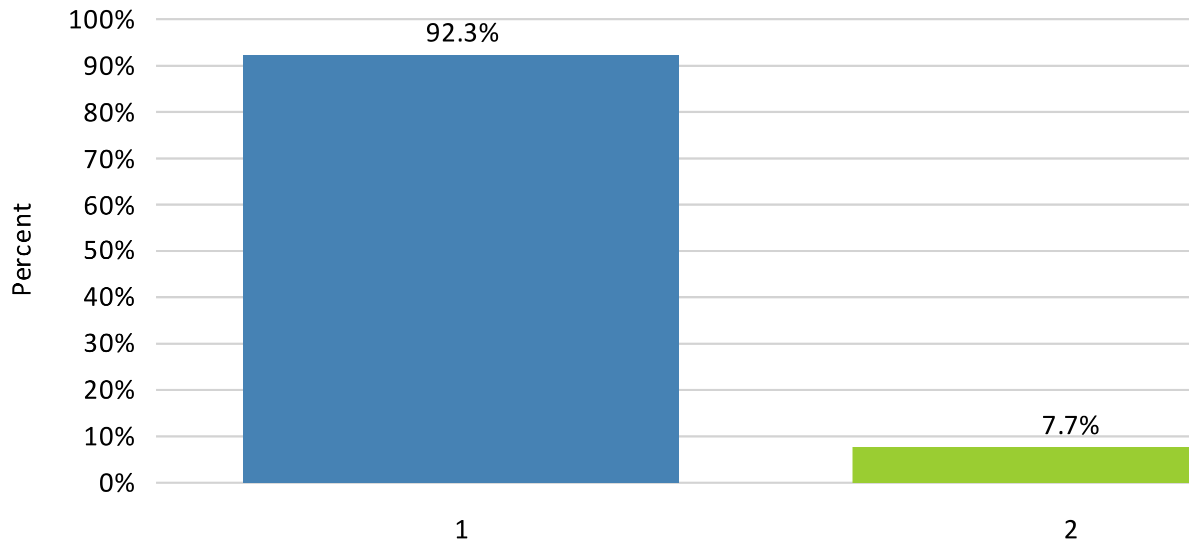


	Name
1	1
2	2
3	3
4	4
5	5
6	I don't know

- Enough for drinking water, but not enough for cultivation. The people who answered that they were pleased had only a few coconut trees or did not grow anything at all. Some people had to travel far to get drinking water because the water in their wells was too hard for drinking. The water in their wells was only good for use in the cultivation.

This is off course a season-based matter, and during the rain seasons most people were happy with the amount of water on their land. The question is if the RB-canal can help these people with an adequate amount of water through the different seasons. It seems like the people got their expectations high.

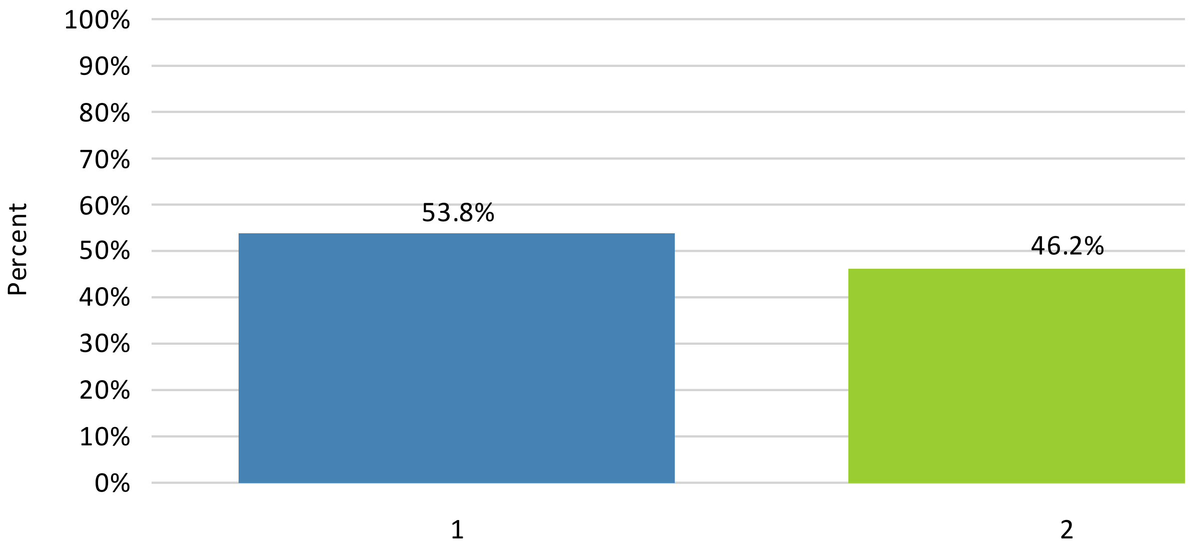
13. Do you know any water borne diseases?



	Name
1	Yes
2	No

-Diarrhea, kidney cancer, urin-stone, cholera, kidney stone and teeth problems (tooth decay, fluorosis) were the ones that most people knew about. Especially kidney cancer was common knowledge. In these areas kidney cancer can be seen as a national disease.

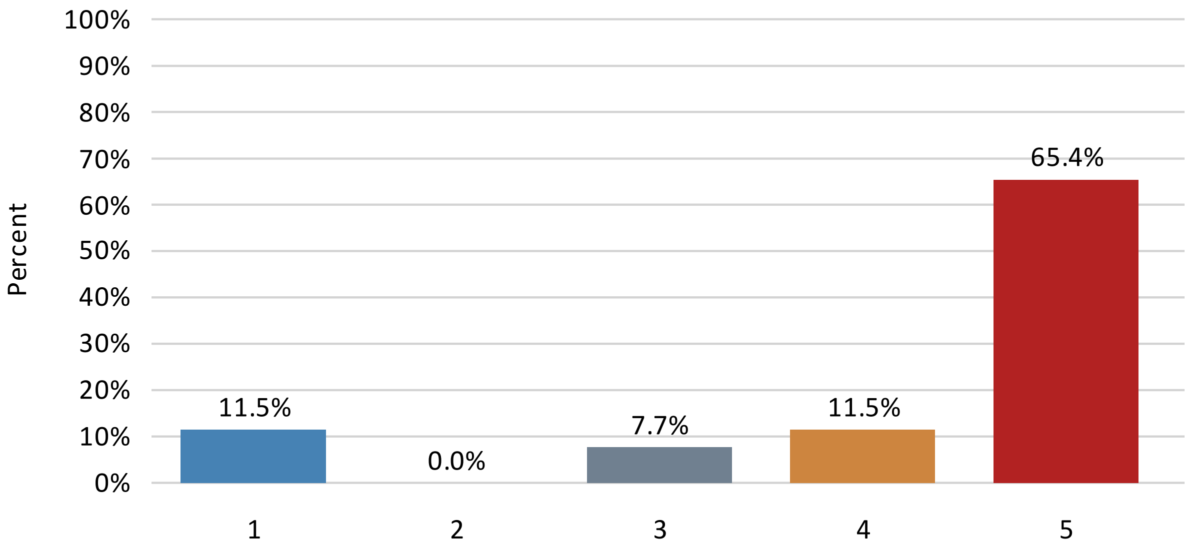
14. Do you know of anyone who has gotten sick as a result of bad drinking water?



	Name
1	Yes
2	No

- A bit over 50 % know anyone affected of water borne diseases. Again, kidney cancer was the most mentioned. We specified that diarrhea did not count as a sickness in this question.

15. How high are your expectations for the future after this project is finished? Agricultural wise, economic wise, do you expect improved living conditions etc? (From a scale from 1-5, where 1 is very low, and 5 is very high)



	Name
1	1
2	2
3	3
4	4
5	5
6	I don't know

- Generally people have high expectations towards this project. Even though they have been affected in a bad way, they were still positive to the project and the effect it can have on future generations and other people. It seemed like the majority of the people asked focused on the whole picture and not necessarily on themselves when asked this question, but many also answered that they expect more water, more blooming crops and more money which in the end would result in improved living conditions. People mentioned new cars, bigger house, water on tap etc.

6.2 Data, calculations and multipliers used for the WEAP simulation

Evaporation Data

16.09.2013

Agromet Division
Dep, of Meteorology.
Colombo.

Maho

EVAPORATION - Monthly Mean (mm)

PAN EVAPORATION DATA

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	2.31	3.24	4.21	4.04	3.29	3.54	3.22	3.65	4.67	3.26	2.40	2.53
2004	3.21	3.99	5.11	4.50	2.90	3.50	3.48	4.93	3.49	2.62	1.67	1.74
2005	2.16	3.39	4.04	2.96	3.36	3.01	3.48	4.60	4.21	2.79	1.93	1.77
2006	1.86	3.25	3.56	3.63	3.02	4.45	3.69	4.37	3.93	2.79	2.51	1.97
2007	6.98	3.03	5.37	3.49	3.81	3.34	3.83	3.42	3.08	2.72	2.27	1.90
2008	1.87	2.67	2.62	3.12	3.42	3.21	3.44	3.40	3.87	2.63	2.50	1.78
2009	2.18	3.52	3.94	3.48	3.38	3.35	3.93	4.10	3.63	3.46	2.06	1.87
2010	2.41	3.62	4.94	3.58	3.26	3.08	3.44	3.33	2.85	2.79	1.99	1.70
2011	1.45	2.40	3.64	3.42	3.57	3.68	4.57	4.14	3.52	3.30	1.77	1.73
2012	2.28	2.99	3.92	3.17	3.71	3.97	4.47	4.57	4.72	4.39	2.00	1.79
Monthly Average	2.67	3.21	4.13	3.54	3.37	3.51	3.75	4.05	3.80	3.08	2.11	1.88

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evaporation i mm	60.1	72.2	93.0	79.6	75.9	79.0	84.5	91.1	85.4	69.2	47.4	42.3

Evapotranspiration

Calculated evapotranspiration using pan evaporation data:

$RH_{mean} = 50\ e°(T_{min})/e°(T_{max}) + 50$ Case B

$ET_o = K_p\ E_{pan}$

Rhmean

84.40578	82.4339	82.82342	82.75315	87.42079	86.2819	86.33418	85.33449	83.38836	84.14467	85.09962	83.53959
81.60368	78.75996	80.30905	82.25612	84.87931	84.75044	84.0873	82.51904	82.0281	83.01317	83.52327	82.43186
80.89549	79.30184	80.47837	82.08663	84.30612	85.99959	84.17301	82.65464	83.05865	81.80359	84.11818	83.33333
82.2367	80.72735	80.84751	80.97032	82.47193	82.40979	82.93085	81.88968	84.36463	84.35947	84.94973	85.61745
84.27257	81.81818	79.20735	83.50981	85.97663	86.18702	86.40023	84.4486	85.20771	85.05237	83.08356	84.23982
83.41667	82.41701	83.33818	83.99187	85.65083	85.59356	85.22271	84.17679	82.95537	80.62875	81.50134	81.25064
79.80014	75.28161	77.14504	79.19552	82.25822	81.9436	79.52748	81.60843	84.94692	82.75207	83.23415	84.06588
80.23325	80.22996	78.15789	81.42684	83.09258	83.26362	81.81644	81.59391	80.34239	80.28141	79.54663	78.94764
#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
#VALUE!	#VALUE!	81.4846	82.51307	84.75402	85.22016	84.02727	83.51803	82.3026	82.32873	82.68544	85.00157

Source: TABLE 5. Pan coefficients (Kp) for Class A pan for different pan siting and environment and different levels of mean relative humidity and wind speed (FAO Irrigation and Drainage Paper No. 24)

Rhmean	75-87	HIGH	Gives Kp:	0.7-0.8

Eto i mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min Kp	56.1	67.4	86.8	74.3	70.8	73.8	78.8	85.1	79.7	64.6	44.3	39.4
Maks Kp	64.1	77.0	99.2	84.9	80.9	84.3	90.1	97.2	91.1	73.8	50.6	45.1

Evapotranspiration from the Pre-feasibility report,
Table 4.1:

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mm	119.38	127	157.48	127	162.56	175.26	190.5	193.04	190.5	157.48	109.22	114.3

Temperature

MAHO

MAXIMUM TEMPERATURE- Monthly Mean
(ºC)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	30.8	33.0	34.8	34.9	33.0	33.2	32.9	33.6	35.2	32.9	31.5	32.1
2004	32.9	34.6	36.5	35.2	32.3	32.0	32.5	34.7	33.9	32.6	31.3	30.7
2005	32.1	34.0	35.9	34.7	34.0	32.8	33.5	35.4	34.4	33.5	31.2	30.8
2006	30.4	32.8	33.0	34.2	33.3	33.1	33.3	34.6	34.2	33.1	32.8	30.5
2007	30.5	33.1	36.7	35.2	33.7	33.5	33.3	34.5	33.5	32.3	32.5	31.0
2008	31.0	32.9	33.3	33.9	33.4	33.1	33.0	33.5	33.1	33.9	32.3	31.7
2009	31.6	33.9	35.9	35.1	33.7	33.0	34.3	34.0	33.0	33.9	32.5	31.6
2010	32.6	35.1	38.0	35.8	34.4	33.5	33.7	33.5	33.5	32.3	32.3	31.4
2011	30.4	31.7	34.7	34.7	33.9	33.6	34.5	34.3	34.0	34.5	32.1	30.7
2012	32.6	33.2	35.5	34.8	34.1	34.1	35.5	35.5	36.2	34.1	32.7	30.9

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Maho

MINIMUM TEMPERATURE - Monhtly Mean (ºC)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	21.2	21.4	22.8	22.9	24.7	24.1	23.9	23.8	23.5	22.4	22.1	21.5
2004	20.8	19.9	22.2	22.7	22.6	22.2	22.2	22.6	21.7	21.5	21.0	19.9
2005	19.9	19.9	21.9	22.3	23.3	23.6	22.9	23.1	22.7	21.3	21.3	20.5
2006	19.6	20.2	20.4	21.2	21.6	21.4	21.9	22.1	23.5	22.8	22.9	21.7
2007	20.9	21.1	21.4	23.6	24.2	24.3	24.2	23.8	23.6	22.7	21.5	21.2
2008	20.7	21.3	22.2	23.1	23.8	23.6	23.2	22.9	21.8	20.8	20.4	19.8
2009	18.9	17.2	19.5	20.5	21.8	21.1	20.2	21.5	23.0	22.2	21.6	21.6
2010	19.7	21.2	21.4	22.5	22.8	22.3	21.4	21.2	20.3	19.6	19.1	18.2
2011	**	**	**	**	**	**	**	**	**	**	**	**
2012	**	**	22.4	22.7	23.7	24.0	24.1	23.8	23.4	22.0	21.4	21.6

** -Data not available
16.09.2013

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Precipitation data

Station: Mahagalkadawal Galgamuwa

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Yearly
2002	60	26.1	64.1	278	57.2	0	0	6	28.5	428.1	676.5	238.7	1863.2
2003	86.3	27.9	73.8	133.6	44.8	16.4	7.3	91.6	0.7	175.2	122.6	39.1	819.3
2004	21.8	0	85.3	284.8	126.3	33.7	6.3	0	320.2	237	122	-	1237.4
2005	112.7	3.6	18.2	363.9	51.7	10.4	64.7	0	0	278.4	443.6	91.9	1439.1
2006	110.6	31.6	289	28.5	54.7	10.5	0	20	47	325.6	628.2	83.2	1628.9
2007	73.6	78	102.7	206.3	2.5	0	4.8	9.5	-	471	199.8	245.8	1394
2008	87.2	71.5	288.3	119.5	0.0	0.0	21.2	60.5	11.1	228.4	303.7	179.0	1370.4
2009	58.3	0.0	105.8	118.8	3.5	17.4	0.0	60.0	4.0	78.6	390.1	144.8	981.3
2010	19.2	0	69	308.4	7.2	6.6	101	90.2	218.2	140.3	276.9	234.1	1471.1
2011	149.0	208.7	21.9	337.6	5.5	0.2	0.0	1.5	45.0	157.1	180.7	-	1107.2
2012	-	69.1	201.5	212	1.5	-	12	0	-	628.6	-	284.9	1409.6
Average	77.9	47.0	120.0	217.4	32.3	9.5	19.8	30.8	75.0	286.2	334.4	171.3	1421.4

	Station: Mediyawa Wewa												
Year	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**Yearly**
2002	0	90.1	214.9	332.2	84.5	21.6	0	26.2	0	505.5	575.6	120.5	1971.1
2003	98.1	54.5	187.2	141.8	85.8	59.5	17.1	46.9	3.6	111.5	147.1	15.8	968.9
2004	56.9	0	67.3	156.8	83.8	14.9	15.9	0	272.1	310.4	200	198.4	1376.5
2005	138.4	16.2	54.3	175.1	73.2	13.9	62	0	0	272.1	419.3	152.4	1376.9
2006	198.6	44.3	158.7	169	30	26.5	4.8	12	NA	788.1	210.7	141	1783.7
2007	92.8	17.6	0	390.3	40.8	NA	NA	9.7	117.9	373.1	338.5	271.5	1652.2
2008	102.5	39.8	386	218.5	0	48.9	76.2	65.3	51.6	387.1	202.4	34.5	1612.8
2009	77.8	0	173.2	165.3	44.7	28.2	0	41.9	0	142.7	254.9	186	1114.7
2010	38	39.6	192	295.7	34.8	7.8	0	130.8	148.3	234.5	469.1	300.6	1891.2
2011	130.5	22.3	42	121.8	56	13.2	0	0	0	168.1	79.7	NA	633.6
2012	0	125.2	164.5	289.5	0	5.3	14.2	3.5	1.9	659.2	328.1	412.6	2004
Average	84.87273	40.87272727	149.1	223.2727	48.50909	23.98	19.02	30.57273	59.54	359.3	293.2182	183.33	1515.588

Precipitation multipliers/factors

Total	Rainfall, mm	Season Type	Factor
2002	1917.15	wet	1.2
2003	894.1	very dry	0.6
2004	1306.95	normal	1
2005	1408	normal	1
2006	1706.3	wet	1.2
2007	1523.1	normal	1
2008	1491.6	normal	1
2009	1048	dry	0.8
2010	1681.15	normal	1
2011	870.4	very dry	0.6
2012	1706.8	wet	1.2
Average	1468.511768		0.963636

Very dry	0.6	881.1
Dry	0.8	1174.809
Normal	1	1468.5
Wet	1.2	1762.214
Very Wet	1.4	2055.9