Socio – Environmental Approach to Drip Irrigation System Implementation as a Climate Change Adaptation Measure within N’hambita Community Carbon Project Area, Mozambique

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**Dedication**

This work is dedicated to the two amazing women, who taught me how to seize the day, love the future and learn from the past - to my grandmothers – Milica Blagus and Zlata Barbir.

Jelena Barbir

**Dedication in Serbian:**

Посвета

Овај рад посвећујем мојим бакама, Злати Барбир и Милици Благус, које су ме научиле како да живим садашњост, волим будућност и учим из прошлости.

Јелена Барбир
Preface

The overall idea for conducting the research in Mozambique has been initiated by being introduced to the N’hambita Community Carbon Project (NCCP) through MSc Jose Carlos Monteiro, the forest researcher and representative of the IIAM (National Institute of Agronomic Research, Mozambique).

After the cooperation has been successfully established, the Memorandum of Understanding has been signed by the three parties: Universita Autonoma de Barcelona, Spain (represented by Jelena Barbir - master student and Maria Prats Ferret - the student’s supervisor), the Envirotrade (represented by Piet Van Zyl, the project manager) and IIAM (represented by MSc Jose Carlos Monteiro, the forest researcher).

This master thesis is an outcome of the 10-month research, which consisted of theoretical investigation and practical field work. The research was initiated in December 2008 and finalized in September 2009. Before starting with the field work, after reviewing the literature, the researcher prepared questionnaires, interviews and a plan of activities well in advance. The field work lasted for four weeks from the middle of March to the middle of April 2009.

In order to improve local farmers’ production in the smaller area and to decrease their vulnerability to the water scarcity, the NCCP managers initiated a small pilot project in 2007 by implementing the drip irrigation systems (DIS) within an agricultural irrigation practice in NCCP area. This research is understood as a first evaluation of this NCCP’s initiation, through social and environmental indicators. The purpose of the study was to examine social and environmental potentials in the area for implementing DIS through individual interviews and questionnaires. Furthermore, the study will assists NCCP in the further decisions making about DIS as well as contribute to the global development and improvement actions of the carbon projects.

The presented master thesis report is a prolonged version of the scientific paper to be presented at the 10th Annual Conference on Environmental Taxation, Water Management and Climate Change, on 23rd – 25th of September 2009, in Lisbon, Portugal. As an output of the conference, the scientific paper has been submitted for publishing in the one of the following international journals: “Critical Issues in Environmental Taxation” (Oxford University Press) or “Management of Environmental Quality” (Emerald Publishing Group).
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The person who inspired me to love Africa and Mozambican nature is my second co-supervisor, the forest researcher, MSc Jose Carlos Monteiro. He made Mozambique my second home, by helping me understand the local people’s customs, and for taking care of me during my stay there.

Furthermore, I want to thank the N’hambita Community Carbon Project management, and all the local people working there. Special thanks to Piet Van Zyl, his wife Ria and their children who made the days and evenings within NCCP area relaxed and pleasant. For the help in the field, I am grateful to Antonio Serra and Philip Powel, and especially to Gary Goss, who inspired us with his humour and positive energy. I want to thank my translator, Nhamo Gochococho, and above all, to the local people in the area who were willing to share their experience and information regarding their agricultural activities with me.

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Contents

Preface ............................................................................................................................................. 3
Acknowledgements ......................................................................................................................... 4
Abbreviations .................................................................................................................................. 7
List of Figures ................................................................................................................................. 8
List of Tables .................................................................................................................................. 9
Abstract ......................................................................................................................................... 10
I. Introduction ........................................................................................................................... 11
   1. The Need for the Study ...................................................................................................... 12
   2. Research Question and Objectives ..................................................................................... 14
II. Theoretical Framework ......................................................................................................... 16
   1. Socio - Environmental Approach ....................................................................................... 16
      a) Environmental and Social Indicators ........................................................................... 17
      b) Adaptive Management Framework ............................................................................ 19
   2. Measures to Cope with Climate Change ............................................................................ 20
   3. N’hambita Community Carbon Project Activities ............................................................. 21
   4. The Study Area .................................................................................................................. 23
III. Methodology ...................................................................................................................... 25
   1. Data Collection and Analysis ............................................................................................. 25
   2. Limitations ......................................................................................................................... 28
IV. Results ................................................................................................................................ 29
   1. Environmental indicators ................................................................................................... 29
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) The Irrigation Water Sources and Water Use</td>
<td>29</td>
</tr>
<tr>
<td>b) Land Use</td>
<td>32</td>
</tr>
<tr>
<td>c) Usage of Fertilizers and Pesticides</td>
<td>34</td>
</tr>
<tr>
<td>d) Plant Losses</td>
<td>34</td>
</tr>
<tr>
<td>e) Garden Productivity</td>
<td>34</td>
</tr>
<tr>
<td>f) The “D” and “T” Parameters</td>
<td>36</td>
</tr>
<tr>
<td>2. Social Indicators</td>
<td>38</td>
</tr>
<tr>
<td>a) Demographic Data</td>
<td>38</td>
</tr>
<tr>
<td>b) Awareness about the Water Significance</td>
<td>39</td>
</tr>
<tr>
<td>c) Coping with the Water Scarcity</td>
<td>40</td>
</tr>
<tr>
<td>d) Social Networking</td>
<td>40</td>
</tr>
<tr>
<td>V. Discussion</td>
<td>44</td>
</tr>
<tr>
<td>1. Efficiency of the DIS in Agricultural Irrigation</td>
<td>44</td>
</tr>
<tr>
<td>2. Successfulness of DIS Implementation in Agricultural Irrigation</td>
<td>49</td>
</tr>
<tr>
<td>VI. Conclusions</td>
<td>54</td>
</tr>
<tr>
<td>VII. Recommendations</td>
<td>55</td>
</tr>
<tr>
<td>VIII. REFERENCES</td>
<td>56</td>
</tr>
<tr>
<td>Appendix 1</td>
<td>61</td>
</tr>
<tr>
<td>Appendix 2</td>
<td>62</td>
</tr>
</tbody>
</table>
Abbreviations

AMF – Adaptive Management Framework
CRS – Constant River Stream
DIS – Drip Irrigation System
DIU – Drip Irrigation Users
DPSIR – Driving Force-Pressure-State-Impact-Response
DSR – Driving Force-State-Response
FAO – Food and Agricultural Organization
GDP – Gross Domestic Product
GHG – Greenhouse gas
GIS – Geographic Information System
GTZ – German Organisation for Technical Cooperation
IIAM – National Institute of Agronomic Research, Mozambique
IPCC – Intergovernmental Panel on Climate Change
NCCP – N’hambita Community Carbon Project
NV – N’hambita Village
OECD – Organisation for Economic Co-operation and Development
SD – Standard Deviation
SPSS – Statistical Package for the Social Sciences
SRS – Seasonal River Stream
WRI – World Resources Institute


**List of Figures**

Figure 1. Location of Mozambique, Sofala Province and the study area 13

Figure 2. Adaptive Management Framework (AMF) 19

Figure 3. The N’hambita Community Carbon Project (NCCP) area, Sofala Province, Mozambique 23

Figure 4. The distribution of the water sources of NV 29

Figure 5. The distribution of the water sources of DIU 29

Figure 6: Map of the N’hambita Village, locating wells, boreholes and rivers 30

Figure 7. The average water consumption in irrigation 31

Figure 8. The distribution of the average water consumption for DIU group 32

Figure 9. Average area of *machamba* (DIU group) 33

Figure 10. Average area of the garden (DIU group) 33

Figure 11. Distribution of different tactics to cope with water scarcity (NV) 40

Figure 12. Distribution of different tactics to cope with water scarcity (DIU) 40

Figure 13. Interviewing one of the NV farmers 41

Figure 14. The DIU farmers of Mutiambamba Village 43

Figure 15: Demonstration of the three comparisons, used to investigate DIS efficiency 45

Figure 16: Pyramid of the irrigation efficiency 48

Figure 17: Adaptive management framework a) finished steps in red colour, steps in process in orange b) recommended steps in green colour 51
List of Tables

Table 1. Display of the gathered data 26

Table 2: Relations between agricultural irrigation and gardens’ productivity 35

Table 3: Economical potential of the DIU farmers to pay the instalments for DIS 36

Table 4. Calculations of DIU’s and NV’s total walking distance (D) and total time consumption (T) in collecting irrigation water daily; (n-presents the number of the interviewees and SD-standard deviation) 37
Abstract

The research was undertaken in Mozambique as a part of the N’hambita Community Carbon Project (NCCP), in the buffer zone of National Park Gorongosa (Sofala Province), in order to investigate, through social and environmental indicators, the efficiency of drip irrigation systems (DIS) and success of DIS implementation in NCCP area. The goal of NCCP is to alleviate poverty and develop sustainable rural communities through creating and safeguarding natural carbon sinks in the Miombo woodlands of central Mozambique. According to many present scientific predictions, the climate change is expected to increase the impact of droughts and water deficit during the dry season within the area. This research takes place in a context of climate change, presenting the activities within the project to mitigate climate change (CO₂ sequestration) and investigating possibilities for climate change adaptation regarding water management within the NCCP area. The methodology of the research is based on interviews, questionnaires, GPS mapping of water sources and observation of the water use within agricultural activities. One of the most important activities of the NCCP regarding the climate change adaptation, considering water management, is their initiative to promote the drip irrigation systems among the local people. This has been done in aim to improve local food production within reduced agricultural area, and to decrease the traditional practice of opening new gardens. The investigation of this NCCP initiation has been done in order to facilitate further decisions regarding drip irrigation implementation within carbon project boundaries.

Keywords: Mozambique, carbon project, water management, drip irrigation system, climate change mitigation and adaptation
I. Introduction

This research has taken place in rural Africa, within the N’hambita Community Carbon Project (NCCP) area, Sofala Province, in Mozambique. The NCCP’s activities started in 2003, in aim to develop sustainable rural communities and to alleviate poverty through the process of carbon sequestration.

The main driving force for the researcher was the fact that the people of rural Africa continuously struggle with water and food related problems. Additionally, the motivation to develop the master thesis research, based on the practical experience in the field, was the opportunity to contribute with the research findings to the further decision making in the NCCP area.

The connection between NCCP’s activities, water management, food production and local communities has been found in drip irrigation systems (DIS) implementation, organised as a pilot project by the NCCP. This pilot project has been initiated so it could improve food production of the local people and to motivate them to reduce deforestation. The research is based on the assumption that the N’hambita Community Carbon Project (NCCP) area has a good socio-environmental potential to adopt drip irrigation system in the agricultural practice.

The master thesis report consists of six chapters: introduction, theoretical framework, methodology, results, discussion, conclusions and recommendations.

The first chapter introduces the reader with the research, presenting the need for the study, the research question and objectives which would later in the research prove to be the guiding threads of the research. The second chapter informs the reader about the theory related with the study, presenting frameworks and terms used further in the results and discussion part. In the methodology chapter, the researcher introduces the methods of data collection and analysis as well as limitations the researcher faced during the investigation. The fourth chapter presents the results as environmental and social indicators. In the fifth chapter, the researcher presents three different sub-chapters which are titled in correlation with the research objectives, creating the common answer on the research question. The last two parts of the research consist of the conclusions and recommendations, developed throughout this research.
The overall idea of the introduction is to examine the rationale behind the study, and its contribution to further decision making regarding NCCP’s and other carbon sequestration projects’ activities and investigations; all in order to explain need for the study and to state the research question.

1. The Need for the Study

Climate change is one of the biggest global problems and threats the world is facing today (Barbir et al., 2008) and many recent studies have tried to estimate the impact of climate change on the environment (Sanchez, 2000; Christensen et al., 2007). According to the Intergovernmental Panel on Climate Change (IPCC) prediction, until the end of 21st century, the global annual median surface air temperature will increase by 3–4°C (Christensen et al., 2007), consequently causing changes in the climate and the environment.

The degree of changes caused by climate change differs among the continents and regions, depending on the ecosystem’s vulnerability. Africa is the second largest continent of the world with the highest rate of population growth in the world (Africa Environment Outlook, 2002), and one of the regions that is the most vulnerable to climate change (Christensen et al., 2007).

As presented by World Resources Institute (WRI) (WRI, 2000), Africa is the continent most highly reliant on the agricultural sector. This can be concluded from the fact that agricultural sector contributes in average 21% of total African Gross Domestic Product (GDP) with a ranging from 10 to 70% between African countries (Christensen et al., 2007). Although this range is relatively wide, when it is compared with the agricultural contribution to GDP within developed countries (which varies from 0.5 to 3%), the demonstration of agricultural importance in Africa becomes apparent (UNDP, 2008).

As stated by Usman and Reason (2004), the agricultural sector is particularly sensitive to periods of climate variability. In addition to that, the IPCC predicts with high confidence that both agricultural production and food safety in many African regions are likely to be compromised.

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1 vulnerability is defined as “the extent to which a natural or social system is susceptible to sustaining damage from climate change” (IPCC, 2001)

2 GDP is the total market value of all final goods and services produced in a country in a given year, equal to total consumer, investment and government spending, plus the value of exports, minus the value of import
under climate change (Hegerl et al., 2007). Regarding this factor, it is immensely important to secure and improve agricultural activities in order to adapt climate variability in Africa.

Agriculture is considered as the most important user of the water resources in Africa. This is primarily in the form of agricultural irrigation, as a response to dry climate and frequent droughts occurring within the continent. Considering that Africa occupies 20% of global land area, its share of global freshwater resources (about 9%) is proportionally low (Shiklomanov 1999) and has to be managed very carefully within agriculture to achieve successful and sustainable development. In order to adapt to population growth, constant temperature increase and decreased rainfall, the total irrigated area is constantly increasing in Africa (Harper, 1995).

Mozambique is situated on South-Eastern African coast, occupying the area of 787 608 km². It has a population of 21 million people of which 14.9 million (71%), live in the rural areas (Food and Agriculture Organisation (FAO), 2000). Furthermore, Mozambique is one of the poorest countries in the world, and is still recovering from 16 years of civil war (1977-1992). This, in combination with the droughts and flood of that period, has alienated about six million people from their land, affecting agricultural activities respectively (Simler et al. 2004).

Figure 1. Location of Mozambique, Sofala Province and the study area

Due to the fact that 63 percent of rural Mozambican children live in absolute poverty and 34 percent of households are food insecure and facing perpetual hunger (WFP, 2009), establishment of better food production in rural areas is of crucial significance for Mozambique. One of the
agricultural improvements and tactics to alleviate poverty is agricultural irrigation, which contributes to food production in the rural areas during the dry period.

According to Hillel (1997), the potential irrigated area in Mozambique, was 3,072,000 ha in 1991, while the actual area under irrigation 106,710 ha (4%). The irrigated area of Mozambique, estimated in period from 2001 to 2003 is 118,120 ha, and 24,220 ha of that area belongs to the Sofala province, which is the second most irrigated province in Mozambique (Siebert, 2006). Considering those data, it is evident that the irrigated area of Mozambique is constantly increasing.

Addressing the water scarcity, undernourishment and constant increase of irrigated areas in the text presented above, the improved efficiency in water use and water conservation is a logical solution to the water shortages. Irrigation is estimated to be the highest water consumer and thus, there is a need to replace existing wasteful irrigation systems with more efficient systems for an instance, drip irrigation systems (DIS) (Harper, 1995).

The initiative of NCCP, within the water management boundaries, is to promote DIS among the local farmers in a bid to improve local agricultural production. This pilot project has been in operating for two years, which is a suitable amount of time to evaluate the pilot project success and relevance for the area. This study can be described as the first evaluation of the NCCP pilot project of DIS implementation, and its findings (regarding social and environmental aspect) are of crucial importance for the future NCCP management decisions regarding this implementation.

Furthermore, this study is understood as an external evaluation, performed by the researcher who is not directly involved in the project; therefore, it assists considerably to more objective estimation of the DIS implementation initiated by NCCP.

2. Research Question and Objectives

The mentioned need for the study induced the formulation of the following research question:

What is the socio – environmental potential to implement drip irrigation systems as a climate change adaptation measure within N’hambita Community Carbon Project area, Mozambique?
The research question considers two aspects, environmental and social, creating the complexity of the research. Approaching the research, while considering those two aspects, should provide a valuable insight into the integration of two perspectives into one general conclusion about the project’s potential to implement DIS within NCCP area.

In order to facilitate the process of answering the research question, the investigation is divided in three main sectors, in accordance with the research objectives outlined.

Objectives:

1. To investigate the efficiency of the DIS in agricultural irrigation within the NCCP area
2. To estimate the success of DIS implementation in agricultural irrigation within the NCCP area
3. To estimate the socio-environmental potential to implement DIS in N’hambita Village’s agriculture
II. Theoretical Framework

This section of the master thesis report aims to present and explain the theoretical framework by introducing the subject to the reader and facilitate the understanding of the subsequent results and discussion sections. It consists of four parts. The first part explains the meaning of the term “socio-environmental approach”, and introduces social and environmental indicators. In the continuation of the first part, the researcher defines Driving Force-Pressure-State-Impact-Response (DPSIR) framework and Adaptive Management Framework (AMF), which are going to be used while the results are discussed. The second part of the theoretical framework presents climate change as the greatest environmental challenge the world is facing today, and introduces measures to cope with climate change. The third part presents the N’hambita Community Carbon Project’s activities related with its initiative for DIS implementation, as a climate change adaptation measure, and finally, the fourth part describes the study area.

Before moving to the next section, the researcher wishes to further clarify two terms used in this report, so as to avoid confusion. The terms in question are: “DIS adoption” and “DIS implementation”. Under the “DIS adoption” term, the researcher considers the complete process of the new technology adoption (from the NCCP’s idea to introduce DIS to the local farmers, trough all the steps of AMF, and to finalize with the phase when DIS is completely accepted and successfully used by the farmers). The “DIS implementation” term, is considered, however, as one step of AMF, where DIS is offered to the farmers who voluntarily signed the contract with the NCCP to use the system.

1. Socio-Environmental Approach

Throughout history, there have been many cases of social collapse induced by the environmental degradation. Some of the most powerful civilizations in history, such as the Mayan and Western Roman Empire, collapsed due to intensive deforestation, which consequently caused soil erosion and decline in soil productivity (Faust, 2001). Additionally water problems and its scarcity have the potential to act as a catalyst in both international and civil conflicts; as is the case between Ethiopia, Sudan and Egypt - depended on the Nile flow; India and Pakistan in conflicts over Kashmir, and Israel and Palestine conflicts over Euphrates (Harper, 1995). Due to numerous examples of the society dependence on the environment, it is constantly confirmed that the socio-environmental relations are strong (Harper, 1995).
Despite the trend of increasing urbanization in sub-Saharan Africa, it is estimated that at least half of the poor people are expected to remain in rural areas by 2035, keeping smallholder farming functioning (IFAD, 2001). Food and Agricultural Organisation (FAO) is underlining the importance of keeping the practice of local people, protecting their culture and customs, while considering agriculture. Although nowadays, the researchers and policy makers are highly aware of the importance of considering social aspect when creating a plan for agricultural changes, they are still struggling to find the right way of doing that (Doss, 2001; Osbahr et al., 2008).

For instance, FAO (FAO, 2008), emphasises a lot of other ways to overcome water bottle-necks, than creating specialised irrigation farm units managed by full-time professional farmers, suggesting more appropriate technologies for rural areas in developing regions. Although this approach is nowadays focused more on local farmers, there is always a possibility of the failure in successful technology adoption, as reported in many case studies (Marra et al., 2003). Implementation of the new technologies, without a significant impact on the local customs, tradition and habits remains a great challenge for the management (Allen et al, 2001).

When implementing a new technology in agriculture, it is immensely important to develop indicators to be investigated further on, in the process of monitoring and evaluation. The choice of the indicators to be investigated is always closely related with the scope of the research (Shields et al., 2002). For instance in this study, once the new technology is implemented, it is of crucial importance to monitor the socio-environmental changes caused by the DIS implementation, through social and environmental indicators.

a) Environmental and Social Indicators

Indicators in general, can be understood as the measurement tool which helps to package complex information into a more simple and useable form for public policy. Particularly this ability describes the indicators as a highly desirable in a progress toward sustainability goals (Shields et al., 2002).

Due to the fact that sustainability is a creation of three dimensions, social, environmental and ecological dimension; the indicators of sustainability are organised in the appropriate three groups as well (Spangenberg, 2002). As this research is focused on the socio-environmental analysis, the social and environmental indicators are developed and investigated.
One of the most important challenges, when quantifying the impact of agriculture on the environment, is to provide the appropriate framework to support the empirical analysis of the relations between agriculture and environment. The Organisation for Economic Co-operation and Development (OECD) claims that in order to estimate agro-environmental linkage, the most important step is to identify and develop policy-relevant indicators, agro-environmental indicators\(^3\) (OECD, 1999). In this regard, OECD additionally presents a Driving Force-State-Response (DSR) framework which helps the policy makers to develop agro-environmental indicators.

In 2001, Wilson and Buller criticised the OECD’s usage of DSR environmental framework, which is focused only on the environmental indicators development, disregarding the social aspect. Arguing the lack of the social intrusion in scientific research in general, the authors state that scientists are mostly reliant on the statistical and numerical results, with the aim of achieving desired conclusions (Wilson and Buller, 2001). In addition, they argue that generalisation is the main enemy of the social research, and that in many cases the statistical significance has to be taken with a reserve when explaining phenomena of interest.

Significant research on the correlation between social and environmental aspects was undertaken by two researchers, Stewart Lockie and Susan Rockloff, who both work in the field of the water resources management. They were investigating the potentials of different frameworks for developing social indicators\(^4\), and combining them with environmental indicators. In 2005, Rockloff and Lockie presented the Driving Force-Pressure-State-Impact-Response (DPSIR) model, as a framework which possesses a good potential to include social aspect in decision making, through the processes of social learning (Lockie and Rockloff, 2005). Driving force-Pressure-State-Impact-Response framework is actually an improved Driving force-State-Response framework, adopted to develop social and environmental indicators in agricultural sector. Furthermore, DPSIR framework is created with aim to understand the interrelation of

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\(^3\) “are selected key statistics which represent or summarize a significant aspect of the state of the environment, natural resource sustainability and related human activities. They focus on trends in environmental changes, stresses causing them, how the ecosystem and its components are responding to these changes, and societal responses to prevent, reduce or ameliorate these stresses.” (SOE Infobase, 2009)

\(^4\) The term has been developed in 1980’s explained as the quantitative measurement of social phenomena (Horn, 1980)
complexity and feedbacks between the causes and effects of agriculture’s impact on the environment.

The DPSIR framework has not been followed when developing social and environmental indicators for this research, because the data collection for developing DPSIR framework demands longer investigation and more time in a field, than the researcher had. That is why, the framework is recommended to be used by NCCP in the future process of DIS adoption. The framework which is used in this research, with aim to present and estimate the NCCP’s success and development, in the process of DIS adoption, is Adaptive Management Framework (AMF).

b) Adaptive Management Framework

Adaptive Management Framework (AMF) is an ongoing process of social learning and consists of five steps: information collation, system analysis and vision, plan making, implementation, and monitoring and reviewing (Figure 2).

![Figure 2. Adaptive Management Framework (AMF) (source: Lockie and Rockloff, 2005)](image)

The information collation is the first phase of the process which helps in identification of social and environmental problems, providing a basis for successful process planning (Habron, 2003). The system analysis and vision phase, is the step of the process where the information collated are analysed with aim to develop a clear vision of the further actions. Additionally, this step is
also understood to have a good potential for the DPSIR approach incorporation (Lockie and Rockloff, 2005). In that way, the system analysis and vision phase is the place where the indicators of interest are developed. In the step of plan making, the complete strategy for implementation is developed and in the step of implementation the strategy is applied in practice. The monitoring phase, evaluates if the new management action meets social and environmental values, and if fulfil agreed targets and goals (Osternbern, 1988). This leads to the new information collation and initiation of second cycle in the process of social learning.

The AMF is used in this research to describe the present state of the DIS implementation process, and to evaluate which steps are fulfilled by the NCCP and which steps should to be repeated or improved.

2. Measures to Cope with Climate Change

As mentioned in the introduction, it is scientifically proven that climate change is happening and that it is going to impact the environment to some degree (Bates et al, 2008). For the most part, the provisions indicate negative impacts of climate change on the environment, but there are also some studies arguing that climate change might bring some positive changes as well (Menendez et al, 2008). Although, the positive impact of climate change is noticeable, it could be neglected in comparison with the negative impact on the environment (IPCC, 2001).

Regarding the south-Africa region, the two provisions for the following period, regarding climate change impact on the water resources, are of significant importance to create adequate future water management decisions for the region. One provision is that arid and semi-arid areas in Africa will expand by about 5 – 8% as a result of climate change (Shah et al., 2008) and another that average runoff and water availability will decline in northern and southern Africa impacting on freshwater ecosystems (Bates et al, 2008). Both provisions point out that northern and southern Africa are the most vulnerable of Africa’s regions to the water scarcity in the future period.

The most widely considered responses to climate change are climate change mitigation (reduction of greenhouse-gas (GHG) emissions and enhancing sinks) and adaptation to the

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5 Are gases in the atmosphere that absorb and emit radiation within thermal infrared range (water vapor, carbon dioxide, methane, nitrous oxide etc)
impacts of climate change (UNFCCC, 2003). To define those terms in the most simple of ways, it could be said that the mitigation is understood as a protection of Nature from society, while adaptation is interpreted as society protection from Nature (Stehr and Storch, 2005).

Coping with climate change in developing countries (which are highly vulnerable and economically unstable), is facilitated by creating synergies between adaptation and mitigation, which consequently increase the cost-effectiveness of the actions, making them more attractive to stakeholders (Barbir et al, 2008). Considering that mitigation efforts will not prevent climate change in the next few decades (Chen et al., 2007) the vulnerability reduction of ecosystems, sectors and communities, by the means of adapting to climate change impacts, is necessary.

The new trend to cope with climate change is carbon sequestration projects initiation all over the world, and especially in developing countries which are highly vulnerable to climate change. The carbon sequestration is interpreted as the process of removing CO\textsubscript{2} directly from the atmosphere and locking it up physically or chemically in carbon sinks, while carbon sinks are described as natural systems that remove and store carbon, e.g. forests, soil, oceans (Farage et al., 2007).

This study took place in the context of the social aspects of climate change, investigating a potential success of an ongoing carbon sequestration project in Mozambique, the N’hambita Community Carbon Project (NCCP) to implement drip irrigation system (DIS) which is to be adopted by local farmers in rural area. The NCCP’s activity of CO\textsubscript{2} reduction from the atmosphere is understood as mitigation to climate change and its initiative to develop sustainable rural communities which are less vulnerable to climate change, as an adaptation.

3. N’hambita Community Carbon Project Activities

Although the NCCP objectives are mainly focused on the forestry and land management within the area, the NCCP managers have decided to incorporate water management into their activities. Due to the fact that this research is focused on the water management in agriculture, within the NCCP, this section will not present the NCCP’s activities related with carbon sequestration and forestry management. Instead, this section will be more focused to present the agricultural irrigation and production.
The main soil type within the study area is generally poor, extremely weathered, and freely draining sandy, sandy silt loams and with a low fertility (Williams et al., 2008). Regarding the land use, NCCP farmers distinguish machambas and gardens. Machambas are rain fed agricultural fields for growing mainly corn, and in most of the cases are bigger than gardens. The local gardens are smaller than machambas, and irrigated by farmers manually, during the dry season. In those gardens, farmers grow vegetables such as: tomato, watermelons, melons, peppers etc. (field observation, 2009).

Furthermore, the local communities within the NCCP area are divided into two categories regarding the gardens’ location: communities with gardens close to a constant river stream (CRS), and those communities that rely on a seasonal river streams (SRS). Due to the tropical and subtropical climate of that region, it is noticeable that during the wet season, communities and vegetation are well provided with water, but then during the dry season, water deficit is rather obvious, especially affecting the communities reliant on the seasonal river streams (interview - NCCP manager, 2009). Provoked by this tropical climate and occurrences of extremely dry periods, there is a need for including measures to climate change adaptation in the project (Andersson et al., 2006).

In order to improve local farmers’ production in the smaller area, to encourage them to stop with the slash and burn\(^6\) practices, to motivate them to use a limited agricultural area for a long term period and to decrease their vulnerability to the water scarcity, the NCCP managers initiated a small pilot project in 2007 by implementing the drum kit drip irrigation systems (DIS) within an agricultural irrigation practice in Mozambique.

Historically, the first planted drip irrigation system has been developed in Israel in the early 1960s, using a micro-tube extending from a plastic, to irrigate trees and about in the same time, in Denmark was used the same kind of tube to water flower pots (Sijali, 2001). This system, modified and adopted to different regions and practices is used today all over the world, and especially within the areas where the water scarcity is rather noticeable. The efficiency of the drip irrigation is estimated at more than 90%, comparably higher than sprinkler irrigation (75%)

\(^6\) consists of cutting and burning of forests or woodlands to create fields for agriculture
Moreover, since its great water use efficiency, it is widely used in the developing countries.

In the process of DIS implementation, the NCCP offered 38 drip irrigation systems (DIS) to random volunteers of the CRS communities, excluding the communities within the dry area (SRS), when distributing the drip irrigation systems (field observation, 2009). All the volunteer-farmers agreed to sign a contract with NCCP. According to the contract, local farmers were obligated to purchase the DIS within 3-year period, paying annual instalments of 57 Euros. For that price, the farmers were offered a drum kit DIS, consisting of a 250 L volume water tank, filter, and the pipes. This drip irrigation system covers and irrigates the garden area of 250m².

4. The Study Area

The research has been carried out in the NCCP area, placed in the buffer zone of National Park Gorongosa, Sofala Province, Mozambique. The boundaries of the NCCP area are the Pungwe River to the South, the Vanduzi River to the West and Gorongosa National Park to the East and North (Figure 3). The biggest river passing through the research area is the Pungwe River, meaning that all the sources of the surface water used by the local people are part of the the Pungwe River Basin.

Figure 3. The N’hambita Community Carbon Project (NCCP) area, Sofala Province, Mozambique (Source: NCCP)
The NCCP area is bisected by the national road (EN-1) that runs between the towns of Gorongosa and Inchope. The larger part of the area lies east of the EN-1 road, where the project establishment and the villages of Bue Maria, Munaganha, N’hambita and Mutiamamba are situated. The rural road (ER-418) runs East-West from the EN-1 road, providing access to these villages. The villages to the west of the road EN-1, Mbulawa, Povua and Pungwe, lie outside the designed buffer zone.
III. **Methodology**

The methodology is defined as a way of conducting a research, usually including the use of different research methods. The research methods are defined as techniques used for data gathering (Bayers, 1996). The different methods used in this research are integrated in a coherent research process which builds on the relative strengths and weakness of each method.

1. **Data Collection and Analysis**

During the 4-weeks field work in NCCP area, qualitative and quantitative data was collected through semi-structured interviews, semi-structured questionnaires, social meetings and direct behaviour observation. During these four weeks, the researcher was accommodated in the NCCP camp (10min walk from N’hambita Village) which facilitated the interviews’ conduction and other activities, such as observation of the daily water usage and social networking.

The first day in the field, the researcher was familiarised with the area and one of the NCCP technicians helped the researcher to create a map (a drawn one) of the N’hambita Village. The map includes the households, rivers, shops as well as the location of all water sources (wells and boreholes) in N’hambita Village. That facilitated organisation of the research in the field to a greater extent.

Focused formal and informal semi-structured interviews were conducted, audio recorded and finally transcribed. The interviews were conducted among NCCP managers, N’hambita Community leaders, some of the NCCP technicians, and N’hambita Village primary school principal and teachers. The NCCP managers and technicians were interviewed with aim to collect information about the project activities and future plans, while the N’hambita Community leaders and primary school staff were interviewed with the aim of investigating the social networks of N’hambita Village.

The local people who were interviewed through semi-structured questionnaires were initially divided into two analysed groups: N’hambita Village (NV) group and Drip Irrigation Users (DIU) group (Table 1).
The NV group consists of 42 female representatives, sampled randomly. Of total 84 households of the N’hambita Village, 42 households (50% of total number), were represented in the interview by one adult woman of the household\(^7\). The interviews have been focused on women, under assumption that they are responsible for the water supply and agricultural activities within NV due to the fact that NCCP is located near, and men are mostly involved in its activities.

The DIU group consists of 35 local farmers (34 male and 1 female) from three NCCP villages (Mutiamambamba, Munhanganha, Bue Maria), who were offered the DIS as a new technology in their agricultural activities. Of overall 38 farmers, who have signed the contract with the project obliging them to use the DIS, 35 of them (92%) have been interviewed. Of those 35 interviewed farmers, 9 farmers stated that they were not using the DIS and due to that questionnaires were not conducted. Instead, those nine farmers were interviewed in order to understand their reasons for not using the drip irrigation system.

Having two groups of farmers, two different semi-structured questionnaires were conducted; one among the DIU farmers and another among the women of N’hambita Village. The questionnaires

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\(^7\) In the NCCP area polygamy is very common, and the households with one man and two or more wives are rather frequent. In those households, women mostly agreed about who will represent the household, or sometimes it was an obligation of the first wife to represent the household in the interview (field observation)
were created differently, because the DIU farmers were asked additionally to compare the data between the years (2006, 2007 and 2008), while NV farmers were asked just about the information from 2008. Both questionnaires were pilot-tested before starting the research and the reliability of the answers was checked by performing the same interviewees twice through the identical questionnaire. The data from the survey questionnaires has been analysed using the descriptive statistics and graphical representations respectively. In order to summarise the patterns in the responses within the investigated groups, arithmetic means, standard deviations and frequency distributions were performed.

Some of the data gathered from the questionnaires, were further processed with a statistical programme: Statistical Package for the Social Sciences (SPSS), version 16.0. The programme was run in order to estimate correlations between some parameters and the significance of the differences between the parameters among the two groups investigated. In order to estimate if there is any significant correlation between two parameters, the researcher was using Pearson parametric test. The Independent Sample T-test has been used in order to estimate if significant difference between parameters exists.

Furthermore, direct behavioural observation was undertaken in the N’hambita Village which focused on the women’s behaviour in their everyday activities relating to the water usage within their households. One meeting was organised in the primary school of the N’hambita Village, in order to investigate the social potential of NV farmers in organising an association, meetings and networking.

The average daily walking distance (garden-water source) and the average daily time spent in collecting the irrigation water were calculated using two equations created by the researcher in accordance with the field data (Equation 1 and 2).

\[
D = \frac{\sum [Dp \times 2 \times Wp]}{20n}
\]

(Equation 1)

\[
T = \frac{\sum [Tp \times 2 \times Wp]}{20n}
\]

(Equation 2)
(D – average daily walking distance [m/day]; Dp – distance garden-water source (m); Wp – irrigation water withdrawal (l/day); T – average daily time spent in collecting the irrigation water [min/day]; Tp – time spent in walking garden-water source (min); n – number of farmers)

The values of Dp and Tp are multiplied by 2 in order to calculate the return distance/time from the garden to water source. As all the farmers use the 20 L water containers to fetch the water, the value of Wp is divided by 20 to estimate how many times farmer has to walk the distance (Dp).

Additionally, the GPS coordinates of N’hambita Village water sources were collected in the field and the map (Figure 6) has been created by Arc Geographical Information System (GIS) programme.

2. Limitations

Because the research was conducted in a sub-Saharan rural area; the field work organisation demanded a different approach to the research than in modern and developed countries. For example, in many cases, the interviewees were shy and uncomfortable to answer interview questions; in those cases the researcher approached the participants by explaining in detail the work and the purpose of the research. Sometimes, the researcher spoke about her own family and the customs of her home country, trying to overcome the social barriers.

Additionally, the official language of Mozambique is Portuguese, and was used mostly during the interviews. Some of the local farmers, however, were using local languages, Sena and Shona. The process of translation was time consuming and sometimes caused misinterpretation and confusion. The researcher needed to explain the translator the purpose and the meaning of some questions on several occasions to avoid potential misunderstandings of the data. This small setback was overcome successfully, since the interviewer had some previous knowledge of Spanish and was able to understand the conversation between interviewees and the translator in Portuguese.
IV. Results

The results are organised into two categories: environmental and social. Environmental data is presented through environmental indicators, and the social data through social indicators. Those two groups of indicators are combined later on, in the discussion part, in order to create the socio-environmental approach to the research question.

1. Environmental indicators

The following environmental indicators are chosen by the researcher with an aim to analyse the efficiency of drip irrigation system (DIS) in agricultural irrigation and to understand the irrigation and agricultural practices within the NCCP area.

a) The Irrigation Water Sources and Water Use

Distribution of the different water sources used by the local people in the irrigation process within two groups (NV and DIU) is presented in the Figures 4 and 5. From these two figures, it is noticeable that irrigation water source diversity is higher within the NV farmers than DIU farmers.

Within N’habita Village, beside surface water streams, four wells and three boreholes are constructed by external organizations (NCCP, German Organisation for Technical Cooperation (GTZ) and UNESCO). Although NV farmers mostly rely, in agricultural irrigation on the surface water streams (Ripisse River-73% and Pungwe River-10%), 7% of the NV farmers, use GTZ wells while, 10% of them get their water for the agricultural irrigation purposes from boreholes.
Additionally, using GPS coordinates of the water sources taken directly in the field, a map (Figure 6) is created by GIS in order to present distribution of NV water sources. As seen from the map, wells and boreholes are equally distributed within N’hambita Village, allowing the local people to approach the drinking water easily. The difficulty is that the gardens are not placed near the water sources, so in order to fetch the irrigation water NV farmers have to walk long distances.

![Figure 6: Map of the N’hambita Village, locating wells, boreholes and rivers (field data)](image)

The DIU farmers supply irrigated water only from the river streams, as their gardens are located next to the river banks. Within DIU group of farmers, 88% of them irrigate their gardens from the Pungwe River, which is characterised as a constant river stream (CRS) while 12% of them use the Ripisse River – a seasonal river stream (SRS) which is closer to the garden. As SRS dries
out during the dry period, those 12% of DIU farmers have to walk longer distances to fetch water from the Pungwe River.

Only 15% of the DIU farmers irrigate their gardens by using just DIS, while the other 85% of the DIU farmers own the additional part of the garden that is irrigated manually. In Figure 7, the distribution of the average amount of irrigated water used daily per square meter is demonstrated between NV and DIU farmers (columns 1 and 2), and drip and manual irrigation within DIU group (columns 3 and 4).

Furthermore, in Figure 7 it is evident that within the N’hambita Village, water is used at the rate of 0.83 l/m²/day. In this case, all interviewed farmers were familiar with the amount of water they use in garden irrigation. An issue that came up, while interviewing the DIU group, was that 50% of the farmers were not able to distinguish the amount of irrigated water spent manually and by using DIS. The data presenting this division within the DIU group is gathered from 50% of the total DIU framers population participating in the study (Figure 7, third and fourth column). The water used by the NV farmers at the rate of 0.83 l/m²/day, is significantly higher than the rate of 0.47 l/m²/day used for manual irrigation by the DIU farmers. The water used in the process of drip irrigation (2.03l/m²/day) is even higher than in both instances of manual practice (Figure 7, column 3).

![The Average Water Consumption in Irrigation (comparison)](image)

**Figure 7. The average water consumption in irrigation (field data)**

Although higher water consumption is noticeable in the case of DIS usage, than in the case of manual irrigation, DIU farmers argued that they achieved better productivity, better quality of
vegetables, faster growth of the vegetable, and reduced plant losses in the part of the garden which was irrigated through the DIS system.

Even though, the results indicate that there is significantly higher water consumption when using DIS in comparison with using manual irrigation, the average amount of water (manual and drip) used by the DIU farmers shows an overall decrease in water consumption in a three-year period (Figure 8).

![The Water Consumption in Irrigation](image)

**Figure 8. The distribution of the average water consumption for DIU group (field data)**

From observing the data of water consumption over the three year period (2006-2008), it is noticeable that the amount of water (l/m2/day) had slightly decreased when DIS was implemented (in 2007), and remained unchanged in the following year (in 2008).

### b) Land Use

As already mentioned in the text, the local farmers of NCCP area distinguish two types of agricultural areas: *machambas* and gardens. Comparing the average garden area of NV and DIU, the NV farmers own smaller gardens (0.38ha) than DIU farmers (0.50ha). The results gathered from the DIU group, while comparing the average areas of *machambas* and gardens in the period of three years; show that the average area of *machambas* has increased yearly (Figure 9).
Considering the gardens (Figure 10), in the period between 2006 and 2007 the average area of the gardens expanded from 0.54ha to 0.57ha, but after implementing the drip irrigation systems in 2007, the average area of the gardens remained unchanged. This result is in accordance with the main NCCP pilot project objective to use drip irrigation system as a technology which will increase garden efficiency and motivate farmers not to expand their agricultural area.

Additionally, 52% of the DIU interviewees explained the researcher their plans to expand the area of their machambas and gardens in the future. The reason for these plans was not to increase the production of the essential food for the households’ needs, but to increase the production of additional food to be sold on the market. This partly shows that the DIU farmers produce enough food for their household’s needs, but the production is not efficient enough for earning additional income. Other 48% of the DIU farmers, who do not plan to expand their gardens, justified their decisions mainly with reporting sufficient food production. Only few of the farmers mentioned the lack of an additional agricultural area next to the river bank for the reason.

The Pearson’s parametric test has been run in order to estimate if there was any significant correlation between the garden area and the amount of irrigated water in both groups of the framers (NV and DIU) in 2008. The results of the test show a significant negative correlation between those two parameters in both groups, when using a statistical significance of \( p=0.01 \). This means that when the garden area increases, the farmers are using less irrigated water per square meter of the garden. The statistical calculations are presented in the Appendix 1.
c) **Usage of Fertilizers and Pesticides**

The results conveying the use of the pesticides show that the DIU and NV farmers do not use any pesticides, or any other alternative method to fight against insects. Regarding fertilizers, only one DIU farmer uses fertilizers as part of DIS system. Additionally, the farmers were asked if they prepare compost or if they use any other natural fertilizer. The answers were always negative, with an explanation that if they notice decrease in soil fertility, they switch to a new piece of land and open a new *machamba* or a new garden.

**d) Plant Losses**

In order to describe the garden productivity, farmers from both groups were asked to explain their plant losses and to categorise the reasons of the plant losses.

In 2008, 32 of 42 NV farmers (71%) reported problems with plant losses in their gardens. Fifty one percentage of those farmers explained that insects destroyed their plants, while 39% of them said that they mainly lost their plants because of the water scarcity and strong sun insulation. The other 10% of the farmers did not clarify the reason of plant losses in the garden.

An unexpected finding is related to the fact that the DIU farmers did not report any difference in plant losses over the three year period, although they did describe the year 2008 as very hot and dry. Nevertheless, they all were eager to explain the differences in the plant losses between DIS and the part of the garden irrigated manually. The losses in the DIS part of the garden was 23%, and in the manual part 35%. Within the DIU farmers, insects were mentioned as the only reason for plant loses (100%).

**e) Garden Productivity**

Due to the fact that the research was focused on the socio-environmental and not on the economical aspects of the agricultural activities, the garden productivity is not estimated through the economical analysis of the agricultural production. The garden productivity is estimated from the farmers’ personal opinions about their production and their estimation if they produce enough food for the family consumption and additional sales on the market.

Comparison of the farmers’ annual earnings is the only analysed economical parameter. The reason why the farmers were asked about the earnings from the gardens’ vegetables is closely related to two factors. One of the factors is related to farmers’ estimation of their income and it
sufficiency for paying DIS instalments, while another one is related to their estimation of their vegetables’ production and its sufficiency for covering the family need as well as selling some vegetables on the market.

In Table 4, it is demonstrated that both groups’ gardens were irrigated respectively, and from those gardens all the NV farmers produced enough food, while 81% of the DIU farmers reported to produce enough food for their families. Forty two percentages of the NV farmers is selling the additional vegetables they produce in the garden, while this percentage is higher (62%) in the DIU group.

<table>
<thead>
<tr>
<th>For the year 2008:</th>
<th>NV farmers</th>
<th>DIU farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of households:</td>
<td>42</td>
<td>26</td>
</tr>
<tr>
<td>Number of households owning a garden:</td>
<td>26 (62%)</td>
<td>26 (100%)</td>
</tr>
<tr>
<td>Households irrigating a garden:</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Households producing enough food:</td>
<td>26 (100%)</td>
<td>21 (81%)</td>
</tr>
<tr>
<td>Households selling the garden products:</td>
<td>11 (42%)</td>
<td>16 (62%)</td>
</tr>
</tbody>
</table>

Table 4: Relations between agricultural irrigation and gardens’ productivity (field data)

Regarding the annual garden production within the DIU farmers, the average annual income per household, in 2006, was 29 Euros; in 2007 (the season when the DIS has been implemented) the average income increased more than double (71 Euros), while in the 2008 it decreased by half. Twenty out of twenty six interviewees (77%) gave the information for the entire three years period (2006-2008) and this data were used in this parameter calculations.

The results regarding the DIU farmers’ ability to pay back the instalments for the DIS are presented in the table below (Table 3).
Looking the DIU farmers’ average annual earnings, and comparing it with the instalments they were obligated to pay yearly for DIS, becomes noticeable that only in the year 2007, the average earnings of DIU group was sufficient for paying the DIS instalments (71 Euros).

Looking at the results individually, for the years 2007 and 2008, the percentage of the DIU farmers who earned enough to pay the instalments was lower than it was expected by the NCCP’s management. In 2007, only 27% of the farmers were able to pay for DIS instalment, but none of the farmers paid (Table 3). In 2008, the situation got even worse. The percentage of the farmers who were earning an income high enough to pay for the DIS instalments was reduced from 27% in 2007 to 19% in 2008. Same as in 2007, in 2008 the farmers did not pay any instalments for DIS (Table 3).

According to the contract, DIU farmers were obligated to pay off the DIS within a three years period or if not, to give the irrigation system back. As reasons for the low earning from the vegetable sale, DIU farmers mentioned low production because of the lack of fertilizers and pesticides, and especially emphasizing the drought period in 2008, which caused the production of low quality vegetables. As a second reason the DIU farmers mentioned the lack of access to the market, and inability to sell even the vegetable they produce (interview – local farmer, 2009).

f) The “D” and “T” Parameters
The D and the T parameters are analysed in order to estimate if the distance “garden-water source” plays a significant role in agricultural irrigation practice of the NV and the DIU farmers.
The “D” parameter is the distance that farmer walks daily to fetch the irrigated water, and the “T” parameter is the time that a farmer spends daily to fetch irrigated water.

Table 4 presents the average distances “garden-water source”, average amount of irrigated water, and D and T parameters, for both groups of farmers. The Equation 1 is used to calculate “D” and Equation 2 is used to calculate “T” (calculations explained in Chapter 3).

<table>
<thead>
<tr>
<th>N'hambita Village: 2008</th>
<th>(n=26)</th>
<th>SD</th>
<th>n=10 (farmers who reported the amount of irrigated water for all 3 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVERAGE distance “garden-water source” (m)</td>
<td>304</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>AVERAGE amount of irrigated water (l/day)</td>
<td>173</td>
<td>182</td>
<td></td>
</tr>
<tr>
<td>D(m)</td>
<td>5977</td>
<td>12311</td>
<td></td>
</tr>
<tr>
<td>T(min)</td>
<td>120</td>
<td>246</td>
<td></td>
</tr>
</tbody>
</table>

DIU group: 2006

| AVERAGE distance “garden-water source” (m) | 160 | 235 | |
| AVERAGE amount of irrigated water (l/day) | 446 | 297 | |
| D(m) | 8284 | 17439 | |
| T(min) | 166 | 349 | |

DIU group: 2007

| AVERAGE distance “garden-water source” (m) | 97 | 157 | |
| AVERAGE amount of irrigated water (l/day) | 514 | 201 | |
| D(m) | 4638 | 9736 | |
| T(min) | 93 | 195 | |

DIU group: 2008

| AVERAGE distance “garden-water source” (m) | 100 | 160 | |
| AVERAGE amount of irrigated water (l/day) | 529 | 191 | |
| D(m) | 4814 | 9904 | |
| T(min) | 96 | 198 | |

Table 4. Calculations of DIU’s and NV’s total walking distance (D) and total time consumption (T) in collecting irrigation water daily; (n-presents the number of the interviewees and SD- standard deviation) (field data)
An Independent Sample T-test was run in order to estimate the significance of the difference in between the NV and the DIU group in relation to the “garden-water source” distance. The results of the Independent Sample T-test showed that the “garden-water source” distance is significantly higher in the NV group than in the DIU group with \( p=0.01 \) \((t=2.742, \text{df}=36.849, \ p=0.0045)\). Calculations are included in the Appendix 2.

2. **Social Indicators**

While analysing the social indicators, the researcher attempts to avoid the quantitative analysis. Instead, the analysis of the research data was focused on the social indicators’ description, including valorisation of the farmers’ statements and comments, as well as the researcher’s observation and overall impression of the NCCP area’s social state.

**a) Demographic Data**

The following demographic description aims to present the average family size and age structure of the NV and DIU groups, and additionally presents the gender division of work regarding the households’ water supply responsibility.

Within N’hambita Village, the average age of the women interviewed was 33, where the youngest interviewee was 17 while the oldest was 71 years old. Additionally, 21% of the interviewed women were not aware of their age. The average age of the DIU farmers was 39, where the youngest interviewee was 20 and the oldest was 65 years old. The average family size within the NV group consisted of 6 family members, while the family size within the DIU group consisted of 8 family members.

Regarding the water supply responsibility within the NV group, 88% of the persons responsible to supply water\(^8\) were adult women of the households; only 7% of the persons supplying their households with water were adult men, while 5% of the households had an adult women and man sharing the responsibility. Within the DIU group the responsibility of supplying the family with water was exclusively carried out by adult women (100%).

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\(^8\) In this concept, the term water is understood as total water used by one household (irrigated water, drinking water, and water for washing and cleaning).
b) **Awareness about the Water Significance**

The environmental awareness of the NCCP management and the people living in the NCCP area is of significant importance for the successful development of NCCP activities. This research is focused on the irrigation practices and in accordance with that, the environmental awareness is investigated within these bounders.

Regarding the NCCP management, the awareness about the water scarcity within the area, the climate change vulnerability, the need to adapt the climate change and to alleviate poverty by assuring better food production, is present. Despite this high awareness and motivation, the NCCP management did not include the water management plan in their policy, and very little improvement and investigation has been done so far regarding this topic.

During the interviews, the NCCP management recognized that the water management should be investigated and implemented to higher extent, because numerous activities within the NCCP were closely related to water use. Although high awareness of the water management importance among the members of the research team was present, improvements in that field were not considered as the main objectives of the project and were consequently slightly underestimated.

The data gathered from the farmers, regarding the water conservation was collected through interviews and divided into two groups (NV and DIU group). The farmers were asked to express their opinion about the water significance and to explain the correlation between forests and water streams.

**NV farmers:**

Considering the interviewees’ awareness about water scarcity and its importance, 95% of them stated that they have enough water for their family. Eighty six percentage of them are aware of the water significance arguing that it is very important to save water and 83% acknowledges that there is a correlation between forest and water streams (by protecting forest you also protect water streams).

**DIU farmers:**

Seventy one percentage of the DIU farmers stated that they had enough water for their household needs, which is a lower percentage when one compare it with the NV farmers. The awareness
about the correlation between water streams and forests was higher among the DIU farmers (92%) than NV farmers (83%).

c) Coping with the Water Scarcity
Among the local people different approaches to solving the water issues are applied. In Figure12, it can be seen that the DIU farmers are more practical when coping with water scarcity during the dry periods of the year, because they mostly rely on their own labour and walk longer distances than usual in their purpose to fetch water.

Within N’hambita Village farmers, the situation is rather different. Only few farmers would walk longer distance or would dig a traditional well in the dry river to fetch water. Since they have additional water sources (e.g. boreholes and constructed wells), they use them. An interesting point to be mentioned about the NV farmers is their belief in the old traditional rituals to attract rain, performed by the community chief, and for 31% of the farmers belonging to the NV group this is the only way to solve the problems related to water scarcity (Error! Reference source not found.).Figure 12..

d) Social Networking
The data about the social networking within the NCCP area was collected through formal and informal interviews and observations of the farmers’ status in the community and inter-farmers cooperation. Additionally, the researcher focused on the observation of the NV farmers’ agricultural activities.
NV farmers:

Observing the N’hambita Village social structure, the researcher investigated the social potentials which could contribute to the N’hambita’s agricultural irrigation development.

One of the N’hambita’s social advantages is its location next to the NCCP establishment, which contributed to improved development of the gender equity. The women in the area have the opportunity to be involved in some of the project activities, and to learn about the NCCP activities. Also, the inhabitants of N’hambita are safer considering health care, due to the medical help offered to them by NCCP.

On the other side, the NCCP establishment next to N’hambita Village caused changes in the work division between the genders. The NV men are more involved than women in the NCCP activities while agricultural activities and housekeeping is the main responsibility of the NV women.

![Figure 13. Interviewing one of the NV farmers (source: in the field)](image)

The initial finding showed that the NV women already had their social association, organised by one of the school teachers. This finding inspired the researcher to focus part of the research on N’hambita Village women, investigating their potential to improve agricultural irrigation practice. While interviewing NV women (Figure 13) and the school teacher, and attending one meeting personally, the researcher observed that the women’s association functions well and that
the women attend the meetings regularly (field observation, 2009). Furthermore, thematic workshops regarding health, water and hygiene are organised within the association.

**DIU farmers:**

Upon investigating the social networking within the DIU group, the researcher discovered that there is cooperation between DIU farmers from the same village, but the level of interaction between the farmers from different villages (e.g. DIU farmers from Munaghanha and Mutiambamba) is not really developed much. The training on DIS usage, organised by NCCP for the farmers before signing a contract, included one hour of DIS demonstration. In addition to that, the farmers were offered a technical help regarding DIS whenever it was required. Although NCCP estimated that this training was sufficient to prepare local farmers for using DIS successfully, many farmers did not find the demonstration effective enough to help them to adopt this new technology.

Interestingly, some of the farmers did not state that the training was ineffective, arguing that they learnt how to use the system during the training which was effective enough. This differentiation between farmers was hard for the researcher to explain. After processing data from the field, the researcher related it with the NCCP location. The results demonstrated that those farmers who were mostly complaining about the system efficiency came from Mutiambamba, the village located far away from the NCCP establishment (Figure 14). In accordance with this, the farmers who said that they know how to use it were mainly from the two villages located close to NCCP. The researcher assumes that these farmers were more eager to go to NCCP in order to clarify their doubts regarding DIS usage.
All the DIU farmers interviewed agreed that they do not have access to the markets because they cannot transport their vegetables, additionally remarking that NCCP should assure them transportation of the vegetables to the market, if they wish them to pay their instalments for DIS.

During the interviews, the NCCP management focused their concerns around the two main points. One was related to the farmers’ constant expectations that the NCCP management will solve all their problems while another one was related to the farmers’ low comprehension of the contracts’ significance.

Regarding the first issue, the NCCP managers stated that they offered the farmers help regarding the systems, but that they are not in the position to solve all their doubts and issues. Considering the fact that NCCP will not stay in the area forever, the local farmers are encouraged to learn how to become less dependent on NCCP. Regarding the second issue, the NCCP managers argued that, for local people it is hard to understand their obligations, once the contract was signed.

In the presentation of the environmental and social indicators, the researcher would focus on their mutual relationships, arguing and explaining the viewpoints in the following chapter – Discussion.
V. Discussion

The following discussion of the results is divided into three sections in accordance with the research objectives. Although the results are divided into social and environmental indicators in Chapter 4, in this chapter, they are combined in an aim to fulfil the research objectives and answer the research question.

1. Efficiency of the DIS in Agricultural Irrigation

In theory (Maisiri 2005; Sijali, 2007), for successful drip irrigation it is necessary for farmers to be supplied with a permanent water source, agricultural land (a garden to grow the vegetables), adequate fertilizers (to assure them the soil fertility) and pesticides (to be successful against insect invasions). In practice among DIU farmers, 100% of them have access to water streams, 100% of them own a garden, but only 4% of them (1 out of 26 farmers) use fertilizers and none of them have the ability to supply, buy and use pesticides.

According to Maisiri’s DIS efficiency investigation in Zimbabwe, it is concluded that DIS cannot be implemented successfully without proper water and nutrient management, and that the yield of the vegetables depends mostly on the fertilizer application method (Maisisri 2005). In addition, Stoorvogel and Smaling (1990) emphasise in their assessment of soil nutrient depletion, that fertilizers affect water productivity in sub-Saharan Africa, describing how the irrigation is more effective when soil is fertile.

As mentioned in Chapter 2, the soil within NCCP area is not particularly fertile, and usage of fertilizers could improve the production significantly (Graham et al., 2002). However, NCCP managers suggested the production and usage of compost, instead introducing the local people with to chemical fertilizers, pointing out the risk of fertilizers over-use can cause environmental problems.

With all this in mind, it can be assumed that in practice DIS efficiency is lower than it is in theory. In order to further investigate this assumption more in detail, the efficiency of drip irrigation was compared with the efficiency of manual irrigation. To estimate if the drip irrigation among the DIU farmers is more efficient than manual irrigation in the NCCP area, three comparisons were made between the manual and the drip irrigation in the field (Figure ).
Figure 15: Demonstration of the three comparisons, used to investigate DIS efficiency

One comparison evaluates the agricultural production of DIU farmers before implementing DIS (2006) and after DIS implementation (2007 and 2008), another comparison is between the NV and DIU farmers (considering agricultural production of the gardens in 2008), and the third one presents the difference in irrigational efficiency between the two parts (manual and drip irrigated) of the DIU gardens (Figure 15). In order to estimate the efficiency of DIS operated by the DIU farmers, water use, land use, and garden productivity are discussed as environmental indicators, and including the social indicators, to estimate the farmers’ opinion about the DIS efficiency.

Access to water sources is a crucial factor in agricultural irrigation for farmers (Sijali, 2007). The DIU farmers’ irrigation relies merely on the surface water sources (Figure 5), which is caused by the gardens’ location next to the river banks. Additionally, this is also the reason why the DIU farmers’ irrigational practice and water use are closely affected by the seasonal changes in the stream flow (Foster et al., 2007).

Regarding the results (Figure 8), the overall water withdrawal was reduced by DIS implementation, but did not demonstrate that farmers spend less water for drip irrigation than for manual irrigation. Conversely, as demonstrated in Figure 7, the DIU farmers used four times more water in the DIS part of the garden than in the part of the garden irrigated manually. According to the results, it can be concluded that the production of DIU farmers is highly reliant their production on DIS, supplying the system with enough water and neglecting the manual irrigation. The results of this research are in accordance with Skaggs’ research in New Mexico
(Skaggs, 2001), where it is argued that DIS might increase water consumption, because farmers never allow their plants to go into water deficit. Furthermore, Skaggs (2001) points out the risk that adoption of DIS could increase water withdrawal and decrease downstream flows.

Taking into account the common farmers’ practice to own a garden next to the river banks, the researcher presents the possibility that, if the agricultural practice within the NCCP area is not controlled, and if the usage of fertilizers and pesticides on the one side and water withdrawal on the other side start to increase, it could lead to eutrophication and pollution of the river streams (Andersson et al., 2006).

Although, Figure 9 demonstrates that average area of machamba, increases yearly, the fact that the area of the garden did not change in the period between 2007 and 2008, reveals the influence of DIS on the agricultural area expansion.

As mentioned in Chapter 2, the initial reason for the NCCP management to begin with the DIS implementation, was to motivate farmers to stop with the slash and burn practice by assuring an efficient food production on constant agricultural field. Regarding the results from 2007 and 2008 (Figure 10), this NCCP’s aim was achieved. The fact that 52% of the DIU farmers still plan to expand their agricultural area in the future, creates a potential threat to the NCCP’s objective. In conclusion, this stagnation of the gardens’ expansion can be understood as a temporary occurrence, and due to that it has to be monitored as environmental indicator in the future.

The negative correlation between the garden area and the amount of irrigated water used per square meter daily is not fixed in the way that even if the farmer has a big garden, he may not able to supply enough water to irrigate it. Additionally, this parameter partly confirms the NCCP’s initial hypothesis that, if the farmers use water in the more productive way, they do not need to expand their agricultural area.

Regarding the annual garden production (Table 2), 81% of the DIU farmers stated that they produced enough food, and 62% of them reported that they sold extra food they produced. As presented in the results, the percentage of the DIU farmers who sell the food is higher than percentage of the NV farmers, demonstrating that the DIU framers have more potential to earn by selling the food, than the NV farmers.
Additionally, as all NV farmers reported that they produced enough food in 2008. The 81% of DIU farmers who reported the same was estimated as quite low, due to the fact that they use the new technology which supposes to improve the production. The researcher tried to explain this phenomenon with the differences in households’ size between the NV group and DIU group. Demographic data (Chapter 4) presents that the average number of family members among the NV farmers is 6 and among the DIU farmers is 8. With this in mind, it is arguable that some of the DIU farmers cannot feed the family from the garden they have, because of the two possible reasons. One is that the family is too big to be fed from the garden, and another one is that the DIS is not efficient enough to increase the garden productivity. For the further confirmation, additional investigation and research are to be undertaken.

Another issue is that the DIU farmers still do not earn enough to pay for the DIS instalments (Table 3). Although the average annual income of the vegetable sale doubled when implementing DIS (2007), comparing with the previous year, in 2008 the annual income decreased by half, in spite of the fact that the DIU farmers continued using the same amount of water daily to irrigate the gardens. The explanation for this can be obtained through examining social indicators and farmers’ observations in the field. The farmers argued that this decrease in income was mainly caused by the very hot and dry climate in 2008. They also explained to the researcher that they want to continue DIS because it helps them to survive dry periods similar to the one from 2008.

Another indicator for the DIS efficiency estimation is the percentage of the plants losses. The DIU farmers argued that the reason of the plant failure are only insects, and that the losses under the drip irrigation are smaller than those under the manual irrigation, because drip irrigated plants are bigger, greener and more resistant. These results are also in accordance with Skaggs findings about the DIS efficiency in improving garden productivity (Skaggs, 2001). Although DIS did improve the yield of vegetables in the DIU farmers’ gardens, the fact that DIU farmers provide DIS with a better water supply than manual irrigation, must not be underestimated (Figure 7).
Summarised conclusions regarding the objective No 1:

DIS is proposed as a good technology for adaptation to climate change by many studies (Karlberg et al, 2007), but for successful adoption it is important to assure that farmers are able to use it in proper way. According to the DIS efficiency estimation, the pyramid figure is created to demonstrate the level of DIS efficiency achieved by the DIU farmers (Figure 16).

![Pyramid of the irrigation efficiency](image)

**Figure 16: Pyramid of the irrigation efficiency**

The base of the pyramid represents the first level of irrigation efficiency achieved by the manual irrigation, and also illustrates that this type of irrigation is the most common within the NCCP area. On the top of the pyramid is DIS efficiency in theory, which represents the level of efficiency achievable when DIS is adopted and used successfully in practice. As the pyramid demonstrates, the theoretical DIS efficiency is hard to achieve in the field, and that is why it is located on the top of the pyramidal illustration.

Using DIS without effective fertilizers and pesticides (or any alternative substitution for them), spending more water than with manual irrigation, not producing enough food in 100% of the households, and not earning enough income to pay for the DIS instalments; places the DIU farmers on a lower efficiency level than the theoretical level. On the other hand, DIS shows a higher level of efficiency than manual irrigation does, the plants are bigger, greener and more resistant to insects, DIS implementation caused stagnation in the garden area expansion, the average overall irrigated water consumption decreased since DIS was implemented, the farmers reported a lower percentage of plant losses in the DIS irrigated part of the garden than in its manual part, and farmers are willing to continue to use it.
Including a description of all the previously mentioned indicators in the DIS efficiency analysis, places the DIU efficiency in the middle of the pyramid (Figure 16).

2. Successfulness of DIS Implementation in Agricultural Irrigation

Many studies have proven that the theoretical efficiency of new technologies is not frequently achieved, mentioning as the main reason a poorly managed implementation process which often disregards the social aspect (FAO, 2000; Shaw, 1987). Regarding the fact that 9 out of 35 DIU farmers gave up the system before even trying to adopt it, points out that those farmers were not ready to take the risk of adopting the new technology. In accordance with this, Marra (2002) is also pointing out in his research that adoption processes are powerfully affected by risk-related issues. In addition to that, NCCP managers’ experiences with the planting trees adoption in the area (interview - NCCP manager, 2009), confirms that community members are suspicious and careful when accepting something new and unfamiliar, and only after several cases of local success, they become willing to try the same.

The overall results regarding the social indicators (e.g. lack of access to the markets, lack of inter-framers cooperation, and low ability to cope with the water scarcity), emphasize that additional effort has to be dedicated to social work and an active participation on the part of farmer, in order to inform and improve decision-making process related to the project. The factor of the great importance for the success of DIS adoption among rural farmers, and their ability to pay for the yearly instalments of DIS, is their capacity to compete in the market (Markelova et al, 2009). In addition to that, Markelova investigated the ability of rural farmers to access the markets and concluded that collective actions, organised by the farmers, can contribute to their market access to high extent (Markelova et al, 2009).

In order to demonstrate the present state and overall success achieved so far in DIS adoption process, the scheme of Adaptive Management Framework is used.

Adaptive Management Framework (AMF)

Although the adaptive management framework has not been initially used by NCCP management when the process of DIS adoption started, it can be discussed now as the
appropriate and useful framework to adopt new technology and also as a useful tool to estimate success of the DIS adoption (Lockie and Rockloff, 2005).

As described in Chapter 2, AMF consists of five steps, starting the cycle with the information collation step (Figure 2). From the interviews with NCCP managers, it can be concluded that there was no base on which the process of pre-DIS implementation information collation was established. Due to that, the researcher starts the AMF cycle with the analysis and vision step while presenting the actual process of DIS adoption (by using AMF). In this step the NCCP managers developed idea and vision of DIS adoption, while in the second step (planning) they developed planned how to distribute the DIS among local farmers. In the third step (implementation) they offered the DISs to the farmers-volunteers.

Of overall five steps included in this framework, the process of DIS adoption is currently on the third step - implementation (Figure 17, a), and with this socio-environmental research, the forth step (monitoring and reviewing), is initiated. In the figure (Figure 17, a), the finalised steps of DIS adoption process are coloured in red while the steps which are initiated with this research are coloured in orange.

Taking into account mostly environmental indicators to estimate the efficiency of DIS and social indicators to estimate how local people think and cooperate among themselves, points out the necessity for evaluating and improving the strategy of DIS adoption by involving local farmers to a greater extent. The social aspect inclusion is in accordance with Kusel’s findings where he suggests that successful adaptive management requires a public role to be taken up the same level as scientific Kusel et al. (1996).
Figure 17: Adaptive management framework a) finished steps in red colour, steps in process in orange b) recommended steps in green colour

The AMF’s 1st cycle (Figure 17, a) is the way of social learning for both parties (NCCP managers and DIU farmers). After this monitoring and review part is finished, it is up to NCCP managers to collate the information and lessons and to decide about the further steps regarding the DIS adoption process. The second part of the Figure 17 (b), demonstrates the suggested initiation of the new AMF cycle, with intrusion of social learning from the first cycle and recommendations developed by the researcher to the NCCP management (coloured in green).

Although the DIS is already implemented, it is not entirely adopted. The adoption strategy has not been developed previously and socio-environmental indicators have not been stated clearly. As a result, it is recommended to start with the 2nd cycle of AMF (Figure 17, b), where all the steps are going to be included and previously elaborated on. In order to state the indicators and to achieve more successful decision-making, it is recommended to include the Driving Force-Pressure-State-Impact-Response (DPSIR) framework, explained in Chapter 2 (Lin et al., 2009; OECD, 1999).
As this NCCP pilot project evaluation emphasises the call for the social aspect inclusion, DPSIR framework seems to be a good tool to develop indicators, due to its potential to integrate social components (Lockie and Rockloff, 2005).

**Socio-Environmental Potential to Implement DIS in N’hambita Village**

The IPCC (Hegerl et al., 2007), predicts that long periods of droughts will affect the area of sub-Saharan Africa, and especially the rural communities dependent on small river streams, are likely to feel the impact of the climate change (Sanchez, 2000). The need to improve the irrigation practice within those communities is obvious, but the way of implementing the appropriate technologies must be chosen carefully and in accordance with the social and environmental potential of a particular area (Lockie and Rockloff, 2005). In order to investigate the socio-environmental potential of the N’hambita Village to adopt new technology (drip irrigation system), environmental and social indicators were investigated.

Due to the fact that drum kit drip irrigation systems are implemented among some volunteer-farmers in NCCP area (DIU farmers), the N’hambita Village’s potential to implement the same system is estimated by using the comparison with DIU. According to the environmental indicators, N’hambita Village does not have the potential to implement the drum kit DIS type, as farmers will not be able to fetch enough water to run DIS properly, and they mostly do not have the sufficient garden area to install the system. In theory, a drum kit DIS’ water tank (which has a capacity of 250 L) should be filled twice per day resulting in the farmer having to fetch 500 L daily. Using the equations 1 and 2 (presented in Chapter 3), it is calculated that in order to fill the drum kit DIS’s water tank with irrigated water, farmers need to walk on average 15,4km/day and assuming that walking speed is 3km/h⁹, they would spend approximately 5h10min daily to run drum DIS properly. Although N’hambita Village has additional water sources such as wells and boreholes to be used even when seasonal river streams of the village dry up, the sources are too far away from the gardens and frequently occupied in a dry period, not allowing people to fetch a lot of water and irrigate big areas of their gardens (interview - local farmer, 2009).

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⁹ The average human walking speed is around 5km/h, but observing the walking speed of the local people in the field, the researcher estimated it as a slower than an average, especially while carrying the 20l-container of irrigated water on the top of their head
Although, the environmental potential is not able to support drum kit DIS implementation within NV, it is sufficient for the other types of DIS. The bucket kit DIS is recommended and appropriate to irrigate small gardens by filling the water container with 40 L of irrigated water (Sijali, 2001). Through changing the existing drum kit DIS type for a more appropriate one, the environmental resources within NV are likely to be sufficient.

Regarding social indicators, it can be concluded that women have a strong potential to improve the garden production, as they are responsible for agricultural activities and water supply, and that a women’s association is already established. Taking into account the traditional water scarcity coping, it is recommendable to keep the garden area small, but with installed water saving technology which will to improve food production and will not demand a great deal of water. Another social advantage of NV is related to its closeness to NCCP, assuring the farmers’ easy access to information regarding DIS and additionally NCCP can also be seen as an additional market where the NV farmers can sell their food.

As stated in the Shaw findings (Shaw, 1987), the most important condition for successful adoption of new technology in rural areas is to adopt technology that is desired by local farmers. Due to that fact, the first step toward DIS implementation in SRS communities is to investigate the local farmers’ desire for using this technology as well as their willingness to organise an association where they could discuss all their doubts and issues, and even initiate the usage of credit loans offered by many external organisations (Pretes, 2002).
VI. Conclusions

The N’hambita Community Carbon Project’s initiative to introduce and adopt drip irrigation system (DIS) in the N’hambita Community Carbon Project (NCCP) area is viewed as being appropriate for this area. Due to the high risk of feeling the impact of climate change in the near future, DIS adoption in that area is a good measure of climate change adaptation (Christensen et al., 2007). Nevertheless, the investigated approach to DIS adoption in NCCP area did not appear completely successful, and has yet to be improved by involving local people more in the process.

Furthermore, the efficiency of DIS investigated among the local people of NCCP area is estimated as higher than manual irrigation, but lower than is expected in theory. Drip irrigation users (DIU) use more water for DIS than they do for manual irrigation, because they mostly rely on their food production within the DIS part of the garden. Although DIU farmers produce more food since using DIS, they still do not earn enough money to pay the instalments for the system.

According to the environmental and social parameters, N’hambita Village is described as a seasonal river stream (SRS) community which has stable social potential to implement DIS. Due to the prediction that the environmental conditions do not support the capacity of drum kit DIS; it is therefore recommendable to adopt DIS with smaller water capacity, which is appropriate to irrigate smaller gardens.

At the end of the conclusion stage, the researcher answers the research question relaying on the gathered data and results. As discussed already, the socio-environmental potential to implement drip irrigation systems, as a climate change adaptation measure within N’hambita Community Carbon Project area, exists. The differentiations in irrigated water availability divide the local communities on the constant river stream (CRS) communities and seasonal river stream (SRS) communities. The environmental potential to implement DIS is different between those two groups, pointing out that the first one can support implementation of drum kit DIS, while for the communities reliant on seasonal river stream are estimated to support DIS with smaller capacity. The social potential is obvious in the both communities’ types, but intrusion of additional social work and improvements is necessary.

The overall conclusion is that DIS has a high potential for improving water management within the NCCP area as well as for improving local farmers’ production. Additionally, if successful in
implementing DIS, NCCP could encourage the same in further carbon sequestration projects, pointing out the difficulties experienced by local farmers in the adoption of DIS.

VII. Recommendations

As an output of this 10-month research, the researcher came up with several recommendations to be considered in the future. The recommendations are divided in two groups: recommendations for the NCCP management and recommendations for the local farmers of NCCP area.

Recommendations to the NCCP management:

- To develop a plan for DIS adoption process within the NCCP area, by following the Adaptive Management Framework (AMF)
- To improve developed Adaptation Management Framework by including social learning and learning from the previous mistakes
- To develop environmental, social and economical indicators by using the Driving Force-Pressure-State-Impact-Response framework, and to include those indicators in the second step of AMF – Analysis and Vision step
- To consider social aspect to a higher extend, investigating carefully the local people need and their desire to adopt new technology, before starting with implementation
- Furthermore, to share the experience from the field, regarding DIS implementation, with other carbon sequestration projects

Recommendations to the local farmers of NCCP area:

- To improve their social networking in aim to be less dependent on the NCCP
- To cooperate together, organising the transportation to the market and in that way assure themselves access to market


Lin, T., Lin, J., Cui, S., Cameron S., 2009. Using a Network Framework to Quantitatively Select Ecological Indicators. Environmental Indicators. 9, 1114-1120 (6).


Appendix 1

Correlation between garden area and water usage

**DIU group**

<table>
<thead>
<tr>
<th>Correlations</th>
<th>area of garden 2008 (m²)</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of the garden 2008 Pearson Correlation (m²)</td>
<td>1.000</td>
<td>-0.714</td>
</tr>
<tr>
<td>Sig. (1-tailed)</td>
<td></td>
<td>0.000**</td>
</tr>
<tr>
<td>N</td>
<td>22.000</td>
<td>21</td>
</tr>
<tr>
<td>Irrigated water (l/m²/day)</td>
<td>Pearson Correlation</td>
<td>-0.714**</td>
</tr>
<tr>
<td>Sig. (1-tailed)</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>N</td>
<td>21</td>
<td>21.000</td>
</tr>
</tbody>
</table>

**Correlation is significant at the p=0.01 level (1-tailed).**

**NV group:**

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<th>Water</th>
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<td>-0.709</td>
</tr>
<tr>
<td>Sig. (1-tailed)</td>
<td></td>
<td>0.000**</td>
</tr>
<tr>
<td>N</td>
<td>24.000</td>
<td>21</td>
</tr>
<tr>
<td>Irrigated water (l/m²/day)</td>
<td>Pearson Correlation</td>
<td>-0.709**</td>
</tr>
<tr>
<td>Sig. (1-tailed)</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>N</td>
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<td>21.000</td>
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**Correlation is significant at the p=0.01 level (1-tailed).**
### Appendix 2

**Independent Samples T-test**

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<th>Std. Deviation</th>
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<td>317.4138</td>
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</table>

<table>
<thead>
<tr>
<th>Independent Samples Test</th>
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</thead>
<tbody>
<tr>
<td>Levene's Test for Equality of Variances</td>
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<tr>
<td>F</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Distance Equal variances assumed</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
</tr>
</tbody>
</table>