CARBON CREDIT PAYMENT OPTIONS FOR AGROFORESTRY PROJECTS IN AFRICA

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ABSTRACT

EVALUATING CARBON CREDIT PAYMENT OPTIONS FOR AGROFORESTRY PROJECTS IN AFRICA

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The potential of using carbon offset credits from agroforestry projects for farmers in developing areas has become more prevalent in both Clean Development Mechanism and voluntary carbon markets. Since the implementation of the Kyoto Protocol, many international development organizations have been interested in using the Clean Development Mechanism (CDM) to help both mitigate CO_2 emissions through agroforestry projects offsets and as a poverty reduction tool. Few organizations that have begun talking with farmers about planting trees for carbon offset credits have been able to tell the farmers how much money they would receive from their new tree growth or the costs they will incur in doing so. For this study, a whole farm budget toolkit was designed to help fill this gap and to help evaluate payment methods for carbon offset credits in agroforestry projects. This toolkit is intended to be used by development assistance organizations and farmers starting carbon credit programs. It gives a rough estimate of payments based on a farmer's or group's unique situation. For testing purposes, previous agroforestry projects were entered into the toolkit to evaluate the benefits accruing to farmers using data on carbon credit payment methods for two previous agroforestry projects in Africa. The toolkit was also field tested in Kenya with individual farmers and a farmers' group.

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TABLE OF CONTENTS

ACRONYMS

CDM	Clean Development Mechanism
CER	Certified Emission Reductions
CFA	Franc Communauté Financière Africaine
CO_2e	Carbon Dioxide Equivalent
Dhs	Moroccan Dirham
ERU	Emission Reduction Units
GHG	Greenhouse Gases
ICRAF	World Agroforestry Center
IET	International Emission Trading
IRR	Internal Rate of Return
JI	Joint Implementation
MCC	Millennium Challenge Corporation
NPV	Net Present Value
SOC	Soil Organic Carbon
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VBA	Visual Basic for Applications

CHAPTER 1

1. Introduction

The negative effect of climate change on the environment has led to new policies for mitigating greenhouse gas emissions. In recent years many countries have ratified policies to help lessen the negative effects of climate change. One common climate change policy is known as the Kyoto Protocol. Under the Kyoto Protocol, the greenhouse gas emissions which are contributing to climate change can be mitigated through various approved mechanisms.

1.1 Climate Change and Carbon Sequestration

Agreements made as a result of the Kyoto Protocol have been the catalyst for agroforestry projects over the past decade. The Clean Development Mechanism (CDM) of the Kyoto Protocol[1] has created an incentive for participating countries to initiate projects for small-holder farmers involved in agroforestry projects in developing countries to receive payments for using their land to sequester carbon.[2]

Agroforestry projects created for carbon sequestration can contribute to the multiple objectives of both farmers and organizations interested in emission reductions. Trees play an important role in the environment and the economy. First, tree planting for agroforestry can help diversify a farmer's production and increase food security by providing products that can eaten or sold (Lal 2010). The use of the carbon market may allow farmers to gain even greater returns

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[1] The Kyoto Protocol defines the purpose of the clean development mechanism in Article 12: "to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3."

[2] Carbon sequestration is the means of taking CO_2 from the atmosphere and converting it to biomass through the complicated process of photosynthesis. The CO_2 equivalents are the designated measurement for greenhouse gas reductions (Meredian Institute 2009).

for planting new trees. It could also lead to a behavior change and give farmers an incentive to plant more trees.

Second, planting trees can also help to combat the negative effects of previous deforestation and soil degradation (Keane et al. 2010). Knowledge of the benefits of trees has been used to combat deforestation and land degradation by restoring deforested areas with new agroforestry development. Restoring deforested areas can have a positive economic impact by improving the soil conditions, which will improve the yields for farmers in areas of poverty (Pnas.org 2010). Deforestation has a negative impact on crop yields by causing high levels of soil degradation, but agroforestry can help improve soil used for farming.

Third, tree planting can also provide ecosystem services that lead to increased crop yields. Improved soil fertility, pest control, and biodiversity are a few beneficial ecosystem services which agroforestry can provide (Scherr 2004). The environmental conditions are improved by adding soil organic carbon (SOC), controlling soil erosion, retaining water and returning nutrients in the soil (Lal 2010). Carbon sequestration through the carbon financial market has recently emerged as a new ecosystem service from agroforestry projects.

1.2 Carbon Credits

1.2.1 Kyoto Protocol

The Kyoto Protocol was established under the United Nations Framework Convention on Climate Change (UNFCCC), negotiated in 1997 and signed into force February 16, 2005. The protocol is a legal agreement by 191 countries from around the world to meet agreed-upon targets in reducing global greenhouse gas emissions. Since the protocol came into force, the carbon financial trading market was officially established as a way to mediate the exchange of greenhouse gas (GHG) emission reductions. Under the protocol, carbon offset credit trading has become an accepted means for companies to meet a portion of this total greenhouse gas emission reduction requirement. The carbon offset credit market trades in CO_2 equivalents (CO_2 e) produced by accepted mitigation activities. Carbon dioxide is only one of many types of greenhouse gases that are being emitted into the atmosphere. It was chosen for the carbon financial market because it is the most common greenhouse gas emitted.

1.2.2 Mitigation Mechanisms

There are three mechanisms under the Kyoto protocol that can be used to meet the mandated emission reduction goals (Oh 2010). Annex 1 countries that signed and ratified the Kyoto Protocol are allowed to participate in International Emission Trading (IET). This mechanism allows countries to sell their emission units to other countries if there is an excess of units. The Clean Development Mechanism (CDM) allows for mitigation projects to be set up in developing (non-Annex 1) countries in exchange for Certified Emission Reductions (CERs) based on the CO_2 reduction equivalents that approved projects generate. Joint Implementation (JI) allows Annex 1 countries, which are complying with the Kyoto Protocol, to invest in projects in other Annex 1 countries that reduce emissions, which entitle them to CERs for their country's reduction requirements. There are two types of interventions that can be used to offset effects of GHG emissions. The first type compensates for GHG emissions by creating a carbon sink. The second type is reduced GHG emissions, primarily through the development of alternative energy. This paper looks at creating carbon sinks through agroforestry projects, using data from small-holder agroforestry projects in Morocco, Senegal, and Kenya.

1.3 Statement of the Problem

Studies have shown that the destruction of forests and degradation of land has led to an increase in GHG emissions. Deforestation is responsible for around 12-17% of total emissions (Keane et al. 2010). While evidence of this relationship has been well established by scientists, the relationship between allowable crop activities and the cost-effectiveness of carbon sequestration through agroforestry projects for farmers has not been thoroughly investigated. The forestry sector is distinct from other markets because depending on how the forest is managed, it can either contribute to GHG emissions through external tree cutting and fires, or it can help reduce emissions through carbon sequestration. Yet, prior studies have shown mixed and contradictory results, because of the conflict between short-term needs of small-holder farmers in developing countries throughout the world and the long-term aspect of agroforestry projects (Keane 2010; Gundimeda 2004). The market price, where supply equals the demand for a CO_2 equivalent, needs to be established in order for farmers to be willing to adopt new tree-planting practices for carbon sequestration. There is a concern that if CDM credit schemes are very profitable for farmers, the wealthier farmers may want to acquire more land, leaving the poorer farmers with the marginal land (Gundimeda 2004; Cacho 2003).

Still, not enough is known about the impact of the new carbon offset market on small-holder farmers' willingness to participate. This is especially a concern when determining the feasibility of new projects. Although agroforestry projects may be profitable, they may not be feasible for the farmer if there are constraints in land, labor, or capital. If land is a constraint, it may not be feasible to replace traditional crops, such as cereals, with tree crops. The rapid growth of the world's population is also inducing a demand for higher grain production. The farmer may need all of the cropping area for household consumption, or grain for cattle (Antle 2003). There may not be sufficient access to credit to meet initial investment costs or the required property rights to the land to receive the carbon offset payments.

If the project is feasible, the introduction of carbon markets is expected to enable farmers to gain a profit from new tree yields and from the compensation for sequestering carbon. Although these additional revenues may seem significant, it remains uncertain whether receiving carbon credit payments before tree production would offset the costs of investment in tree crops. There will also be less crop production due to land use change, potentially lowering farm profit initially. It is also suggested by Torres (2009) that the Kyoto Protocol does not offer enough incentives for this mechanism to be implemented on a large scale, because of the opportunity costs associated with land and transaction costs. However, the potential effects of the CDM and the new carbon financial markets are creating optimism in developing countries, because of the prospect of halting deforestation, promoting food security, improving environmental conditions and the soil organic carbon, and providing carbon offsets (Skutsch 2009; Lal 2010).

1.4 Purpose of the Study

It is important to assess the *ex ante* outcomes of agroforestry projects to justify the claims that sale of the carbon offsets credit is financially beneficial to farmers. The purpose of this study is to evaluate the impact of carbon credit payment types on the net present value of farmers' investments in agroforestry. Although forestry projects are known to be environmentally beneficial by helping with the reduction of CO_2 emissions through carbon sequestration and improving SOC, the economic benefits are not well known because of the complexity of the contracts that must be formed between the buyer and seller (Kerr 2004). With the uncertainty of knowing whether the payment incentives for entering a carbon credit program are sufficient, farmers may be hesitant to participate in the carbon market with new agroforestry activities, creating a potential market failure for carbon markets for agroforestry (Torres 2009).

1.5 Research Questions

The major questions that will be researched are: (1) What is the impact of the addition of carbon credits on the net present value of agroforestry projects? And (2) Which payment scheme would make new agroforestry projects the most attractive to farmers, in terms of net present value and low or nonexistent cash flow deficits? These research questions will be of special concern to the small-holder farmers or development organizations deciding whether to take on new agroforestry projects for the purpose of obtaining carbon credits. Carbon credit payments may be the deciding factor in whether a farmer chooses to plant new trees, because the additional payment could provide a crucial incentive for the adoption of new trees.

1.6 Limitations and Assumptions

Several assumptions are made in the study. The first assumption is that farmers are eligible to participate provided that they are not converting a pre-existing forest area into newly planted tree crops. Deforestation in order to plant new trees for carbon sequestration would produce a carbon debt. Second, it is assumed that farmers have the needed capital or access to credit to cover the initial investment in establishing the trees. Third, it is assumed that there are guidelines under the CDM that farmers must meet in order to participate in the CDM market. A major requirement of CDM is that tree-planting activities must lead to a net increase in the carbon stock currently on the farm, making the project an additionality. This means that farmers must have proof that they are doing more than just “business as usual” in order to gain access to the carbon market (Meredian Institute 2009).

Leakage is another concern for new CDM projects. Leakage is considered to be the net change of GHG emissions which may occur indirectly outside of the project because of any changes made by the new project activities. With the addition of new projects, leakage elsewhere cannot occur, such as cutting down trees to plant crops in a new field, because the old field is under the new agroforestry project. Under the CDM there is also the issue of permanence. With agroforestry projects, carbon storage is not permanent, due to natural loss or disturbances (Seeburg-Elverfeldt 2010). The trees should be maintained for the length of the contract. The farmer also must have the property rights for the designated area of forestry and be able to maintain those property rights during the contract period, while the trees are growing. Lastly, it is assumed that the agro-climatic conditions of the area will allow for good growth and productivity of the trees being planted.

The following chapters include information and analysis regarding carbon credits for small-holder farmers in Morocco, Senegal, and Kenya. Chapter 2 contains a description of the conceptual framework and methodology. The third chapter describes the design of the toolkit used. Chapter 4 presents the results given by the toolkit from the Moroccan and Senegal data and field testing from Kenya. The final chapter discusses impacts of carbon credits and potential future research needs.

CHAPTER 2

2. Conceptual Framework and Methodology

2.1 Carbon Credits

The innovative idea of promoting sustainable small farmer development while offsetting CO_2 emissions has been used in many new CDM agroforestry projects since the Kyoto Protocol was ratified in 2005 (Thomas et al. 2010). The Clean Development Mechanism was created with the dual purposes of promoting the involvement of farmers in the international carbon financial market and creating carbon offsets. Farmers who are interested in a higher income are able to become the seller of a good that is suitable for local markets and the international carbon market. Under the CDM, the carbon that is produced through agroforestry projects must be able to stay where it is sequestered, so transportation costs are avoided (Cacho et al. 2005). The exchange of carbon offsets behaves like a service, because no physical material is exchanged between the buyer and the farmer. The buyer is willing to pay someone for creating a carbon sink by sequestering carbon in tree biomass.

The creation of a market for carbon offsets has production and transaction costs. The World Agroforestry Center (ICRAF) has identified at least five different types of transaction costs for establishing carbon credit projects in agroforestry: search and negotiation costs: approval costs; project management costs; monitoring costs; and enforcement and insurance costs (Cacho 2002).

Contracts which include the details for validation and verification of agroforestry projects between the buyer and the farmer must be established in order for the farmer to participate in the carbon market. A third party required under CDM is typically involved to monitor the tree growth and to verify that the trees are being used properly. Typically this organization, which links the buyers to the farmer, facilitates the exchange of carbon offsets. The farmer must be willing to protect the trees and use them only as stated in the contract. Most contracts for carbon credit projects are designed to be long-term, ranging from twenty to sixty years (Olschewski 2005). The farmer must ensure that the biomass that has accumulated in the tree will stay there until the contract has ended. If the contract negotiated is not being followed by the farmer, the contract may be terminated, and the farmer will lose the carbon credit privileges. Some contracts may be legally bound, so farmers must comply with the terms of the agreement, or pay penalties.

2.2 Advantages

Although the carbon credit market is fairly young, there have been positive reports on farmers receiving payments for carbon offsets. Ravindranath (2007) lists three areas that agroforestry has a positive impact: climate (by reducing CO_2 levels), biodiversity conservation, and socio-economics, or welfare improvement. The research suggests that agroforestry has a medium impact on the climate and biodiversity conservation, and a high impact on social welfare.

The high impact on social welfare improvement is an important aspect for farmers in developing countries who need assistance with sustainable development. The medium impact on the climate is also significant, because of the negative effect of climate change that is associated with agriculture (Tubiello 2008). Ravindranath suggests a medium impact on biodiversity conservation.

2.3 Economic Analysis Framework

Planting new trees will cause farmers to incur additional costs before the trees begin to generate benefits. The farmer must be able to compensate for the negative incremental net benefit during the years in which the investment costs make the with-project costs more than the without-project costs. In later years, the trees will mature and, depending on the tree species, potentially give products that can be sold. By adopting agroforestry practices, the producer must be able to give up a percentage of the land that may have otherwise had an alternative land use. The new trees will incur maintenance costs, such as watering, pruning, or other activities that could require additional labor. In the early years of the project, the trees will also have to be protected from grazing animals or other threats that might damage the trees, so additional costs may be incurred for fencing. Hiring additional people to watch the area can be expected, as well. Also, the uncertainty about or whether the investment will result in a positive net present value and incremental net benefit after planting trees may cause farmers to be hesitant about investing in a new agroforestry systems.

An investment analysis will allow the farmer to evaluate the costs and benefits of the alternative land use agroforestry project. Investment analysis of the project is done through comparative budgeting techniques. The net benefits of the without-project case are compared with the net benefits of the with-project case, giving incremental net benefits. Budgeting assesses the inflows and outflows of the new project. A common profitability indicator used in investment analysis is Net Present Value defined as $\sum_{t=1}^{n} \frac{B_t - C_t}{(1-r)^t}$. NPV shows the entire project's worth in present value terms. An investment is considered to be profitable if NPV is ≥ 0. In general[3], leaving risk issues aside, a farmer would implement any investment that is profitable, providing that sufficient capital (and labor) is available to cover initial investment costs, and any negative

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[3] In this study, the yearly benefits minus the yearly costs, or B_t-C_t, are referred to as the "net benefits," and net benefits with the investment minus net benefits without the investment are referred to as "incremental net benefits."

cash flows (negative incremental net benefits in the initial years before the investment begins to generate full returns) are acceptable. If the net present value is negative, the project should not be adopted, because the farmer will lose money on the investment, relative to the alternative farming system.

A computerized budgeting tool was developed in this study as an instrument to calculate the expected benefits of carbon credits and to analyze the profitability of investing in trees. The added carbon credits payments may be the crucial factor in determining whether the farmer accepts the project. Carbon credit payments made to the farmers every few years during the project may not seem significant, but the contract may allow for forward payments to help compensate for high initial investment costs. The farmer will be able to better assess the uncertainty by using the calculator to carry out sensitivity analysis.

Some assumptions had to be made concerning decision-maker preferences in order for this budgeting tool to align with farmer choices. The toolkit does not take into account the possibility of risk for new project investment, so risk neutrality is assumed. The toolkit also assumes that the farmer or the enumerator has perfect information for the inputs used in the farm budget. This includes average yield for each crop, average prices per unit, and operating expenditure costs for the farm. The user should have information on the cost of monitoring with CDM. The section on carbon credits in the toolkit is not information that a typical farmer would have perfect information on, unless the farmer was already involved in an agroforestry carbon credit program. The user facilitating the questions in the budgeting toolkit should have perfect information of the cost of monitoring compliances with CDM. Another farmer preference that is assumed is the discount rate. The discount rate of the farmer is assumed to be high. The toolkit was designed primarily for small holder farmers, so they have a relatively high discount rate.

There is a short-run time horizon, because small holder farmers are concerned with meeting household needs. The toolkit also makes the assumption that there are no externalities and public goods. Since the toolkit does not take these into account, the results of the profitability analysis are underestimated in the toolkit budget.

2.4 Study Implementation and Information Selection

2.4.1 Study implementation

The study was implemented by evaluating the profitability of new agroforestry projects involving carbon offset sales. Data from the two projects were used to calculate farm profitability with and without carbon credits, compared to the profitability of the conventional farming system. If the net present value is greater than or equal to zero, the investments are economically profitable (Antle and Stoorvogel 2008). This study evaluates the impact of carbon credit payments on the profitability of agroforestry investments, but will also examine alternative payment methods to find the method which offsets initial investment costs and provides a positive annual incremental net benefit.

CO_2 prices will also be analyzed to determine the price per metric ton of CO_2 that will allow agroforestry projects to be profitable. In 2008, the CDM prices ranged from $22 to $29 USD per metric ton of CO_2 in Europe (Committee on Climate Change 2008). In the same year, the Chicago Climate Exchange price per metric ton of CO_2 ranged from $1.00 to $7.40 (Chicago Climate Exchange 2008). The average market price for CO_2 equivalents for CDM projects in 2008-2009 was 10 Euros, which is about 14 USD (Alexeew 2010). The market price for the CO_2 equivalents will be increased for each project for a sensitivity analysis, until a payment scheme can be selected that allows for the incremental net benefit to be positive for most or every year.

Given that each agroforestry project will have different investment and maintenance costs, the amount to compensate for those costs will vary with each project.

2.4.2 Information Selection

The data used in this paper comes from previous studies that analyze new agroforestry projects in Africa. Each data set selected was required to have a clearly defined budget that included crops and new tree production. The budgets could also have livestock production activities. The information selected for this paper includes the revenues and costs for several different types of crops and at least one new tree type. The trees used in the data could be used for any type of agroforestry, excluding uses for lumber, fuelwood, charcoal, or any other form of energy source that would take away from the creation of the carbon sink aspect of the new trees.

2.5 Carbon credit payment options

There are several carbon credit payment options which smallholder farmers may be able to receive. Three types of payment options are: sell as you go, renter payments, and up-front payments (Kerr 2004). The renter payments will not be considered in this study.

With the sell as you go payment option, the farmer is paid for the amount of carbon that is sequestered by the trees. The farmer is only allowed to sell the carbon that the trees have already sequestered. The buyer of the carbon credit contract will pay the seller (the farmer) a set rate each year to keep trees for carbon offsets. This type of payment method can end at any time. In the sell as you go payment scheme, the yearly interval of carbon credit sales will be predetermined within the contract. The buyer will receive the carbon offsets produced, but can also choose to stop buying the credits at any time.

In the up-front payment method, the farmer can be paid in advance for the carbon that the trees will sequester over a set amount of years. The up-front payments will be referred to as the forward payment scheme. Buyers of carbon credits may need carbon credits up-front, so they are more willing to pay for all the credits at one time. The idea of receiving the payment for carbon credits up- front may also be an incentive for small holder farmers to get involved in new agroforestry projects. The decision tool used in this paper allows the farmer to compare these two payment methods within the current overall farm budget.

The choice of method of payment to use may change the net present value of the project, but it will also change the number of years during which the project has a negative annual incremental net benefit. This can be accomplished if the carbon credit payment is sufficient to offset the high initial costs of planting and tree establishment that would typically outweigh the net inflows from the tree and other farm activities. If the new trees were planted from seedlings, there will not be a marketable product from the new trees for several years until the tree matures, causing a gap in the farmer's income until the trees start producing.

The yearly interval at which carbon credit payments occur can also affect the net present value of the project. There are verification costs each time a third party has to verify the trees on the producer's property. The farmer will have a higher monitoring and enforcement transaction cost if the interval is every year. The producer could decrease total costs if tree verification were every 5 years for 30 years, instead of every year for 30 years.

CHAPTER 3

3. Whole Farm Agroforestry Carbon Financial Calculator

The Whole Farm Agroforestry Carbon Financial Calculator is a computer model or toolkit developed in Microsoft Excel, using VBA programming techniques. The toolkit was designed with two purposes in mind: First, for use as a basic budgeting tool for analysis of agroforestry investments by small-holder farmers in developing countries; and second to evaluate various carbon credit payment schemes for potential agroforestry projects (ICRAF/MSU 2010). The basic budgeting tool combined with the evaluation of carbon credit payment schemes is intended to show farmers how a range of credit payment methods and intervals can assist them in offsetting the initial costs of investing in new agroforestry production. The design of the calculator is not region specific; it aims to accommodate small-holder farmers in developing countries throughout the world.

The calculator is set up in the form of a questionnaire, but it is subdivided in sections based on farm activities. When all of the questions are answered in a section, the user can move on to the next section, or tab, in the Excel program. The program is designed to build from the previous answers from the user, so some of the questions asked will determine how the rest of the calculator is run. Depending on how questions are answered, the program may add or hide sections. If the user states that there are only two different types of fields, then questions will be asked for only those two field types. If the user states that there is no livestock production, the section on livestock does not appear and will not be placed in the budget.

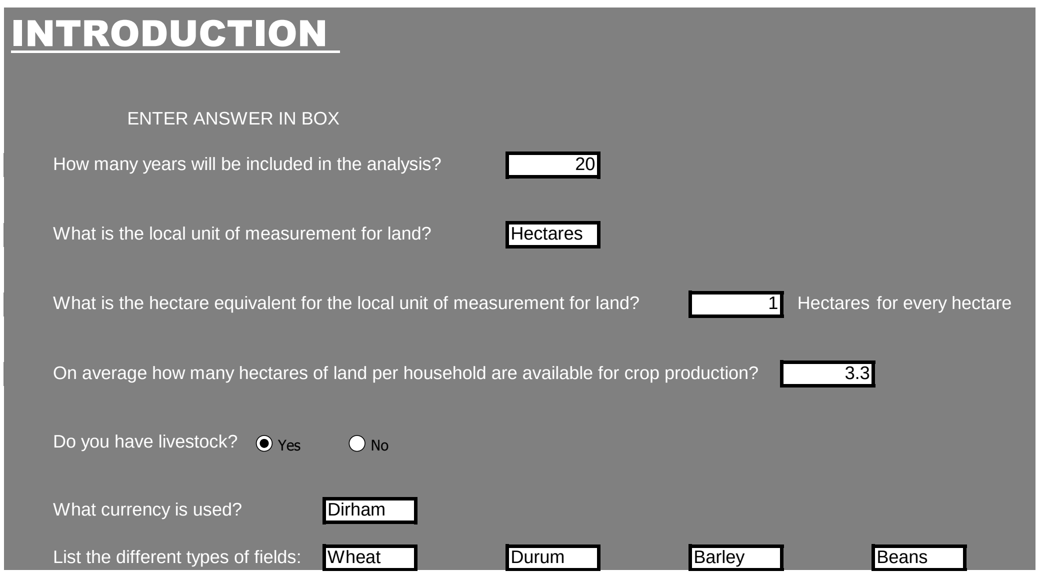
Many of the answers to the questions that are asked are simply placed in a designated box, or cell, near each question. A few of the questions must be answered by clicking the appropriate option button or check box, by moving a spinner, or by choosing an answer from a drop-down box. The questionnaire asks two basic types of questions: non-numerical and numerical. The non-numerical questions are used to help report and describe specific farm activities, such as the currency that is used, the name of the crops planted, or the task names for hired labor. The numerical questions are mostly used for budget calculation purposes. The program uses the numbers that are entered by the user and performs behind the scenes calculations to create the whole-farm budget analysis when all of the sections have been completed.

The farm- or region-specific information about the expected farming activities must be entered a series of six tabs or sections in the Excel spreadsheet, namely: introduction, crop production, livestock, current tree production, new tree production, and carbon credits. Based on the farm activity information given by the user, the program generates a final budget report for up to 30 years. The information needed for the toolkit spreadsheet includes the operating expenditure and the value of production for each type of crop, livestock, and tree in production. If the gross inflows and outflows per year are already known from previous studies, they can be entered manually on the final spreadsheet page.

3.1 Introduction

Basic farm activity and budgeting information is required in the introduction of the program to set up how the rest of the calculator runs. The number of years included in the analysis will determine the time period of the budget. By entering the local unit of land measurement, the user can put measurements in local units throughout the rest of the program. The hectare equivalent for the local unit of measurement for land will help with comparing the local values with other sources. The average number of local land units that are available per household for crop production will determine the maximum area that the farmer can dedicate to crops. If livestock is accounted for in the farm budget, the user can select the “yes” option button and questions about the livestock will be asked. Lastly, the number of field types will be listed in the introduction. Field types are representative of specified areas of land where crops are grown. For each area listed, the program will then bring up a section which asks questions about that field type.

Figure 3.1 Carbon Financial Calculator Introduction Example



Introduction Questions:

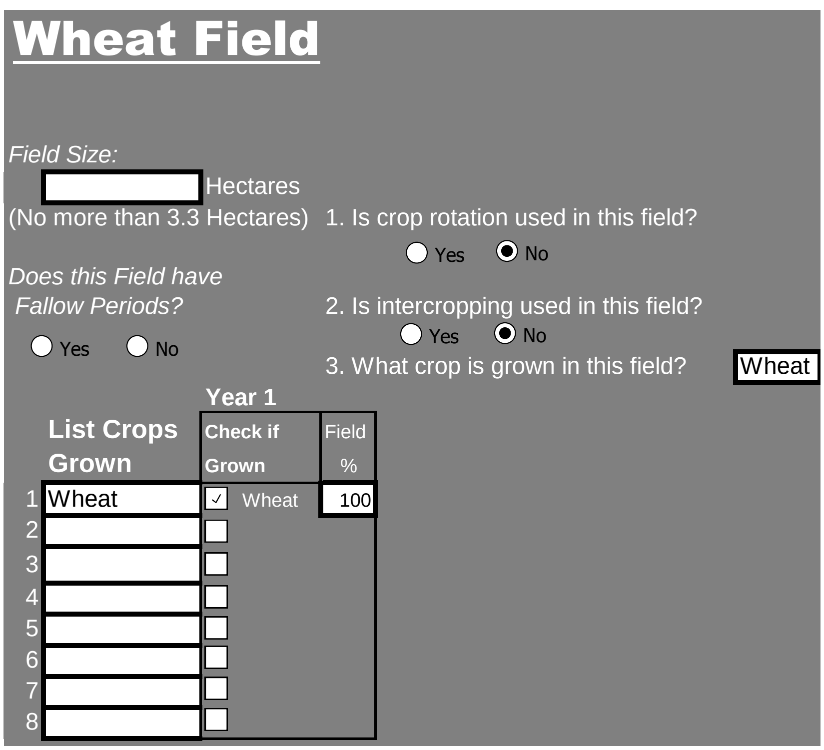
1. How many years will be included in the analysis?
2. What is the local unit of measurement for land?
3. What is the hectare equivalent for the local unit of measurement for land?
4. On average how many local land units are available per household for crop production?
5. Do you have livestock (yes/no)?
6. What currency is used?
7. List the different types of fields (maximum of 6):

3.2 Crops

In the cropping sections, the field types and the different types of crops that are grown in the field are recorded. If fallow periods are used, the farmer can enter the ratio between the years in fallow and the years in production for each type of field. In the crop value of production section, the farmer can also give details for different types of cropping systems, like intercropping and rotation cycles, and up to eight different types of crops in six fields.

For each year in the cropping cycle that the crops are grown, there is a box to check if the crop is in production. Each time that the box is checked, the average field percentage that is under production for that crop must be entered. A single field may have multiple crops, so the percentage of field cover from each crop each year is averaged and multiplied by the field area to get the averaged area of each crop per field.

Figure 3.2 Example of Field Section in Carbon Financial Calculator

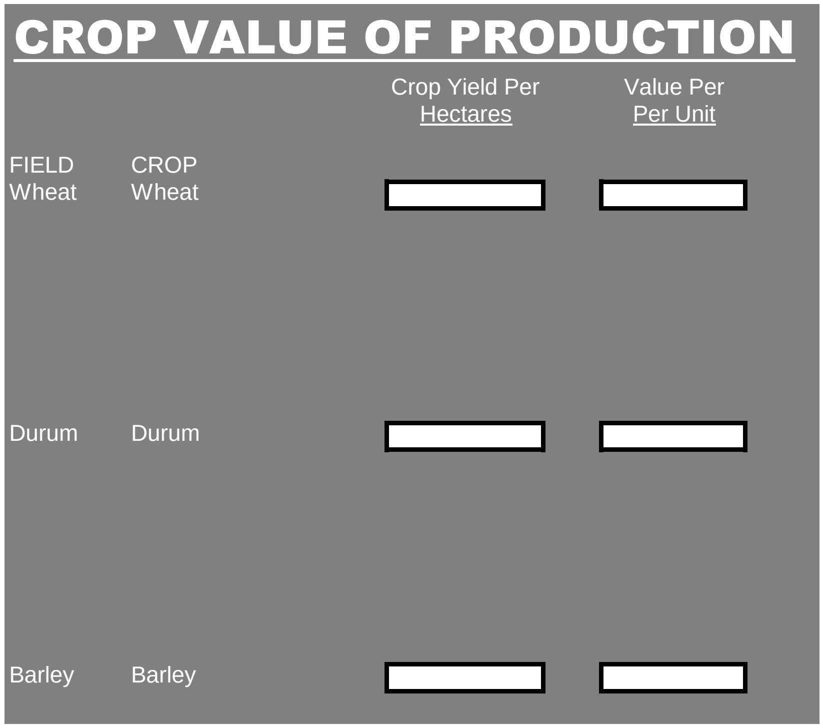


Field Questions:

1. Field Size
2. Does this field have fallow periods? (yes: 3, no: 5)
3. How many years is this field in fallow?
4. How many years is this field in crop production between fallow periods? (go to 8)
5. Is crop rotation used in this field? (yes: 6, no: 7)
6. How many years is the rotation cycle? (go to 8)
7. Is intercropping used in this field? (yes: 8 , no: 9)
8. List crops that are grown in this field (maximum of 8): (go to 10)
9. What crop is grown in this field?
10. Check if in production (for each year, type of crop, and type of field)
11. Enter the field percentage of crop (for each year for each type of crop in each type of field)

In the crop value of production section, the average crop yield for each crop grown in each field is entered. The value per unit of each crop type for each field is also recorded. Behind the scenes, the crop yield is multiplied by the value of the unit production and the average yearly percentage that the field is in production to calculate the crop value of production for every crop type. The results from all of the crop types are summed to get the total crop value of production.

Figure 3.3 Crop Value of Production Section in Carbon Financial Calculator

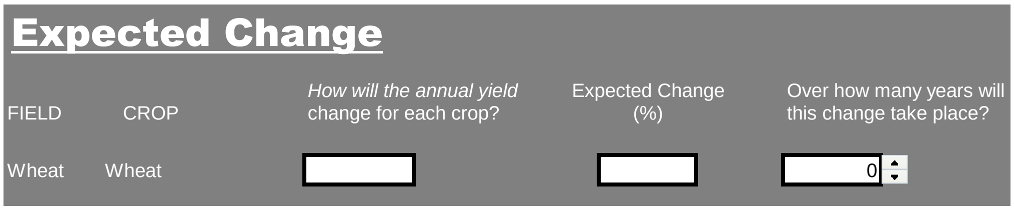


Crop Value of Production Questions:

1. Crop yield (per local land area unit)
2. What is the value per unit produced?

The user has the option to account for the expected percentage change over time in the yield of each crop, whether constant, increasing, or decreasing. Crop yields vary over time because of changes in soil fertility, droughts, or other environmental factors. Applying expected yield change to the crops grown is optional, but valuable as a sensitivity analysis. For example, if one type of crop yield is predicted to steadily decrease, the user can specify that the crop yield will go down by an estimated percentage over a projected amount of time. The new average yield will be calculated behind the scenes by adding or subtracting the appropriate amount per year. The percentage change is applied equally over the time period specified.

Figure 3.4 Expected Change Section of Carbon Financial Calculator

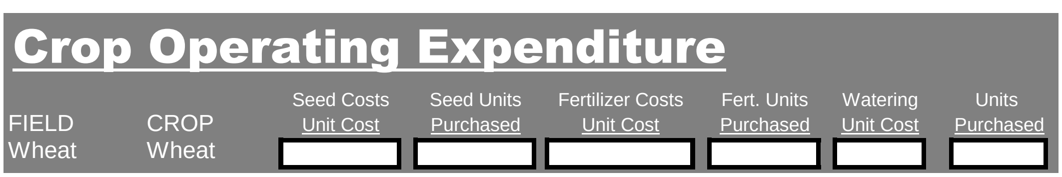


Expected Change Questions

1. How will the annual yield change for each crop? (constant, increasing, decreasing) (constant: end)
    a. What is the expected change? (%)
    b. Over how many years will this change take place?

The crop operating expenditure section asks the user about the average crop outflows for each field. Seeds, fertilizer, watering, and hired labor are included in the costs. The costs per unit are multiplied by the units used for each type of expense for each crop and then summed to get the total crop operating expenditure.

Figure 3.6 Crop Operating Expenditure for Carbon Financial Calculator



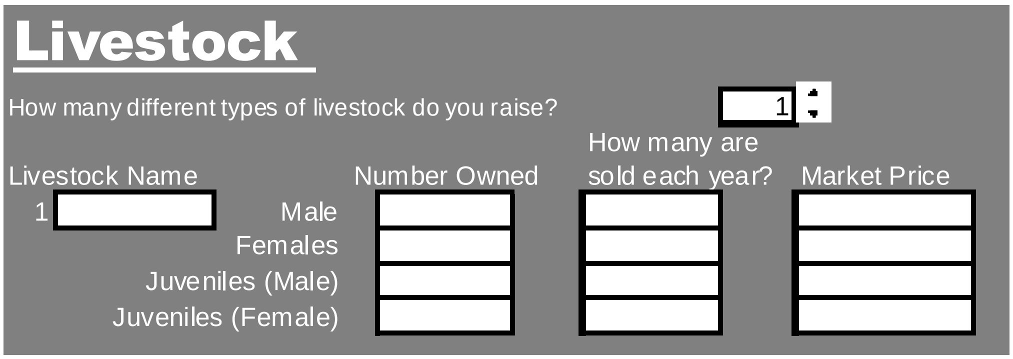
Crop Operating Expenditure Questions

1. Seed costs per Unit
2. Seed Units Purchased
3. Fertilizer Cost per Unit
4. Fertilizer Units Purchased
5. Watering Unit Cost
6. Watering Units Purchased
7. Is Hired Labor Used? (yes/no) (no: end)
    a. Task Name
    b. Cost per Laborer/Task
    c. Number of Laborers
    d. Days Worked per Task?

3.3 Livestock

If the user indicates in the introduction that livestock are raised, three livestock sections will appear in the toolkit. In the first section, the farmer can choose up to five different types of livestock species that are raised. For simplicity, only the larger animals are accounted for, and not the smaller farm animals such as chickens. Each species type is labeled and sorted by gender and age group: adult male, adult female, juvenile male, juvenile female. For each group the number owned is recorded. To calculate the inflow from livestock that is sold, the average number sold per year is multiplied by the average market price per head for each group and species. The average inflow for other marketable products, such as milk or wool can also be inputted. The average unit price for the product sold is multiplied by the average units which are sold each year for each livestock type.

Figure 3.6 Livestock Section for Carbon Financial Calculator

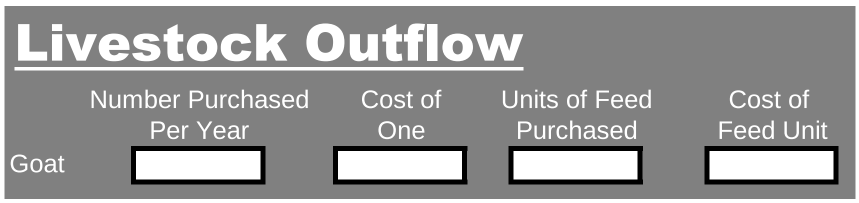


Livestock Questions:

1. How many different types of livestock do you raise (maximum of 5)
2. Number Owned (per type)
3. Number sold each year
4. Market Price
5. Are there other marketable products? (yes:6, no: end)
    a. Species type (male, female, juvenile male, juvenile female)
    b. Product name?
    c. Unit price?
    d. Units sold per year?

In the first section, the average livestock inflows are calculated. In the second and third sections, the livestock outflows are figured by calculating the average maintenance and hired labor costs for each livestock type. If the farmer is purchasing livestock on a yearly basis, the average number purchased per year is multiplied by the average cost per head. The maintenance outflow for feed is calculated by taking the units of feed purchased and multiplying it by the cost of a unit of feed. If hired labor is used for the livestock type, it can be accounted for in the budget per task or per laborer. If the hired labor is paid for per task, then the cost of each task is multiplied by the number of days worked on the task, and summed for all tasks. If the hired labor is paid for per laborer, the cost per laborer is multiplied by the number of days worked per laborer, and summed for all laborers.

Figure 3.7 Livestock Outflow Section for Carbon Financial Calculator



Livestock Outflow Questions (for each type of livestock)

1. Number Purchased each year?
2. Cost per Animal
3. Unit of feed purchased?
4. Cost of Feed Unit?
5. Is hired labor used? (yes: 6, no: end)
    a. Task name?
    b. Cost per task/laborer?
    c. Number of tasks/laborers?
    d. Days worked per laborer?

For veterinary or medical costs, the average annual cost per head of livestock per year can be entered. If there are more livestock expenditures the average number of units purchased for one animal per year is multiplied by the average cost per one expense unit per animal and species group.

Figure 3.8 Livestock Outflow Costs (continued) for Carbon Financial Calculator

Livestock Outflow						
	Type of Livestock	Vet or Medical Cost Per Head Per Year	Name of Other Cost	Units Used	Cost of Unit	Number of Units Used per Year
Goat						

Livestock Input Costs Questions (continued)

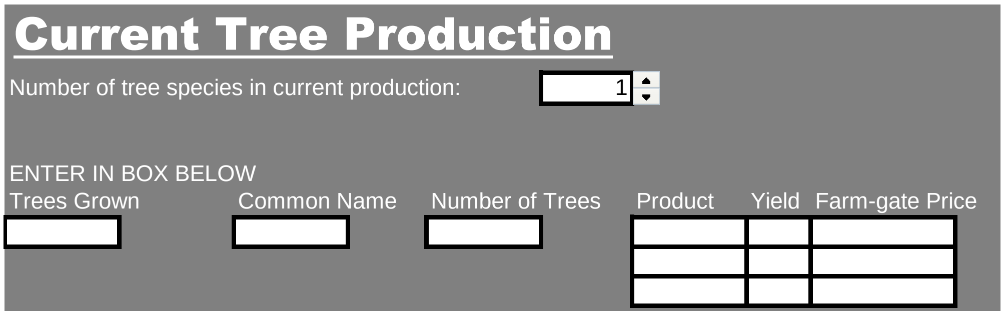
1. Veterinary or medical costs per head per year?
2. Name of other cost
    a. Units Used?
    b. Cost per unit?

3.4 Current Trees

The farmer may have some tree species in production prior to planting new trees for carbon credits. Information for average inflows and outflows of the current trees can be entered into the budget in the current tree production and the current tree expenditure sections of the program. This information is a part of the final whole farm budget analysis, but these current trees cannot be accounted for in any carbon credit payment scheme. One of the qualifying factors for farmer to receive carbon credits is that the trees must be planted in addition to those already on the farm.

The current tree production section takes into account all of the inflows from the new trees, for the five most important tree species. Both the local and the common name can be included. The average number of trees for each species must also be recorded. If the trees in production have a marketable product, the average annual yield for a single mature tree is multiplied by the market value of a single unit of the product, multiplied by the number of trees of that tree species, to get the current tree value of production.

Figure 3.9 Current Tree Production Section for Carbon Financial Calculator



Current Tree Production Questions:

1. Number of tree species in current production
2. Local Name?
3. Common Name?
4. Number of Trees?
5. Marketable product name?
    a. Yield?
    b. Market Value?

The current tree expenditure section adds the costs of the trees to the whole farm budget. In the program they are split into two different groups: expenditure from hired labor and expenditure from other costs. If the farmer hires non-family labor to maintain the trees, the *yes* option button can be selected, and questions about the hired labor will appear in the calculator. The task name can be entered. The costs for hired laborers can either be accounted for by task or by laborer. If there are other costs, they can also be accounted for. The costs per unit are multiplied by the units used, and then all of the expenditures are summed to get the current tree expenditures.

Figure 3.10 Current Tree Expenditure Section for Carbon Financial Calculator

Current Tree Expenditure Questions:

1. Is hired labor used? (yes/no) (yes:2, no:5)
    a. Cost per laborer/task
    b. Number of tasks/laborers
    c. Number of days per laborer?
2. Are there other costs? (yes/no) (no: end)
    a. Name of other cost?
    b. Cost per unit?
    c. Units used?

3.5 New Trees

The new tree production section requires the same information about the value of production and the operating expenditure of the current tree production, but also includes the timing of production, maintenance costs, and establishment costs. The farmer will not be able to sell tree products until several years after the new trees are planted. The user is able to allocate any new tree maintenance costs over the years in which they occur.

The calculator also allows the farmer to designate where the new tree crops will be planted. If tree crops will be planted on non-crop land, then there is no interference with crop yield. However, if the new trees will be planted where the crops are growing, a percentage of the crops will be taken out of production, since crops generally do not grow well where shaded by the tree crown. The percentage taken out of crop production is estimated by taking the average yearly growth of the crown diameter of the tree out of crop production (equation 3.11). The area of crown diameter estimated is subtracted from the field area each year. One assumption is that the new trees planted will have a crown diameter of 1 meter, which will be taken out of crop production in the first year per tree planted. As the crown diameter continues to increase, the area taken out of crop production will increase until the tree reaches maturity. This approach was recommended by a forestry expert to estimate the area taken out of crop production. The equation is conservative and may be an overestimation, because crops are sometimes grown under the crown diameter of intercropped trees and the shading effect is not 100% of crown diameter.

Slope of Tree Crown Growth

$$\text{Slope} = \frac{\Delta Maturity}{\Delta Year} \qquad \text{(Equation 3.11)}$$

$$= \frac{\Delta M}{\Delta Y}$$

$$= \frac{M_n - M_0}{Y_n - Y_0}$$

Where:

M_n = Area at Maturity = (π)(Approximate Crown Diameter at Maturity)

M_0 = 1

Y_n = Year at Maturity

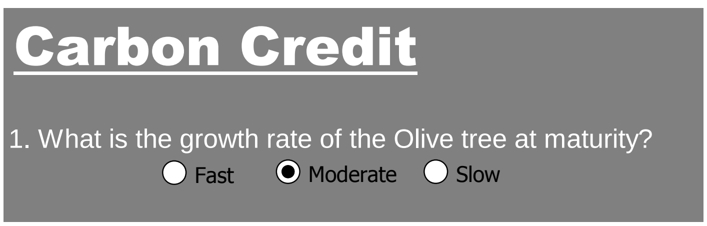
Y_0 = 0

$$= \frac{M_n - 1}{Y_n}$$

3.6 Carbon Credits

There are two sections, or tabs, for the carbon credit questions. The first section simply asks if each tree species is fast, moderate, or slow-growing. The growth rate that is chosen will determine the average amount of carbon sequestered each year. The slow-growing trees will sequester less carbon than the fast-growing trees.

Figure 3.12 Carbon Credit Section for Carbon Financial Calculator



Carbon Credit (1) Question:

1. What is the growth rate of tree species *n* at maturity?

The second section on carbon credits takes information from the new tree section and asks which payment options are available. The calculator takes the information given by the user and provides a graph that shows how much the user will receive from forward payments or on a yearly payment basis.

Calculation of the metric tons of carbon produced per year was based on information from U.S. Department of Energy (1998), which calculated the average biomass accumulation of fast, moderate, and slow-growing trees. The average mortality rate is multiplied by the yearly biomass accumulated for that year. The pounds of carbon that the tree will sequester each year for up to 30 years is found in the table.

Table 3.13 Total Pounds of Carbon Sequestered by Tree Type Over T Years Since Planting for Slow, Moderate, and Fast Growth Rates

Total Pounds of Carbon Sequestered by Tree Type Over *T* Years Since Planting			
T	Slow	Moderate	Fast
0	0	0	0
1	1.1	1.7	2.4
2	2.4	3.9	5.6
3	3.9	6.5	9.6
4	5.6	9.5	14.5
5	7.5	13	20.3
6	9.6	17	26.9
7	12	21.5	34.5
8	14.5	26.5	43.1
9	17.3	32	52.6
10	20.2	38	63.1
11	23.3	44.5	74.5
12	26.6	51.4	86.8
13	30.1	58.8	99.9
14	33.8	66.7	113.9
15	37.6	75	128.7
16	41.7	83.7	144.4
17	45.9	92.8	160.9
18	50.3	102.4	178.1
19	54.8	112.3	196.1
20	59.5	122.6	214.8
21	64.3	133.3	234.2
22	69.2	144.3	254.3
23	74.2	155.7	275
24	74.9	167.4	296.4
25	84.6	179.5	318.4
26	90.2	192.2	241.6
27	96	205.1	265.4
28	101.9	218.3	389.7
29	107.8	231.7	414.5
30	113.8	245.4	439.7

In general terms, the payment per interval was calculated in the following steps:

1. Pounds of C sequestered by slow-, moderate-, and fast-growing trees over S years.
2. Pounds of C converted to pounds of CO_2 (multiplying by the conversion factor 3.67).
3. Pounds of CO_2 converted to metric tons of CO_2, using the conversion factor 0.4545/1000.
4. Metric tons of CO_2 multiplied by the value per ton.
5. Value of CO_2 reduced by a percentage held in reserve for insurance purposes.[4]
6. Adjusted value expressed per payment interval by dividing by the (length of the payment period / interval of the payment).

These steps are embodied in the following equation adapted from Simpson (2010):

$$P = \frac{(1-R)(3.67) \cdot V \cdot \left(\frac{0.4545}{1000}\right)[N_1 \cdot C(S,1) + N_2 \cdot C(S,2) + N_3 \cdot C(S,3)]}{L / I} \quad \text{(Equation 3.14)}$$

Where:

P = Payment

R = the percentage that is held in reserve

V = the value of sequestering CO2 per metric ton

N1 = the number of slow-growing trees planted

N2 = the number of moderate-growing trees planted

[4] A specified percentage is typically held for insurance purposes for each project. Riskiness is associated with forestry projects, so costs must be deducted from the total carbon credit payments in case farmers do not follow through with their contract or there is a natural disaster like a fire that destroys the trees.

N3 = the number of fast-growing trees planted

C(S,1) = the total carbon sequestered by a slow-growing tree over S years

C(S,2) = the total carbon sequestered by a moderate-growing tree over S years

C(S,3) = the total carbon sequestered by a fast-growing tree over S years

L = Payment period in years

I = interval of payments in years

3.6.1 Forward Payments

For this payment option, referred to either as the forward payment option or the up-front payment scheme, carbon is sequestered for *S* years, but the payment period, *L,* over which payments are made is shorter than *S* and the payment is made in intervals, *I.* The payment period, *L,* is set in the calculator to be ≤ 30 years. The area under the carbon sequestration curve of each tree type is divided into the designated payment intervals. The carbon sequestration curve measures the amount of carbon that is sequestered per year. All of the payments will be equal and spread out over the amount of time chosen by the farmer. The time frame over which farmers can choose to receive their payments is 1 to 30 years.

Discounting is not always used when constructing up-front carbon credit payment schemes (Cacho 2003). In investment analysis, discount rates are fixed for the entire period of the investment. For projects that are up to 30 years, the discount rate has been assumed at 0-3.5% (Guo et al. 2006). Since most agroforestry projects are long-term, the discount rate should be very small. A discount rate was set at zero for the forward payment option. The 0% discount rate is debated, but it is used in order to maximize the social utility (Guo et al. 2006, Neumayer 1999).

3.6.2 Sell as You Go Plan

In the sell as you go payment plan, the payment will increase over time, because the annual accumulation of biomass increases. The yearly payments are a sub-interval within the function of each tree's growth curve. In order to get the amount of carbon sequestered in year *T*, the total amount of carbon sequestered in all the years before *T* must be subtracted from the total amount of carbon sequestered up to the end of that year: $C(T_K, n) - C(T_{K-1}, n)$. The tree growth rate is represented by *n.* If *n*=1, it is a slow-growth tree. When *n*=2, it is a moderate-growing tree; and *n*=3 is a fast-growing tree. The farmer will not get paid for more than the carbon sequestered for each year of payment.

$$P_K = (1-R)(3.67) \cdot V \cdot \left(\frac{0.4545}{1000} \right) \{ N_1 \cdot [C(T_K,1) - C(T_{K-1},1)] + N_2 \cdot [C(T_K,2) - C(T_{K-1},2)] + N_3 \cdot [C(T_K,3) - C(T_{K-1},3)] \} \quad \text{(Equation 3.15)}$$

Where:

P = Payment

R = the percentage/100 that is held in reserve

V = the value of sequestering CO2 per metric ton

N1 = the number of slow-growing trees planted

N2 = the number of moderate-growing trees planted

N3 = the number of fast-growing trees planted

C(TK,1) = the total carbon sequestered by a slow-growing tree over T years

$C(T_K,2)$ = the total carbon sequestered by a moderate-growing tree over T years

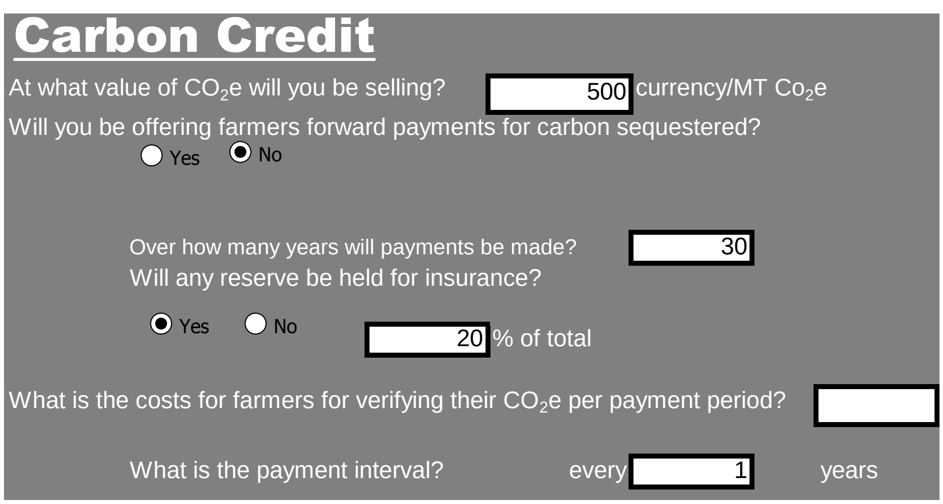
C(TK,3) = the total carbon sequestered by a fast-growing tree over T years

K = the payment interval

The major difference between the set-ups of equations (3.14) and (3.15) is that the forward payment equation calculates the same payment amount for all intervals, while the yearly payment equation calculates a payment that increases for each additional interval. The variable *I* is equal to 1 in the sell as you go payment scheme, so it is omitted from the equation. The trees will continue to grow and accumulate biomass with either method, but the farmer decides when to be compensated for the accumulation of the biomass in the trees.

The calculator has the ability to display a variety of payment plans. The carbon dioxide equivalent, CO_2e, is the equivalent of a metric ton of CO_2. The payment interval is by year, so the farmer can also choose to be paid every other year, every two years, and so on. Depending on the project, there may be a verification cost for each payment interval. In some instances where the yearly payment method is used, the verification costs could be greater than the value of the carbon sequestered, especially in the first few years. If this is the case the farmer would not want to start receiving payments until the trees have sequestered enough carbon to allow for a payment greater than the verification cost.

Figure 3.16 Carbon Credit (2) Section for Carbon Financial Calculator



Carbon Credit (2) Questions

1. At what price will CO_2e offsets be sold?
2. Will farmers be offered forward payment for the carbon sequestered? (yes/no)
    a. Number of years trees will sequester carbon?
3. Over how many years will payments be made?
4. Will any reserve be held for insurance?
5. What is the cost to farmers for verifying their CO_2e per payment period?
6. What is the payment interval?

3.7 Whole-farm budget

After the inflows and outflows are entered into the toolkit, the program will automatically enter the average yearly results from each section into a separate budget spreadsheet form. The yearly net benefit with the addition of new trees is calculated by summing the total operating expenditure from the crops, livestock, and current trees and subtracting it from the total value of production. The net benefit with the addition of new trees is also calculated in the budget spreadsheet by summing the total operating expenditure from all areas and subtracting it from the total value of production. To find the incremental net benefit for the addition of trees to the farm, the net benefit without the new trees is subtracted from the net benefit with the new trees.

CHAPTER 4

4. Results

4.1 Morocco

4.1.1 Moroccan Data

Data from Millennium Challenge Corporation economic rates of return calculations of the Morocco Compact was used in the calculator to determine the effect that a carbon credit payment scheme could have on increasing the cash flow and overall profitability of investing in trees[5]. The Moroccan project was designed to introduce agroforestry and terracing on rain-fed hillsides, where annual crops were leading to high levels of soil erosion. Olives were the main tree type introduced to the hillsides. Olives are not considered fast growing trees, but the Moroccan project was an easy case to use with the toolkit. The smaller farmers in this project did not have any type of current olive tree production, but some of the farmers had small areas of almond or fig trees (Table 4.1). The budgets show the economic rate of return for two farm sizes and agro-climatic zones. There are ten different budgets characterized by different farm land area and location. The budget for the low hills area with farms that use less than 5 hectares of land was evaluated using the carbon calculator.

[5] http://www.mcc.gov/documents/agreements/compact-morocco.pdf

Table 4.1 Current Trees by Agroecological Zone and Farm Size in Morocco

Agroecological Zone	Farm Size < 5 ha	> 5 ha
Low Hills	-	-
Western Hills	Almond Fig	Almond Fig
Eastern Hills	Almond Fig	Almond Fig
Average Atlas	Almond	Almond
High Atlas	Almond	Almond

The crops that are in production without the project include wheat, durum, barley, and beans. Livestock included in the budget are cattle, sheep, and goats. Olive, almond, and fig trees are introduced as the new tree crops in the with-project cropping plan. The majority of the new plantings were olive trees. The crops stay in production after the trees are planted, but some of the yields decrease over a period of time because some of the cropping land is taken up by terracing and growth of the trees.

Some assumptions had to be made when entering data in the calculator. The number of hectares planted in new trees was given in the report, although the exact number of trees that were planted for the project was not given. The number of trees planted is a required variable in the calculator, so the number had to be estimated. There are typically 100-400 olive trees planted in a hectare of rain-fed farming (Tubeileh 2004). In the Morocco project an average of 1.5 hectares per farm were planted with olive trees. The number of trees that was used in the calculator was 100 per hectare, which equals 150 trees per farm. It is also assumed that the growth rate of the olive tree is moderate.

Because there is not a universal price for carbon, the payment that the farmer received for carbon sequestration associated with additional tree production was also assumed in the budget.

The price of carbon varies with the market and what organization is handling the project. An average price of about 12 USD was used for this project, which is a conservative estimate for Europe. Moroccan currency is used in the calculator, so the 12 USD was converted to 100 dirhams (Dhs) based on average currency rates. An amount of 20% of the payment is subtracted for insurance, to account for the possibility of leakage due to environmental conditions or actions that would prevent or stop the trees from growing.

4.1.2 Moroccan Pay as You Go Payments

In this project, the initial tree investment costs are all put into the first year. The annual amounts of pay as you go carbon credit payments are shown in Figure 4.2. With 100 trees per hectare, a value of CO_2 equivalents at 100 dirhams, and moderate tree growth, the net benefit and the incremental net benefit without carbon credits were negative in the first year. The net benefit in the first year with the new olive trees but without the carbon credits is -7,126 Dhs (Table 4.4). In the second year of the project the net benefit with the trees becomes positive.

Figure 4.2 Morocco Pay as You Go Payments per Year

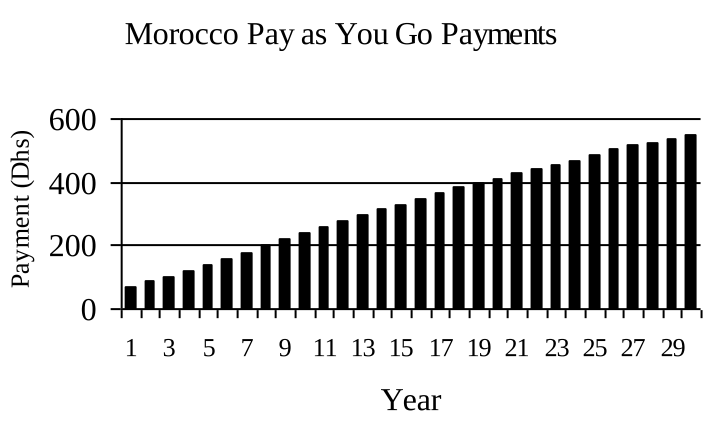


Table 4.3 Incremental Net Benefits With and Without Pay as You Go Carbon Credit Payments for Olive Trees

Morocco With and Without Pay as You Go Payment			
Year	Incremental Without (Dhs)	Incremental With (Dhs)	Carbon Credit Payment (Dhs)
1	(11,875)	(11,807)	68
2	(1,225)	(1,137)	88
3	(950)	(846)	104
4	450	570	120
5	1,550	1,690	140
6	3,900	4,060	160
7	5,400	5,580	180
8	6,900	7,100	200
9	8,400	8,620	220
10	9,900	10,140	240
:	:	:	:
30	9,900	10,447	547

The incremental net benefit in the first year without the use of carbon credits is -11,875 Dhs. Table 4.3 shows that the incremental net benefit is not positive until the fourth year. The first year's incremental value is significantly more negative, compared to the next two years, which averages -1,000 Dhs. If the initial project costs were spread out over a couple years, the negative incremental net benefit would not be as great as it is.

Table 4.4 Morocco Whole Farm Budget Pay as You Go Payments

Morocco Whole Farm Budget Pay as You Go Payments															
Low Hill < 5 ha															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
INFLOW															
Value of Production															
Total Crop	3,555	3,556	3,557	3,558	3,559	3,560	3,561	3,562	3,562	3,563	3,801	3,801	3,801	3,801	3,801
Total Livestock	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482
Total Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inflow	11,037	11,038	11,039	11,040	11,041	11,042	11,043	11,044	11,044	11,045	11,283	11,283	11,283	11,283	11,283
Total New Tree	0	0	0	1,500	3,000	4,500	6,000	7,500	9,000	10,500	10,500	10,500	10,500	10,500	10,500
Total Inflow with New Tree	11,037	11,038	11,039	12,540	14,041	15,542	17,043	18,544	20,044	21,545	21,783	21,783	21,783	21,783	21,783
OUTFLOW															
Operating Expenditure															
Total Crop	2,788	2,788	2,788	2,788	2,788	2,788	2,788	2,788	2,788	2,789	2,825	2,825	2,825	2,825	2,825
Total Livestock	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
Total Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outflow	6,288	6,288	6,288	6,288	6,288	6,288	6,288	6,288	6,288	6,289	6,325	6,325	6,325	6,325	6,325
Total New Tree	11,875	1,225	950	1,050	1,450	600	600	600	600	600	600	600	600	600	600
Total Outflow with New Tree	18,163	7,513	7,238	7,338	7,738	6,888	6,888	6,888	6,888	6,889	6,925	6,925	6,925	6,925	6,925
NET BENEFIT w/out New Trees	4,749	4,750	4,751	4,752	4,753	4,753	4,754	4,755	4,756	4,757	4,958	4,958	4,958	4,958	4,958
NET BENEFIT with New Trees	(7,126)	3,525	3,801	5,202	6,303	8,653	10,154	11,655	13,156	14,657	14,858	14,858	14,858	14,858	14,858
INCREMENTAL NET BENEFIT	(11,875)	(1,225)	(950)	450	1,550	3,900	5,400	6,900	8,400	9,900	9,900	9,900	9,900	9,900	9,900
Carbon Credit															
Total Credit	68	88	104	120	140	160	180	200	220	240	260	276	296	316	332
NET INCOME w/ Carbon Credits	(7,058)	3,613	3,905	5,322	6,442	8,813	10,334	11,855	13,376	14,897	15,118	15,134	15,154	15,174	15,190
INCREMENTAL NET BENEFIT	(11,807)	(1,137)	(846)	570	1,690	4,060	5,580	7,100	8,620	10,140	10,160	10,176	10,196	10,216	10,232

Table 4.4 Morocco Whole Farm Budget Pay as You Go Payments (continued)

Morocco Whole Farm Budget (continued)														
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
3,801	3,801	3,801	3,801	3,801	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811
7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11,283	11,283	11,283	11,283	11,283	11,293	11,293	11,293	11,293	11,293	11,293	11,293	11,293	11,293	11,293
10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
21,783	21,783	21,783	21,783	21,783	21,793	21,793	21,793	21,793	21,793	21,793	21,793	21,793	21,793	21,793
2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825
3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325
600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925
4,958	4,958	4,958	4,958	4,958	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968
14,858	14,858	14,858	14,858	14,858	14,868	14,868	14,868	14,868	14,868	14,868	14,868	14,868	14,868	14,868
9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900
348	363	383	395	411	427	439	455	467	483	507	515	527	535	547
15,206	15,222	15,242	15,254	15,270	15,296	15,308	15,324	15,336	15,352	15,376	15,384	15,396	15,404	15,416
10,248	10,263	10,283	10,295	10,311	10,327	10,339	10,355	10,367	10,383	10,407	10,415	10,427	10,435	10,447

4.1.3 Moroccan Forward Payments

If the farmer is able to choose a carbon credit payment scheme that allows forward payments, the first year of initial costs could be covered if all the payments were forwarded (paid up front) to the first three years. Under this payment scenario, the incremental net benefit does not increase with each year of the project.

If all of the payments over the 30 years of the project are forwarded to the first five years, the year 1 incremental net benefit with carbon credits becomes -9,915 Dhs (Table 4.5). This payment scenario is with a market price of carbon at 100 Dhs. The incremental net benefits become positive in year 2 and continue to increase each year. The incremental net benefit is much higher in later years. With this payment scenario, the new project benefits starts negative in year one, reaches 3,510 Dhs in year 5, and peaks in year 10, at 9,900 Dhs. With and without benefits are the same for the remaining 20 years.

Table 4.5 Morocco Incremental Net Benefits With and Without Forward Payments for Carbon Credits for Olive Trees

Morocco Incremental Net Benefits With and Without Forward Payments (Dhs)			
Year	Without Payments	Forward Payments to Year 3	Forward Payments to Year 5
1	(11,875)	(8,608)	(9,915)
2	(1,225)	2,042	735
3	(950)	2,317	1,010
4	450	450	2,410
5	1,550	1,550	3,510
6	3,900	3,900	3,900

Table 4.6 Morocco Whole Farm Budget Forward Payments

Morocco Whole Farm Budget Forward Payments															
Low Hill < 5 ha															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
INFLOW															
Value of Production															
Total Crop	3,555	3,556	3,557	3,558	3,559	3,560	3,561	3,562	3,562	3,563	3,801	3,801	3,801	3,801	3,801
Total Livestock	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482
Total Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inflow	11,037	11,038	11,039	11,040	11,041	11,042	11,043	11,044	11,044	11,045	11,283	11,283	11,283	11,283	11,283
Total New Tree	0	0	0	1,500	3,000	4,500	6,000	7,500	9,000	10,500	10,500	10,500	10,500	10,500	10,500
Total Inflow with New Tree	11,037	11,038	11,039	12,540	14,041	15,542	17,043	18,544	20,044	21,545	21,783	21,783	21,783	21,783	21,783
OUTFLOW															
Operating Expenditure															
Total Crop	2,788	2,788	2,788	2,788	2,788	2,788	2,788	2,788	2,788	2,789	2,825	2,825	2,825	2,825	2,825
Total Livestock	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
Total Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outflow	6,288	6,288	6,288	6,288	6,288	6,288	6,288	6,288	6,288	6,289	6,325	6,325	6,325	6,325	6,325
Total New Tree	11,875	1,225	950	1,050	1,450	600	600	600	600	600	600	600	600	600	600
Total Outflow with New Tree	18,163	7,513	7,238	7,338	7,738	6,888	6,888	6,888	6,888	6,889	6,925	6,925	6,925	6,925	6,925
NET BENEFIT w/out New Trees	4,749	4,750	4,751	4,752	4,753	4,753	4,754	4,755	4,756	4,757	4,958	4,958	4,958	4,958	4,958
NET BENEFIT with New Trees	(7,126)	3,525	3,801	5,202	6,303	8,653	10,154	11,655	13,156	14,657	14,858	14,858	14,858	14,858	14,858
INCREMENTAL NET BENEFIT	(11,875)	(1,225)	(950)	450	1,550	3,900	5,400	6,900	8,400	9,900	9,900	9,900	9,900	9,900	9,900
Carbon Credit															
Total Credit	1,960	1,960	1,960	1,960	1,960	0	0	0	0	0	0	0	0	0	0
NET INCOME w/ Carbon Credits	(5,165)	5,485	5,761	7,162	8,263	8,653	10,154	11,655	13,156	14,657	14,858	14,858	14,858	14,858	14,858
INCREMENTAL NET BENEFIT	(9,915)	735	1,010	2,410	3,510	3,900	5,400	6,900	8,400	9,900	9,900	9,900	9,900	9,900	9,900

Table 4.6 Morocco Whole Farm Budget Forward Payments (continued)

Morocco Whole Farm Budget (continued)														
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
3,801	3,801	3,801	3,801	3,801	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811
7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482	7,482
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11,283	11,283	11,283	11,283	11,283	11,293	11,293	11,293	11,293	11,293	11,293	11,293	11,293	11,293	11,293
10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
21,783	21,783	21,783	21,783	21,783	21,793	21,793	21,793	21,793	21,793	21,793	21,793	21,793	21,793	21,793
2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825	2,825
3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325	6,325
600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925	6,925
4,958	4,958	4,958	4,958	4,958	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968	4,968
14,858	14,858	14,858	14,858	14,858	14,868	14,868	14,868	14,868	14,868	14,868	14,868	14,868	14,868	14,868
9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14,858	14,858	14,858	14,858	14,858	14,868	14,868	14,868	14,868	14,868	14,868	14,868	14,868	14,868	14,868
9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900

4.1.4 Discussion of Moroccan Results

The net present value of the project shows what the 30-year project would be worth in present day terms. Given a market price of carbon of 100 Dhs and a discount rate of 10%, the net present value, NPV, of the project is 84,861 Dhs. The equation used for net present value for evaluating this agroforestry project is: $NPV = \sum_{t=1}^{t} \frac{B_t - C_t}{(1+r_t)}$. The costs, C_t, are subtracted from the benefits, B_t, to get the cash flow for each year. The discount rate is evaluated over a range from 5-20% to provide a sensitivity analysis. This range is typical when assessing agroforestry investments.

Table 4.7 shows the NPV for the pay as you go scenario under different assumptions about the value/ton of CO_2 and discount rate. Table 4.8 shows how the NPV changes with the forward payments scenario.

Table 4.7 Morocco NPV per Discount Rate and the Value of a Metric Ton of CO_2 in Morocco Dirhams (Dhs) for Pay as You Go Payments

Morocco Net Present Value for Pay as You Go Payments				
CO_2 Value/Ton (Dhs)	Total NPV Per Discount Rate			
	5%	10%	15%	20%
0	169,741	90,529	53,819	34,556
25	170,816	91,092	54,163	34,792
50	171,890	91,656	54,507	35,029
100	174,040	92,783	55,195	35,500
150	176,189	93,911	55,883	35,972

Table 4.8 Morocco NPV per Discount Rate and the Value of a Metric Ton of CO_2 in Morocco Dirhams (Dhs) for Forward Payments

Morocco Net Present Value for Forward Payments				
CO_2 Value/Ton (Dhs)	Total NPV Per Discount Rate			
	5%	10%	15%	20%
0	169,741	90,529	53,819	34,556
25	171,969	92,573	55,708	36,315
50	174,197	94,616	57,597	38,074
100	178,653	98,704	61,376	41,591
150	183,109	102,791	65,155	45,109

The difference between the incremental net benefits of the project without carbon credits, the project with a forward payment method, and the project with the pay as you go payment methods is in Table 4.9. The incremental net benefit for the scenarios with carbon credit payments is only slightly higher than the incremental benefits without the carbon credits, because the value of carbon credits is very low compared to what the farmer receives for fruit production. The forward payments are only until the fifth year to make up for the high initial establishment costs. In years 6-30, the increment net benefit of the without-carbon credits scenario is equal to that for the forward payments scenario. If the discount rate is not known, the internal rate of return can be used to calculate the break-even discount rate for a specified carbon credit price. The IRR before carbon credits is 24.5%. The Morocco pay as you go case has an IRR of 25.2%. The forward payment scheme has an IRR of 33.2%.

Table 4.9 Morocco Incremental Net Benefits without Carbon Credits, With Forward Payments and with Pay as You Go Payments

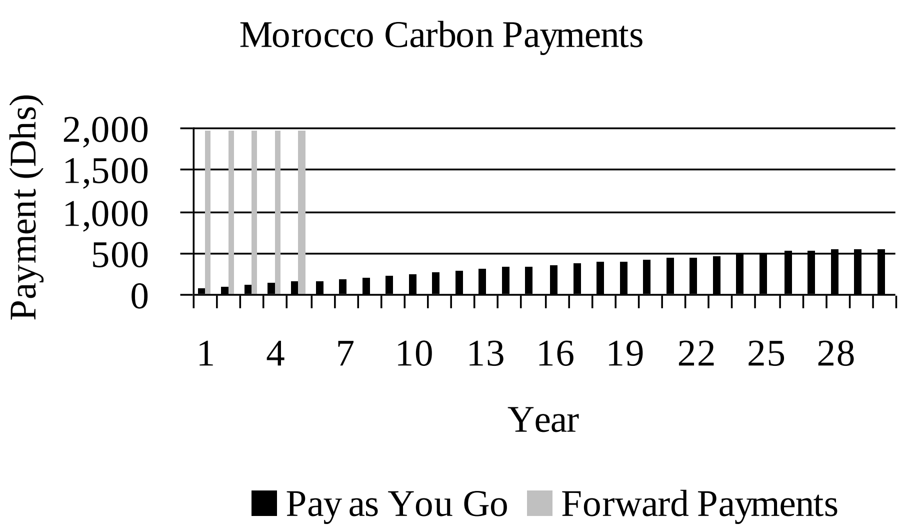
Morocco Incremental Net Benefits			
Year	Without Carbon Credits	Forward Payment	Pay as You Go Payment
1	(11,875)	(9,915)	(11,790)
2	(1,225)	735	(1,115)
3	(950)	1,010	(820)
4	450	2,410	600
5	1,550	3,510	1,725
6	3,900	3,900	4,100
7	5,400	5,400	5,625
8	6,900	6,900	7,150
9	8,400	8,400	8,675
10	9,900	9,900	10,200
:	:	:	:
30	9,900	9,900	10,584

The payment scenarios can be ranked by looking at the method which offers the highest net present value. The discount rate used when calculating NPV was 15% and the carbon credit payment per metric ton of CO_2 was set at 100 Dhs. The forward payment option has the highest NPV at 61,376 Dhs. The pay as you go scenario ranks below the forward payment option with an NPV of 55,195 Dhs. The NPV without the use of carbon credits is still positive, but falls beneath both methods that use carbon credits. The order of NPV's was not affected by the choice of the discount rate. Figure 4.11 compares the carbon credit payment between the pay as you go and the forward payment options. The forward payment method takes the sum of the pay as you go payments and spreads it out over the first five years.

Table 4.10 Morocco Net Present Value Method Ranking

Morocco Net Preset Value (Dhs)		
Rank	Payment Type	NPV
1	Forward Payments	61,376
2	Pay as You Go	55,195
3	Without Payments	53,819

Figure 4.11 Pay as You Go and Forward Carbon Credit Payments



4.2 Senegal

4.2.1 Senegal Data

Information from budget tables found in Seyler (1993) was used in the calculator. Seyler's research addressed why the use of the *Acacia albida* tree was declining in Senegal farming systems, and dealt with ways to promote intercropping with this acacia tree.

The budgets calculated by Seyler were adapted and updated from the crop budgets prepared by Martin (1988). Seyler's budget included millet and peanuts and covered 20 years of farm production. Yields of millet and peanut crops adjusted for variations of yearly rainfall are incorporated in the original budget. The annual rainfall factor was generated by a random number process, taking into account the maximum and minimum number of days of rainfall in the region. The crop yields are multiplied by the rainfall factor. The linear rainfall adjustment equation drawn from the Seyler Senegal study and used in the budget for the millet crops is $y = 11.3 \times R + 54.6$. The equation used for peanuts is $y = 14.6 \times R + 54.6$. The estimated number of days of rainfall is represented by the variable R in the equations. The calculated poor-rain "*R*" factors range from -0.03 to -0.19. The calculated "*R*" factors for an average rain year ranged from -0.05 to 0.08. If it was a good year for rain, the yield was multiplied by factors between 0.14 and 0.28.

The tree that is introduced for the project is *Acacia albida*, which is synonymous with *Faidherbi albida.* This tree has been known to increase the yield of the crops which grow under the crown of the tree up to about 250% (Seyler 1993; Okorio 1994). A more conservative approach was taken by Seyler, allowing for a 40% increase in the millet crop yields under the tree crown cover for the 20 years of production.

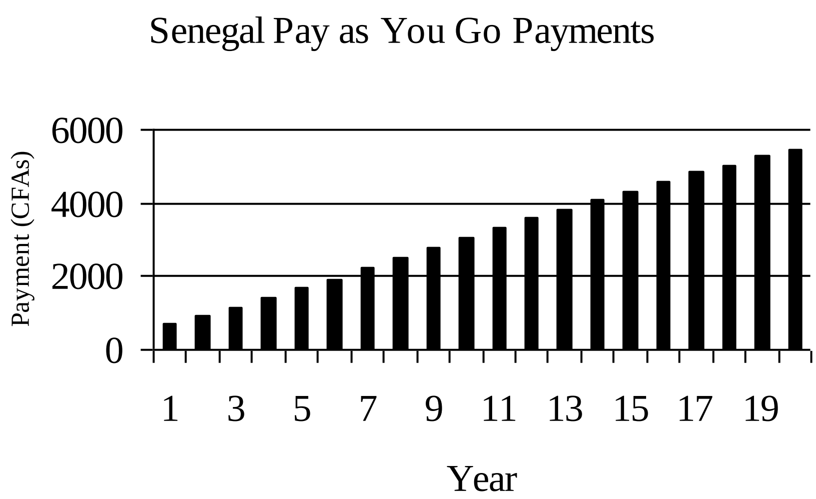
There are many benefits from the introduction of intercropping with the acacia tree. For example, Seyler's budget incorporated adjusted yields to reflect the increase of soil fertility as the trees start to grow. Several products that the tree produces in later years can be sold by the farmer, such as poles, fuelwood, forage, and pods from the acacia tree. For purposes of this study, we assume that the producer would not be able to sell the poles and fuelwood, given the agreements made when signing a carbon credit contract. The forage and the pods were included in the whole farm carbon calculator, but the poles and the fuelwood that could have been sold were not taken into account, because it would have defeated the purpose of creating a carbon sink.

Assumptions that had to be made about the Senegal data included the growth rate of the trees planted, and the price of the CO_2 equivalents being sold. The growth rate was set as fast, because the species is generally known as fast-growing (Garrity et al. 2010). The price of carbon was again set at 12 USD, which converts to about 5500 CFA. A 20% amount for insurance is subtracted to account for the possibility of leakage due to environmental conditions or actions that would prevent the trees from growing.

4.2.2 Senegal Pay as You Go Payments

The base case for this study was the farm budget for millet and peanuts. The with-project scenario includes new acacia tree plantings along with the current crop production. Forty acacia trees were planted per hectare. The tree plantings for this project were spread out over the first few years of the project, which spreads out the initial costs of the project. The annual amount of pay as you go payments is shown in Figure 4.12. Table 4.13 shows the incremental net benefit with and without the annual carbon credit payments under the pay as you go scenario.

Figure 4.12 Senegal Pay as You Go Payments per



Year

Table 4.13 Incremental Net Benefits With and Without Pay as You Go Carbon Credit Payments for Faidherbia

Senegal Pay as You Go Payments			
Year	Incremental Without (CFA)	Incremental With (CFA)	Carbon Credit Payment (CFA)
1	(4,731)	(4,028)	703
2	(8,731)	(7,794)	937
3	(8,231)	(7,059)	1,172
4	(5,231)	(3,796)	1,435
5	(5,231)	(3,532)	1,699
6	(5,231)	(3,298)	1,933
7	(1,000)	1,226	2,226
8	(1,000)	1,519	2,519
9	(1,000)	1,783	2,783
10	5,288	8,364	3,076
:	:	:	:
20	83,288	88,766	5,478

Table 4.14 Senegal Whole Farm Budget Pay as You Go Payments

Senegal Whole Farm Budget Pay as You Go Payments														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
INFLOW														
Value of Production														
Total Crop	92,208	99,354	85,954	87,470	110,952	92,863	86,394	67,897	112,323	106,873	99,029	79,751	72,164	78,689
Total Livestock	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inflow	92,208	99,354	85,954	87,470	110,952	92,863	86,394	67,897	112,323	106,873	99,029	79,751	72,164	78,689
Total New Tree	0	0	0	0	0	0	0	0	0	10,000	12,000	14,000	48,000	48,000
Total Inflow with New Tree	92,208	99,354	85,954	87,470	110,952	92,863	86,394	67,897	112,323	116,873	111,029	93,751	120,164	126,689
OUTFLOW														
Operating Expenditure														
Total Crop	57,468	57,468	57,468	57,468	61,468	57,468	50,468	50,468	61,468	61,468	57,468	50,468	50,468	50,468
Total Livestock	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outflow	57,468	57,468	57,468	57,468	61,468	57,468	50,468	50,468	61,468	61,468	57,468	50,468	50,468	50,468
Total New Tree	4,731	8,731	8,231	5,231	5,231	5,231	1,000	1,000	1,000	4,712	4,712	4,712	9,712	9,712
Total Outflow with New Tree	62,199	66,199	65,699	62,699	66,699	62,699	51,468	51,468	62,468	66,180	62,180	55,180	60,180	60,180
NET BENEFIT w/out New Trees	34,740	41,886	28,486	30,002	49,484	35,395	35,926	17,429	50,855	45,405	41,561	29,283	21,696	28,221
NET BENEFIT with New Trees	30,009	33,155	20,255	24,771	44,253	30,164	34,926	16,429	49,855	50,693	48,849	38,571	59,984	66,509
INCREMENTAL NET BENEFIT	(4,731)	(8,731)	(8,231)	(5,231)	(5,231)	(5,231)	(1,000)	(1,000)	(1,000)	5,288	7,288	9,288	38,288	38,288
Carbon Credit														
Total Credit	703	937	1,172	1,435	1,699	1,933	2,226	2,519	2,783	3,076	3,339	3,603	3,837	4,101
NET INCOME w/ Carbon Credits	30,712	34,092	21,427	26,206	45,952	32,097	37,152	18,948	52,638	53,769	52,188	42,174	63,821	70,610
INCREMENTAL NET BENEFIT	(4,028)	(7,794)	(7,059)	(3,796)	(3,532)	(3,298)	1,226	1,519	1,783	8,364	10,627	12,891	42,125	42,389

Table 4.14 Senegal Whole farm Budget Pay as You Go Payments (continued)

Senegal Whole Farm Budget (continued)					
15	16	17	18	19	20
94,905	85,381	115,032	104,906	108,934	76,234
0	0	0	0	0	0
0	0	0	0	0	0
94,905	85,381	115,032	104,906	108,934	76,234
44,000	62,000	70,000	70,000	70,000	102,000
138,905	147,381	185,032	174,906	178,934	178,234
57,468	50,468	61,468	61,468	61,468	50,468
0	0	0	0	0	0
0	0	0	0	0	0
57,468	50,468	61,468	61,468	61,468	50,468
9,712	10,712	17,712	17,712	17,712	18,712
67,180	61,180	79,180	79,180	79,180	69,180
37,437	34,913	53,564	43,438	47,466	25,766
71,725	86,201	105,852	95,726	99,754	109,054
34,288	51,288	52,288	52,288	52,288	83,288
4,335	4,599	4,833	5,038	5,273	5,478
76,060	90,800	110,685	100,764	105,027	114,532
38,623	55,887	57,121	57,326	57,561	88,766

4.2.3 Senegal Forward Payments

If the farmer can choose a forward payment scheme, the negative net incremental value can be offset in practically all years. The largest negative incremental net benefit value without carbon payments is -8,731 CFA in year two. If all payments are moved to the first 5 years, the equal payment per year, 12,584 CFA, is enough to cover the year two costs. However, the initial costs are spread out for more than five years, leaving a negative incremental net benefit in years 6-9. If the payments are forward to the first 7 years, only year 8 and 9 will have negative incremental net benefits.

Table 4.15 Senegal Incremental Net Benefits With and Without Forward Payments

Senegal Incremental Net Benefits With and Without Forward Payments (CFA)			
Year	Without Payments	Forward Payments to Year 5	Forward Payments to Year 7
1	(4,731)	7,853	4,258
2	(8,731)	3,853	258
3	(8,231)	4,353	758
4	(5,231)	7,353	3,758
5	(5,231)	7,353	3,758
6	(5,231)	(5,231)	3,758
7	(1,000)	(1,000)	7,989
8	(1,000)	(1,000)	(1,000)
9	(1,000)	(1,000)	(1,000)
10	5,288	5,288	5,288

Table 4.16 Senegal Whole Farm Budget Forward Payments

Senegal Whole Farm Budget Forward Payments														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
INFLOW														
Value of Production														
Total Crop	92,208	99,354	85,954	87,470	110,952	92,863	86,394	67,897	112,323	106,873	99,029	79,751	72,164	78,689
Total Livestock	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inflow	92,208	99,354	85,954	87,470	110,952	92,863	86,394	67,897	112,323	106,873	99,029	79,751	72,164	78,689
Total New Tree	0	0	0	0	0	0	0	0	0	10,000	12,000	14,000	48,000	48,000
Total Inflow with New Tree	92,208	99,354	85,954	87,470	110,952	92,863	86,394	67,897	112,323	116,873	111,029	93,751	120,164	126,689
OUTFLOW														
Operating Expenditure														
Total Crop	57,468	57,468	57,468	57,468	61,468	57,468	50,468	50,468	61,468	61,468	57,468	50,468	50,468	50,468
Total Livestock	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outflow	57,468	57,468	57,468	57,468	61,468	57,468	50,468	50,468	61,468	61,468	57,468	50,468	50,468	50,468
Total New Tree	4,731	8,731	8,231	5,231	5,231	5,231	1,000	1,000	1,000	4,712	4,712	4,712	9,712	9,712
Total Outflow with New Tree	62,199	66,199	65,699	62,699	66,699	62,699	51,468	51,468	62,468	66,180	62,180	55,180	60,180	60,180
NET BENEFIT w/out New Trees	34,740	41,886	28,486	30,002	49,484	35,395	35,926	17,429	50,855	45,405	41,561	29,283	21,696	28,221
NET BENEFIT with New Trees	30,009	33,155	20,255	24,771	44,253	30,164	34,926	16,429	49,855	50,693	48,849	38,571	59,984	66,509
INCREMENTAL NET BENEFIT	(4,731)	(8,731)	(8,231)	(5,231)	(5,231)	(5,231)	(1,000)	(1,000)	(1,000)	5,288	7,288	9,288	38,288	38,288
Carbon Credit														
Total Credit	12,584	12,584	12,584	12,584	12,584	0	0	0	0	0	0	0	0	0
NET INCOME w/ Carbon Credits	42,593	45,739	32,839	37,355	56,837	30,164	34,926	16,429	49,855	50,693	48,849	38,571	59,984	66,509
INCREMENTAL NET BENEFIT	7,853	3,853	4,353	7,353	7,353	(5,231)	(1,000)	(1,000)	(1,000)	5,288	7,288	9,288	38,288	38,288

Table 4.16 Senegal Whole Farm Budget Forward Payments (continued)

Senegal Whole Farm Budget (continued)					
15	16	17	18	19	20
94,905	85,381	115,032	104,906	108,934	76,234
0	0	0	0	0	0
0	0	0	0	0	0
94,905	85,381	115,032	104,906	108,934	76,234
44,000	62,000	70,000	70,000	70,000	102,000
138,905	147,381	185,032	174,906	178,934	178,234
57,468	50,468	61,468	61,468	61,468	50,468
0	0	0	0	0	0
0	0	0	0	0	0
57,468	50,468	61,468	61,468	61,468	50,468
9,712	10,712	17,712	17,712	17,712	18,712
67,180	61,180	79,180	79,180	79,180	69,180
37,437	34,913	53,564	43,438	47,466	25,766
71,725	86,201	105,852	95,726	99,754	109,054
34,288	51,288	52,288	52,288	52,288	83,288
0	0	0	0	0	0
71,725	86,201	105,852	95,726	99,754	109,054
34,288	51,288	52,288	52,288	52,288	83,288

4.2.4 Senegal Discussion

The forward payments for this payment scenario are only up to the fifth year, because the establishment costs were spread out through six years. The pay as you go payment creates an increasingly higher incremental value throughout the project, but it is negative until the seventh year of production.

The NPV without the carbon credits, with a discount rate of 10%, is 368,508 CFA. The NPV increases to 388,700 CFA with the use of carbon credits, a carbon price of 5500 CFA, and a 10% discount rate. The NVP will change as the market price for carbon changes. If the discount rate is not known, the internal rate of return can be used to calculate for the break-even discount rate for a specified carbon credit price. In the Senegal case, the IRR before carbon credits was calculated to be 20.3%. In the forward payment case there is no internal rate of return, but in the pay as you go case, the IRR is 24.5%. Given a discount rate and a time horizon, calculating a break-even carbon price can be done by lowing the carbon price until NPV=0. In the Senegal project, there is income from more than just carbon credits, so even without the carbon credits, the NPV will remain positive.

Table 4.17 Senegal NPV per Discount Rate and the Value of a Metric Ton of CO_2 in Senegal CFAs for Pay as You Go Payments

Senegal Net Present Value for Pay as You Go Payments				
	Total NPV Per Discount Rate			
CFA	5%	10%	15%	20%
0	639,322	405,359	281,772	211,610
1375	648,265	410,912	285,505	214,297
2750	657,207	416,464	289,238	216,984
5500	675,092	427,570	296,703	222,358
8250	692,977	438,675	304,169	227,733

Table 4.18 Senegal NPV per Discount Rate and the Value of a Metric Ton of CO_2 in Senegal CFAs for Forward Payments

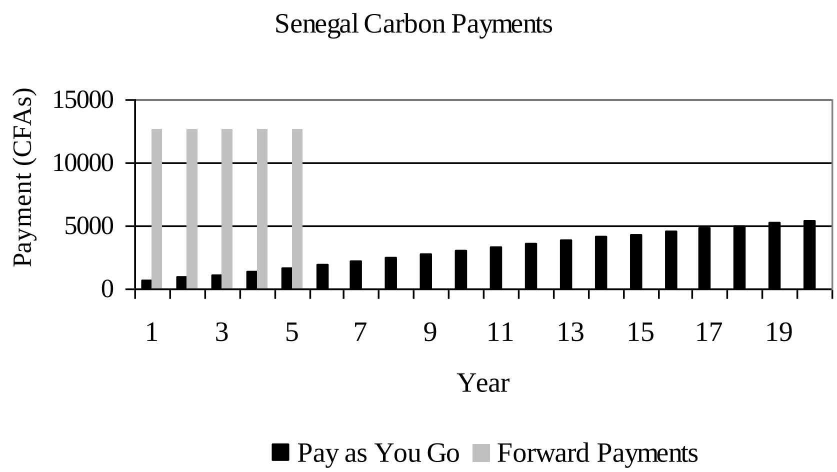
Senegal Net Present Value for Forward Payments				
	Total NPV Per Discount Rate			
CFA	5%	10%	15%	20%
0	639,322	405,359	281,772	211,610
1375	653,624	418,478	293,900	222,900
2750	667,925	431,596	306,028	234,190
5500	696,529	457,833	330,283	257,770
8250	725,132	484,070	354,539	279,351

The net present value rankings in Table 4.19 show that forward payments will have the highest NPV, followed by the pay as you go payment method. The discount rate used to calculate NPV is 15%. The table also shows that even without the carbon credit payments, the project is still profitable. Figure 4.20 shows the carbon credit payments for both payment methods. The forward payment option spreads the sum of the pay as you go payments equally over the first five years.

Table 4.19 Senegal Net Present Value Method Ranking

Senegal Net Preset Value (CFA)		
Rank	Payment Type	NPV
1	Forward Payments	330,283
2	Pay as You Go	296,703
3	Without Payments	281,772

Figure 4.20 Senegal Pay as You Go and Forward Carbon Credit Payments



4.3 Kenya

The calculator was field tested in November 2010 near Kisumu, Kenya, with farmers involved in recent forestry projects. The farmers interviewed were also interested in planting more trees in the future. Four different types of farms were visited. Each farmer had recently planted trees and knew that they were going to plant more trees in the next year or two. Some of the farmers knew more about trees than others, but all were growing both crops and trees on their land. The first farmer had extensive knowledge about trees, and had many species planted around his house and fields. The second farm that was visited was a woman-headed household. She was a widow and was actively planting trees on the non-crop land around her house. She was excited about planting more trees, but she did not know a lot about the trees she was planting or specific trees that she was going to be planting in the future. Without farmer knowledge of trees, it was very difficult to enter data into the toolkit. The third farm we visited was a women's farming co-operative. The women were working together to plant trees. Their cropping areas and systems were very similar, so the farm information was averaged and entered in the toolkit. The fourth farmer had a much larger farm compared to the previous farms visited. He also had intensive tree production areas for making poles for a local telephone company.

The field testing revealed limitations and false assumptions within the calculator. The major problems with the toolkit were assumptions about the type of trees produced, and the use of the whole-farm budget approach instead of a partial budget, as discussed below.

4.3.1 Timber

In the calculator, the current tree production is the average of the tree outflows and the yearly inflows of marketable products that the farmer either is selling or could. Using a yearly average income is a good approach for trees that have a pre-existing consistent annual yield, like fruit or nut trees that are already in production. It is more difficult to estimate a yearly average income for trees that are not being used for a yearly marketable product. The farmer may have timber trees that will be harvested in one year, but not consistently every year. Trees that are used for timber do not necessarily have product that is going to be sold on an annual basis. The farmer might cut down the trees as they are needed or when they have matured. Harvesting a forested area for timber or fuelwood may happen a few times over a period of 30 years, so a set annual income and operating expenditure for current tree production may not fit the farming system. Tree species that were of interest in Kenya included gravelia, eucalyptus, markhemia, mysopisis, casuarinas and albizia. These trees are generally used for construction or fuel wood.

For the new tree production, it is assumed that the trees used for timber and fuelwood could not be used for carbon credits, because of the conditions set by the IPCC. Forests planted for timber production are not eligible as a CDM project under the Kyoto Protocol. However, not all carbon credit markets are under IPCC regulations. There are some voluntary markets that have formed regulations that do not follow all of the IPCC conditions for eligibility. Within voluntary markets, tree production for timber may be an acceptable project.

If carbon credits became larger compared to alternative revenue flows from fruit and nut trees, it might affect the choice of tree species planted. Farmers may start growing very fast growing trees that accumulate a lot of biomass in a short amount of time instead of choosing slower growing fruit and nut trees.

4.3.2 Partial Budgeting

The toolkit was designed for whole-farm budget analysis. If the intended outcome of using the toolkit is to evaluate carbon credit payments, then the whole-farm approach may not be needed. If the new trees are not going to affect crop, livestock, or current tree production, then a partial budget analysis could be used instead. Even though the calculator was designed to evaluate at the whole-farm level, it can also be used to evaluate part of the farm or just the new tree production and the net benefits that are generated from the new trees. Based on field testing, the whole farm budget can take anywhere from one to two hours for a farmer to complete, depending on the farm size and the familiarity of the program with the enumerator. Using partial budgeting instead of a whole farm budget approach can be a less complicated and less time-consuming way of evaluating carbon credit payments.

4.3.3 Group Projects

Carbon credit payments from agroforestry projects are low compared to the income that could be received from tree products. Because farmers may not be interested in the low per-farm carbon credit payments, some projects are signing contracts with large groups of farmers as a community investment program. The payments earned by each farmer are combined and made available for community development. The community can decide how the combined payment should be used. Some newer projects are beginning to use the payment for carbon sequestration for maintaining and improving the community infrastructure or creating micro-credit funds for community members. The Community Development Carbon Fund of the World Bank is one type of carbon credit program that is designed to allow farmers to sequester carbon on their land and promote sustainable development for the community.

CHAPTER 5

5. Summary and Conclusion

5.1 Impacts of Carbon Credits

The use of carbon credits in agroforestry projects for farmers in developing countries is not well understood by farmers or organizations hoping to develop new agroforestry projects. It has the potential to alleviate poverty and increase food security simultaneously if used correctly.

The impact of new agroforestry projects for carbon sequestration will vary depending on the contract, the carbon market, and the location of the new project. With the forward payment method, most or all of the initial investments can be covered, so that the farmer incurs little initial out-of-pocket costs.

The results presented in Chapter 4 show that payment schemes have a positive effect on the profitability and cash flow. The profitability of the project may change depending on the intervals for CO_2e verification per payment period. The effect of the cash flow is very different with each payment scheme. The discount rate will also have an effect on the net present value. The higher the discount rate, the lower the net present value will be. Although the Moroccan and Senegal projects were managed differently, they have some similarities. They both show that carbon credits can assist by covering the initial investment costs. In all cases the net present value is positive for this project, even without the carbon credit payments.

The length of the contract that is signed between the farmer and the buyer may also determine the outcome of the project. If the contract is over a relatively short amount of time, then the trees that were planted may not have generated enough biomass to make a difference in the farmer's income. The longer the project, the more credit the farmer can receive, because the trees will continue to accrue biomass until they reach maturity.

Beside the variables that are in the equation that calculates the payment, there are several other conditions that could affect the outcome of using carbon credits. If the initial investment costs are really high, the best forward-payment scheme may not be enough to cover the initial costs. If there are unfavorable environmental conditions that decrease the survival rate or negatively affect tree growth, the trees may not survive or produce enough for the project to be profitable.

5.3 Limitations of the Study

The calculator evaluates two carbon credit payment methods, but in this study a limitation was being able to compare the results of the calculator with current agroforestry projects for carbon credits, due to lack of data availability.

Another limitation to this study was having precise biomass accumulation information on specific trees. The calculator is designed to be an estimation of carbon credit payments, but the result could have been more accurate if information on the amount of carbon sequestered was species specific or based on data from that region of the world. The data that is used is acquired from trees planted in urban and suburban areas in the United States using typical hardwoods, which may or may not correspond to the average growth rates and bioaccumulation of common hardwood trees in Africa.

5.4 Recommendations for Further Study

Carbon credit payments from agroforestry projects are low compared to the income that could be received from tree products. Because farmers may not be interested in the low per-farm carbon credit payments, some projects are signing contracts with large groups of farmers as a community investment program. The payments earned by each farmer are combined and made available for community development. The community can decide how the combined payment should be used. Some newer projects are beginning to use the payment for carbon sequestration for maintaining and improving the community infrastructure or creating micro-credit funds for community members. The Community Development Carbon Fund of the World Bank is one type of carbon credit program that is designed to allow farmers to sequester carbon on their land and promote sustainable development for the community.

Future research to further evaluate carbon credit payment options could explore current projects and compare the results of the calculator with the ongoing payment methods and amount. This could help support the use of the calculator as a way to estimate payments for farmers before they begin a carbon credit project. Another future study could use linear programming to assess which carbon credit payment method would maximize profit for a community or a farmer, taking into account resource constraints such as labor, land, or investment capital, and assessing how many trees the farmer could plant in a new project. This paper looks at the farmer benefits from carbon credit payments, but it does not look at the why buyers would want to use these different types of payment schemes.

Although agroforestry research has been carried out for many years, further research on biomass accumulation for specific tree species will be useful to understand which trees will be most beneficial for farmers to plant for the carbon financial market. Research on agroforestry projects is also important to better understand both environmental and economic benefits.

Appendix

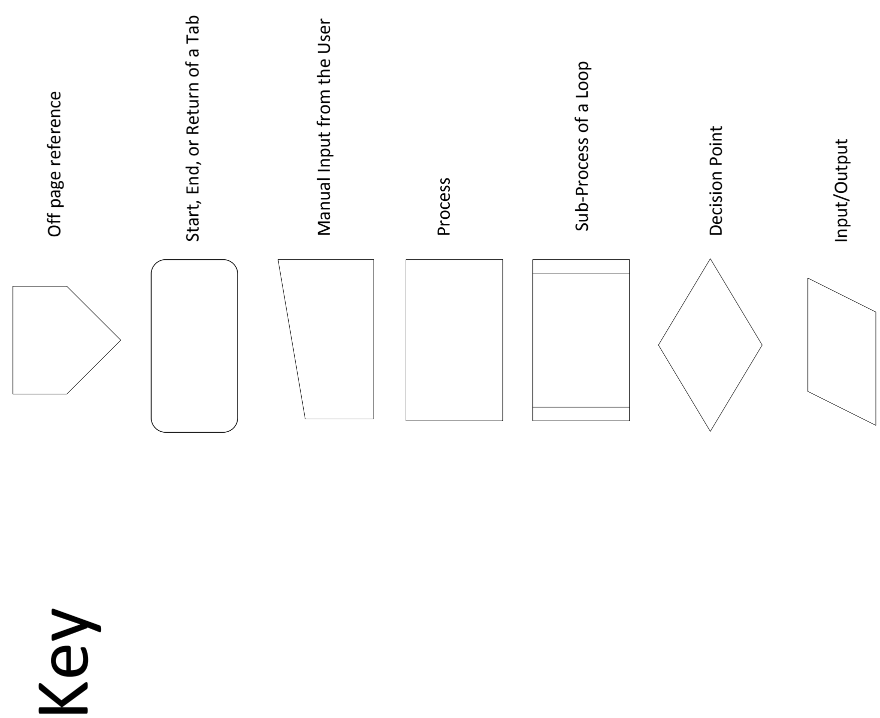
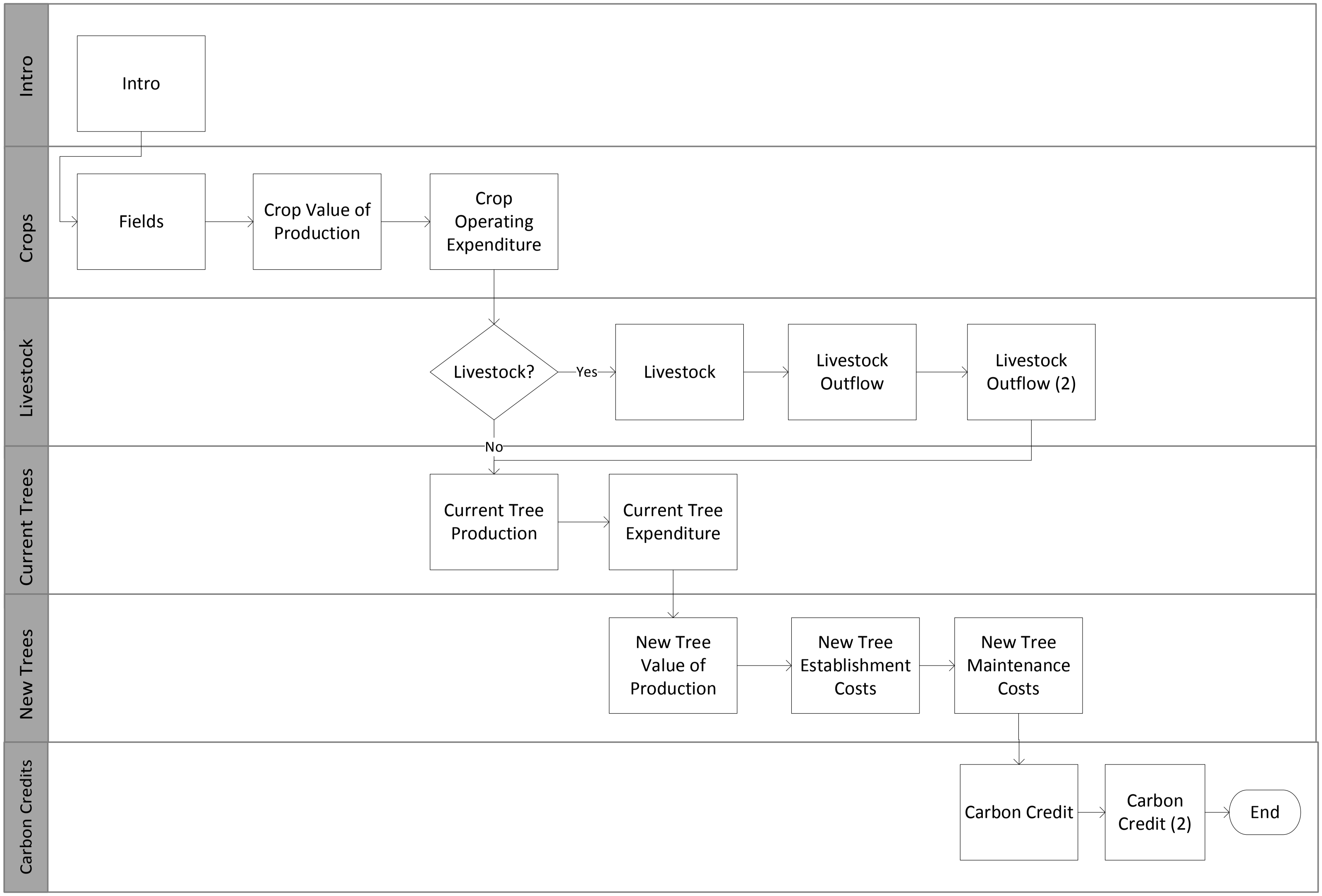
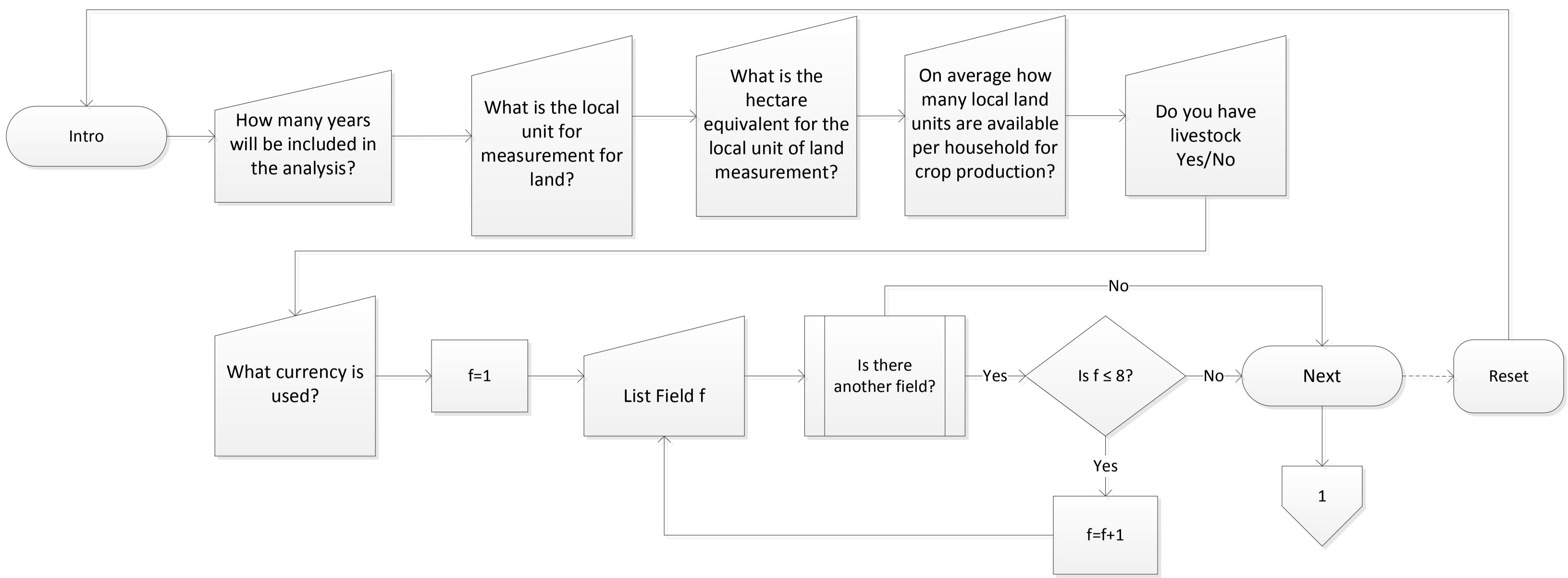


Figure 1a Key to Toolkit Diagrams

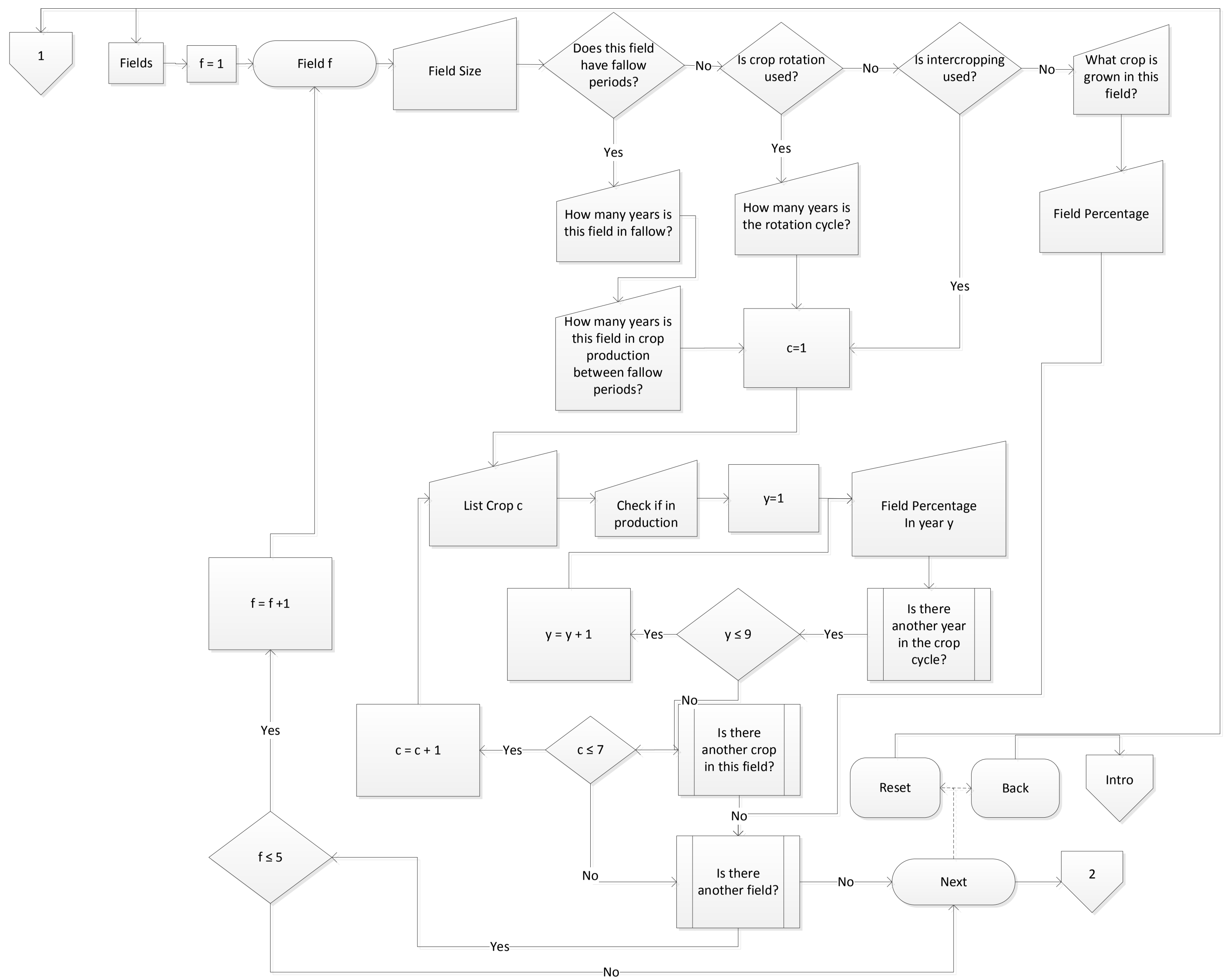
Appendix Figure 21b Overview of Toolkit Diagrams



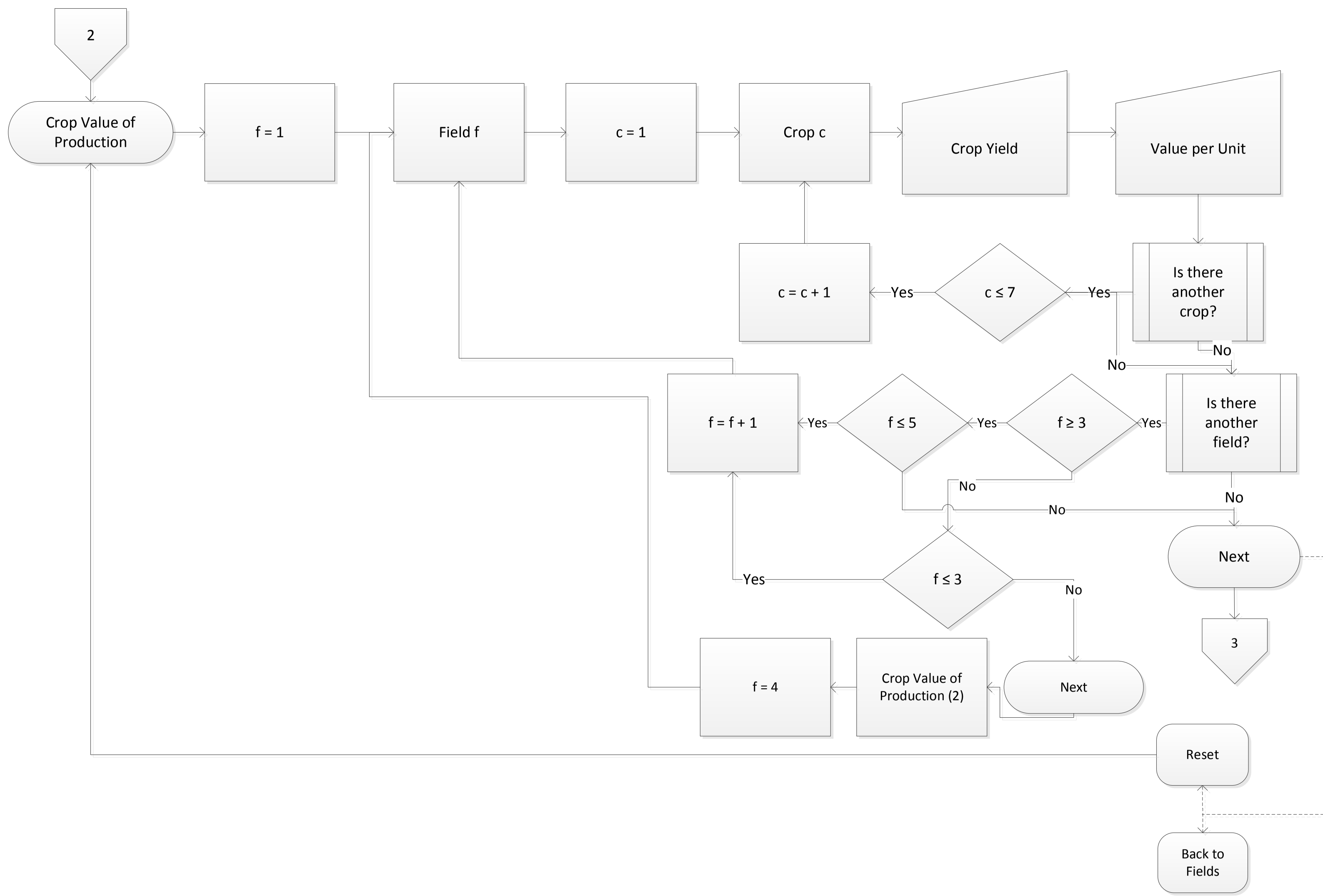
Appendix Figure 2 Introduction Diagram



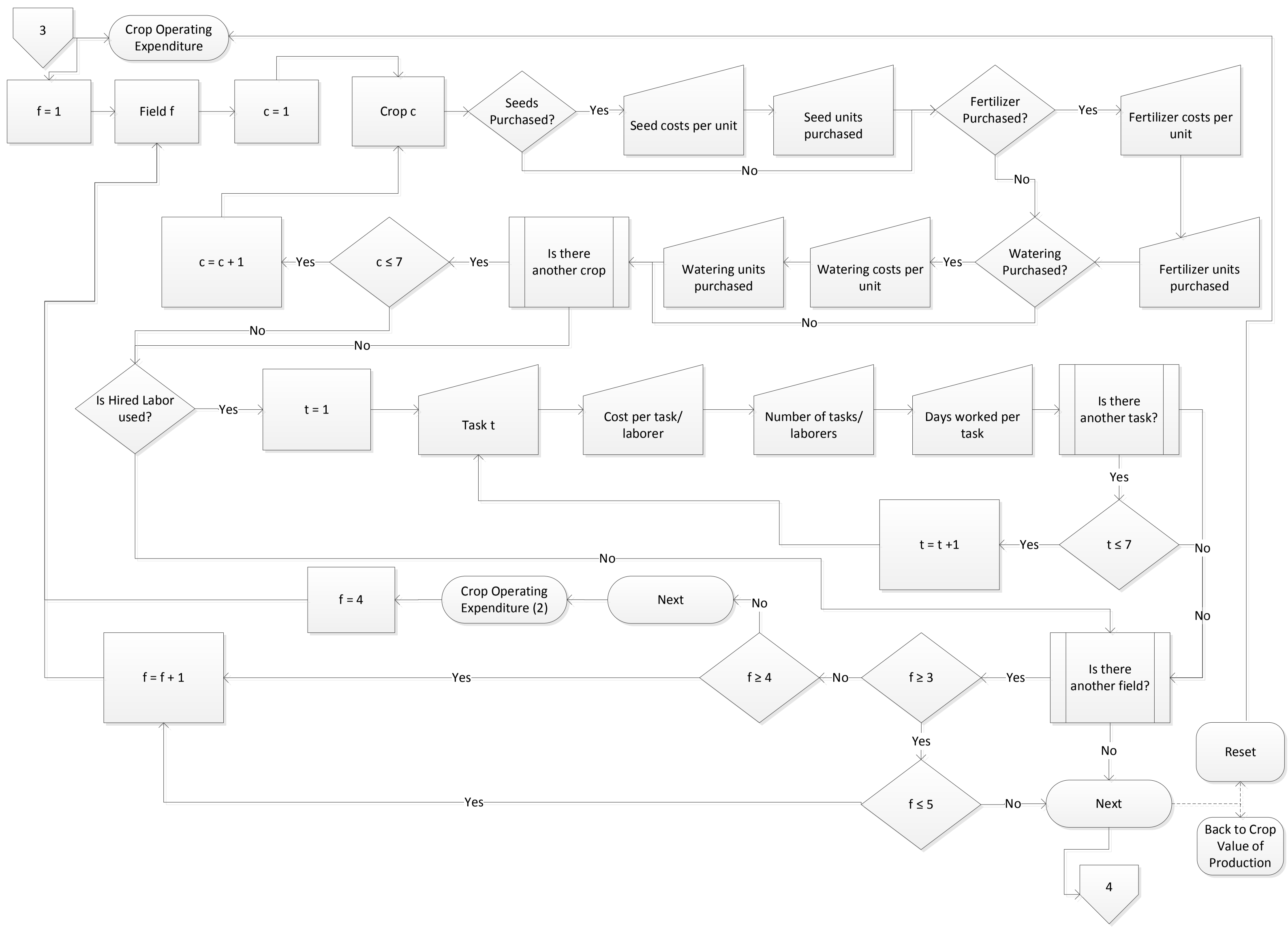
Appendix Figure 3 Fields Diagram



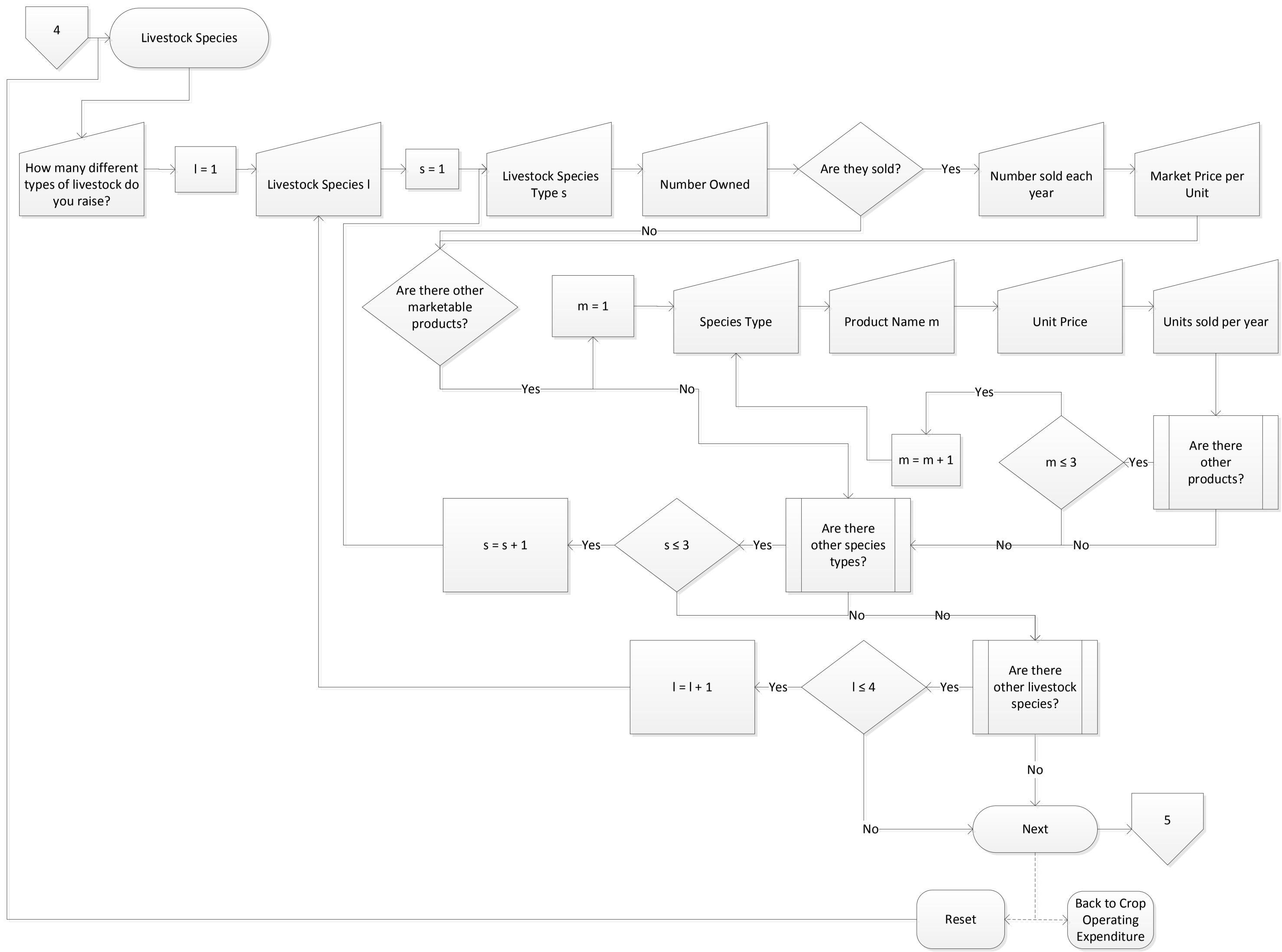
Appendix Figure 4 Crop Value of Production Diagram



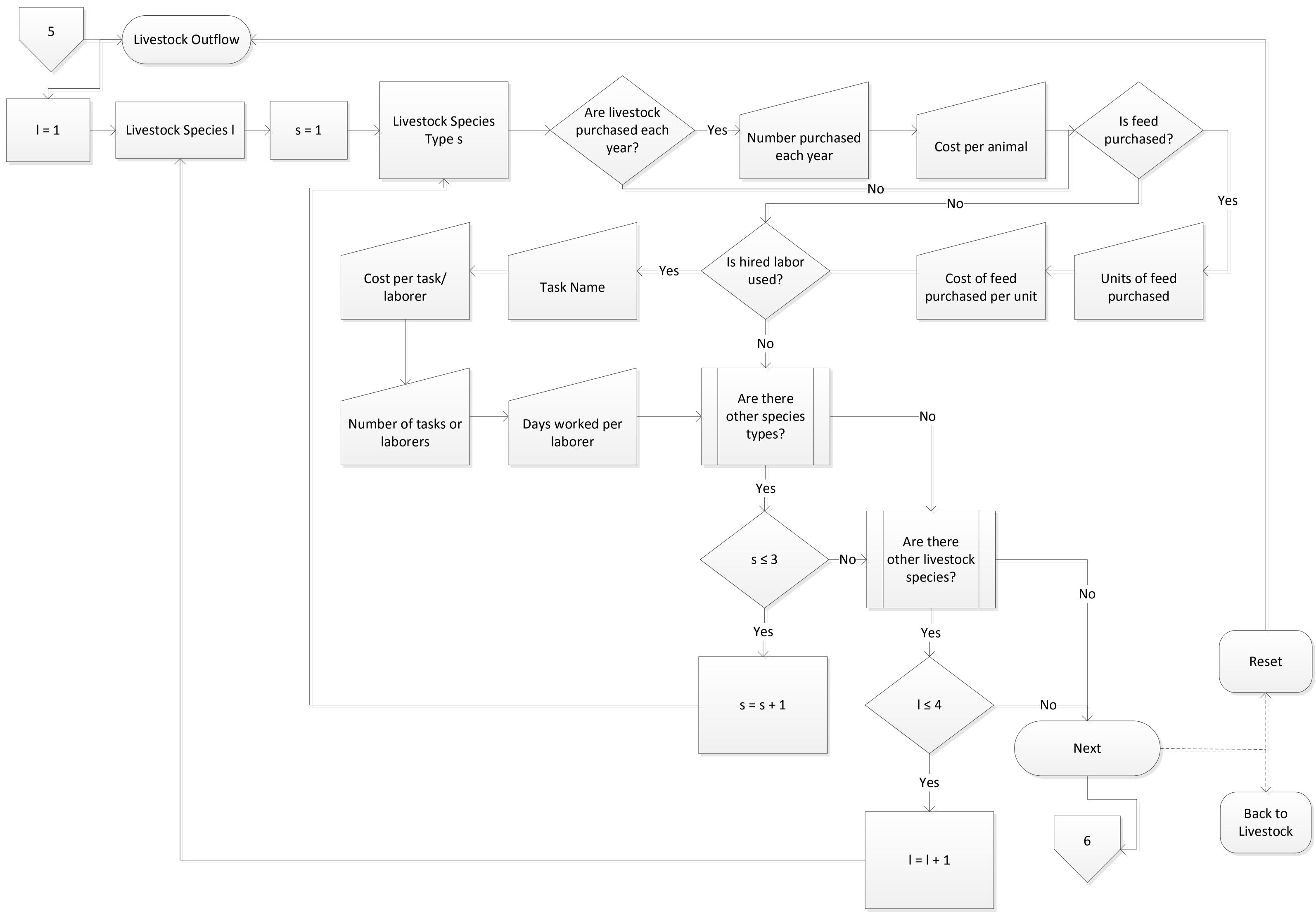
Appendix Figure 5 Crop Operating Expenditure Diagram



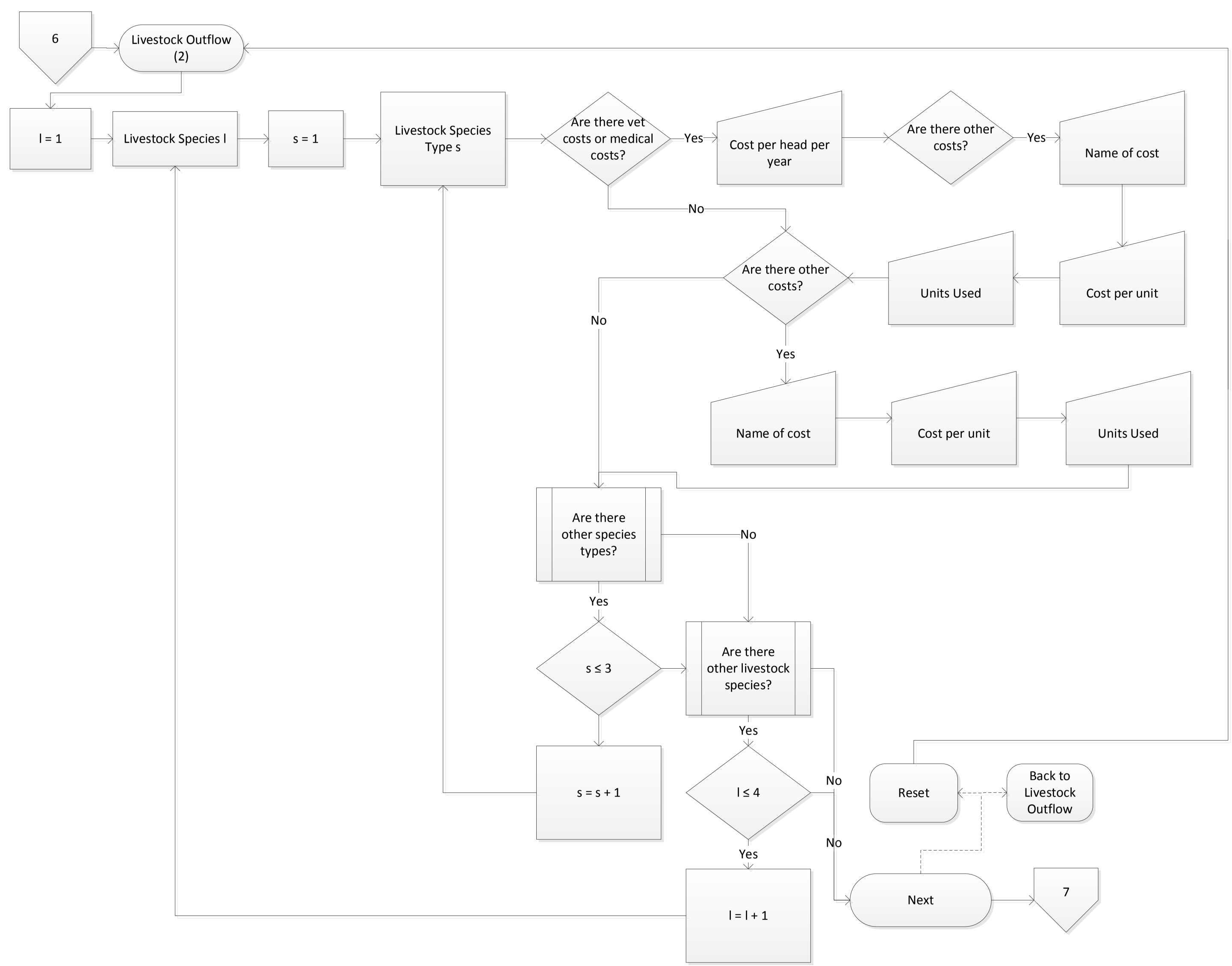
Appendix Figure 6 Livestock Species Diagram



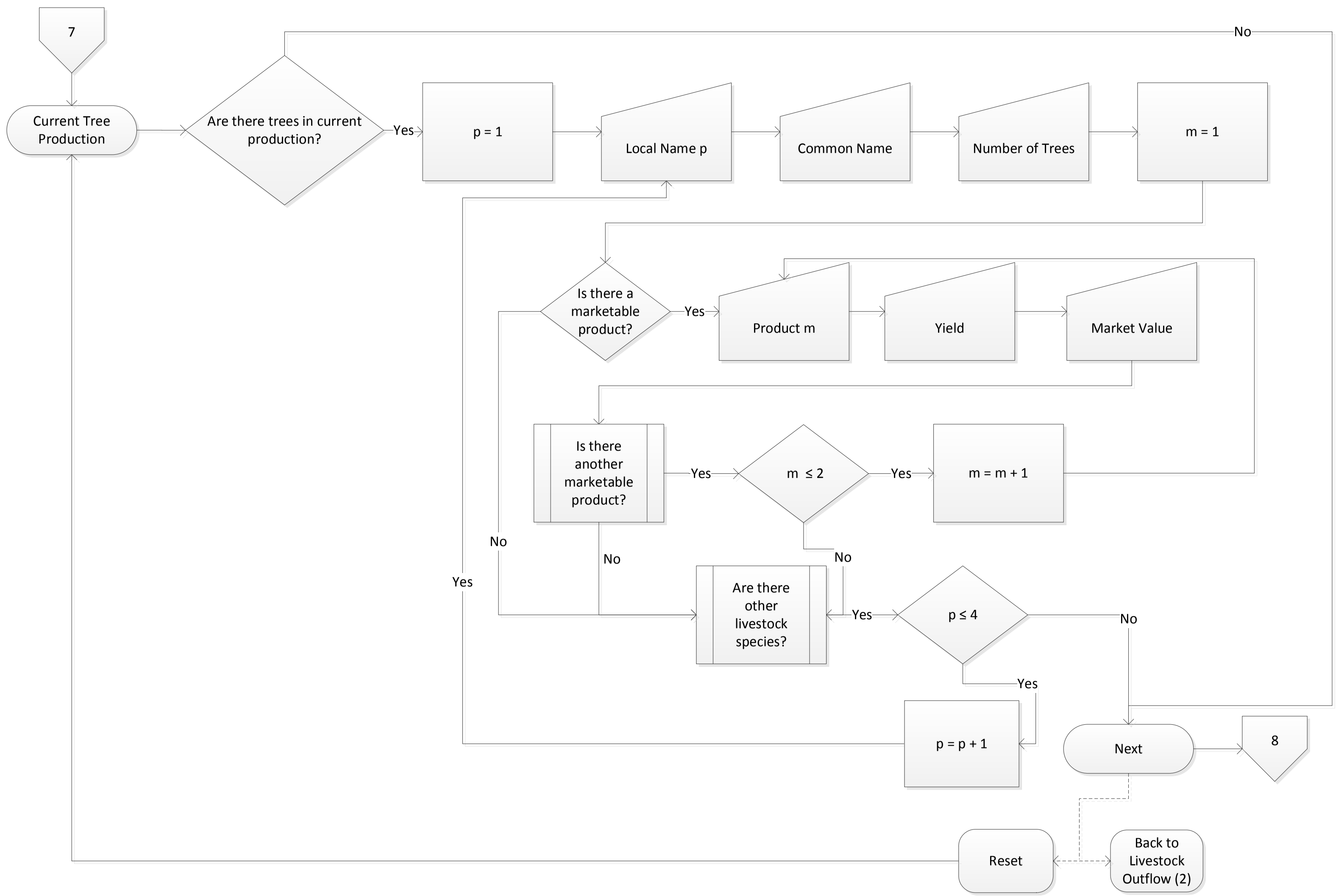
Appendix Figure 7 Livestock Outflow Diagram



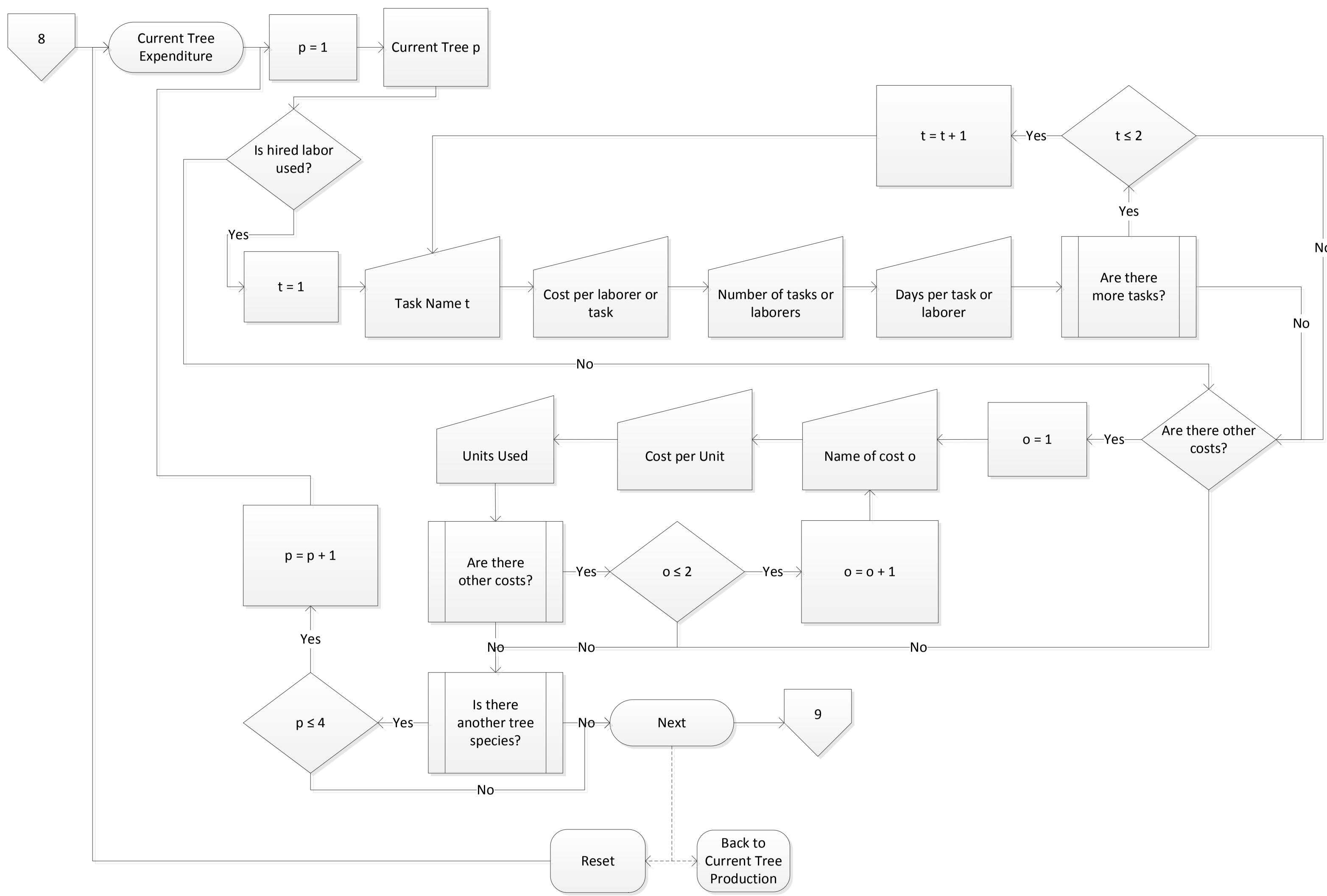
Appendix Figure 8 Livestock Outflow (2) Diagram



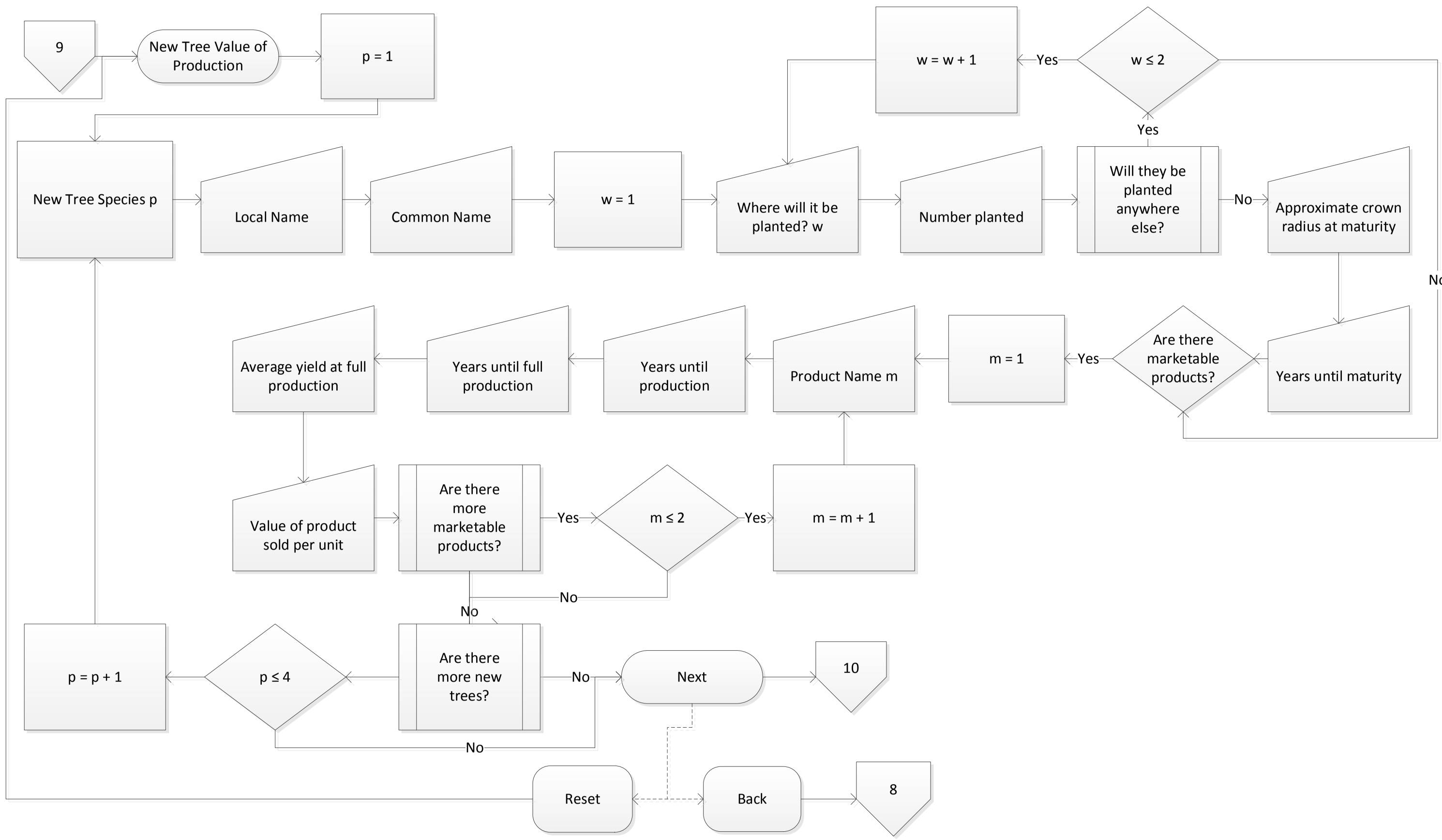
Appendix Figure 9 Current Tree Production Diagram



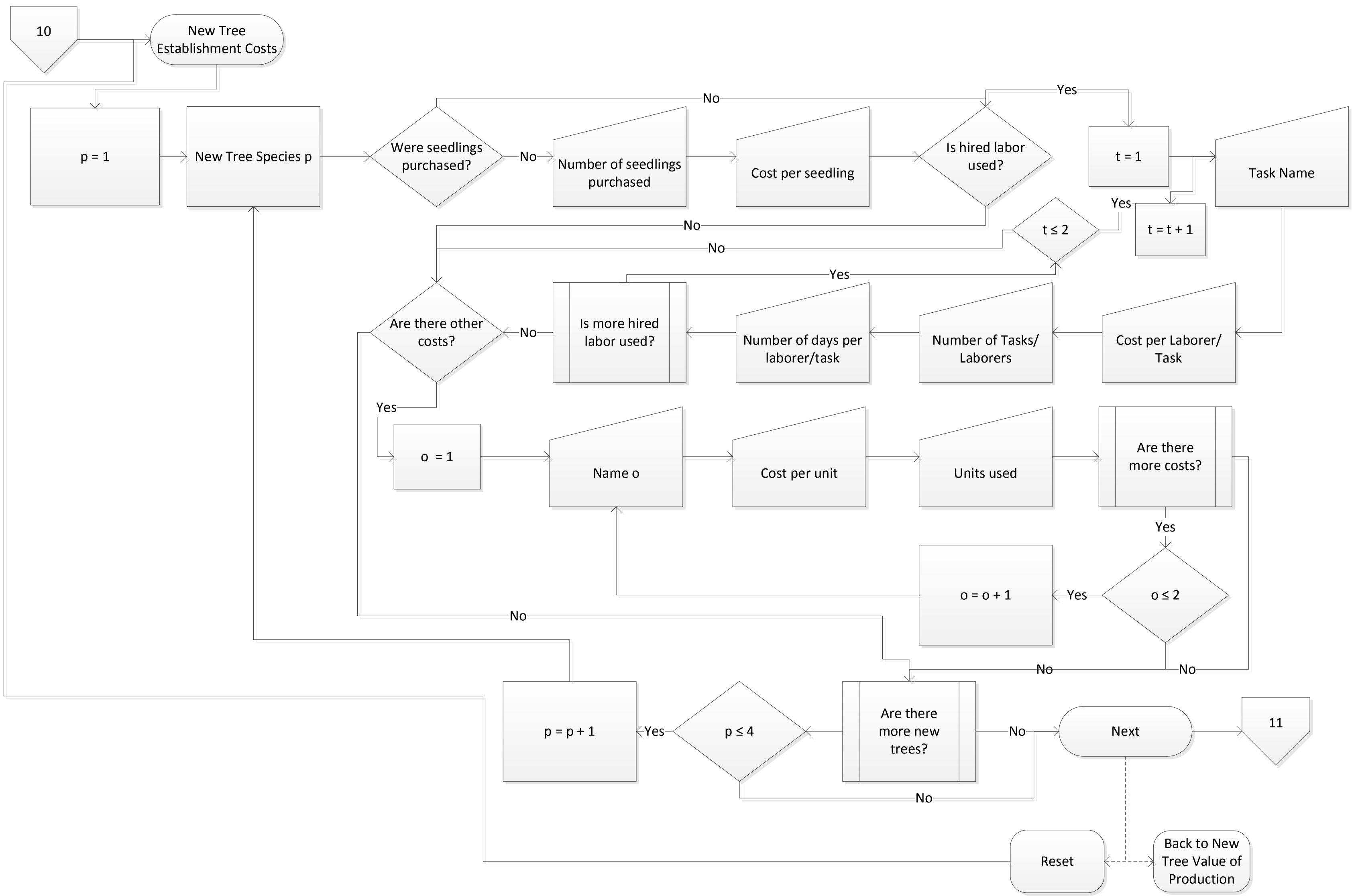
Appendix Figure 10 Current Tree Expenditure Diagram



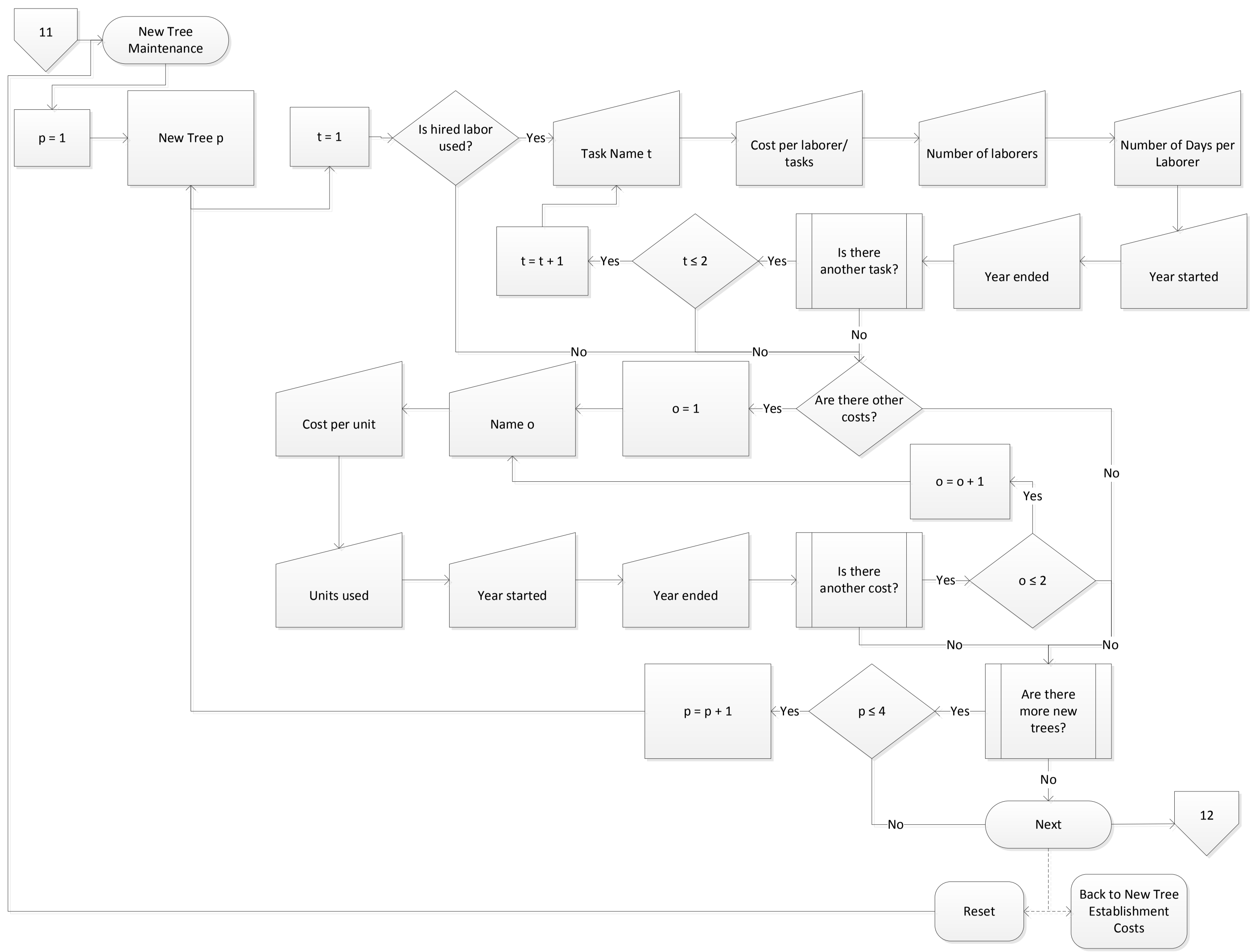
Appendix Figure 11 New Tree Value of Production Diagram



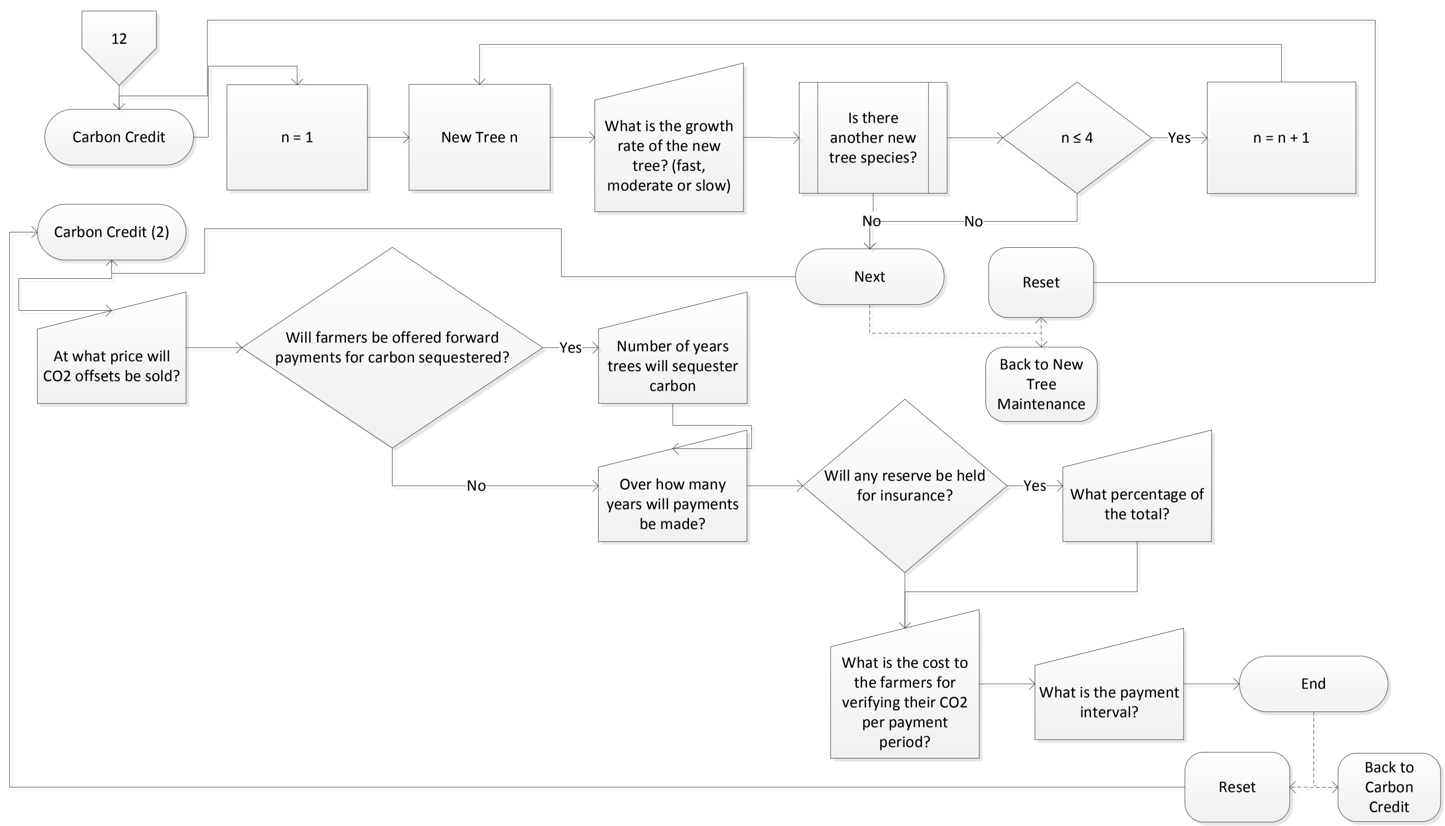
Appendix Figure 12 New Tree Establishment Costs Diagram



Appendix Figure 13 New Tree Maintenance Diagram



Appendix Figure 14 Carbon Credit Diagram



REFERENCES

Alexeew, J., L. Bergset, K. Meyer, J. Petersen, L. Schneider, C. Unger. 2010. An Analysis of the Relationship between the Additionally of CDM Projects and their Contribution to Sustainable Development. *International Environmental Agreements: Politics, Law and Economics* 10:233-248.

Antle, J. M. and B. Diagana. 2003. Creating Incentives for Sustainable Agricultural Practices in Development Countries: The Role of Soil Carbon Sequestration. *American Journal of Agricultural Economics* 85.5: 1178-1184.

Antle, J., J. Stoorvogel. 2008. Agricultural Carbon Sequestration, Poverty, and Sustainablility. *Environmental and Development Economics* 13:327-352.

Cacho, O.J., G. R. Marshall, and M. Milne. 2002. *Smallholder Agroforestry Projects: Potential for Carbon Sequestration and Poverty Alleviation.* Working Paper 03-06, FAO Agriculture and Economic Development Analysis Division, Rome, Italy.

Cacho, O. J., R. L. Hean, and R. M. Wise. 2003. Carbon-Accounting Methods and Reforestation Incentives. *The Australian Journal of Agricultural and Resource Economics* 47.2: 153-179.

Chicago Climate Exchange. 2008. December 2008 Market Summary. *CCX Market Report* 5.12.

Committee on Climate Change. 2008. Carbon Markets and Carbon Prices. *Building a Low-Carbon Economy - The UK's Contribution to Tackling Climate Change* 145-169.

Department of Energy (DOE). 1998. Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Setting. Voluntary Reporting of Greenhouse Gases Program. Washington, DC.

Garrity, D. P., F. K. Akinnifesi, O. C. Ajavi, S. G. Weldesemayat, J. G. Mowo, A. Kalinganire, M. Larwanou, and J. Bayala. 2010. Evergreen Agriculture: A Robust Approach to Sustainable Food Security in Africa. *Food Security* 2: 197-214.

Gundimeda, H. 2004. How ‘Sustainable’ is the ‘sustainable development objective’ of CDM in Developing Countries like India? *Forest Policy and Economics* 6: 329-343.

Guo, J., C. Hepburn, R. Tol, D. Anthoff. 2006. Discounting and the Social Cost of Carbon: A Closer Look at Uncertainty. *Environmental Science & Policy* 9:205-221.

ICRAF/MSU. 2010. Whole-Farm Agroforestry Carbon Financial Calculator: Facilitator's Guidebook. Draft. World Agroforestry Center (ICRAF); Michigan State University.

Keane, J., J. MacGregor, S. Page, L. Peskett, and V Thortensen. 2010 “Development, Trade and Carbon Reduction: Designing Coexistence to Promote Development.” Working Paper 315, Overseas Development Institute, London, United Kingdom

Kerr, S. 2004. Efficient Contracts for Carbon Credits from Reforestation Projects. *New Zealand Science Review* 61.1: 18-22

Lal, R. 2010. Enhancing Eco-efficiency in Agro-ecosystems through Soil Carbon Sequestration. *Crop Science* 50: 120-129.

Martin, F. 1988. “Budgets de culture au Sénégal*:* Annexe 1: Budgets de Culture et Analyses des Marges dans le Basin Arachidier.” MSU International Development Reprint Paper No. 28 F. East Lansing, Michigan.

Meridian Institute. 2009. “Reducing Emissions from Deforestation and Forest Degradation (REDD): An Options Assessment Report.” Prepared for the Government of Norway, by Arild Angelsen, Sandra Brown, Cyril Loisel, Leo Peskett, Charlotte Streck, and Daniel Zarin. Available at: http://www.REDD-OAR.org.

Neumayer, E. 1999. Global Warming: Discounting is Not the Issue but Substitutability Is. *Energy Policy* 27:33-43.

Oh, T. H., S. C. Chua. 2010. Energy Efficiency and Carbon Trading Potential in Malaysia. *Renewable and Sustainable Energy Review* 14: 2095-2103.

Okorio, J. and J. Meghembe. 1994. The Growth and Yield of *Acacia albida* Intercropped with Maize (*Zea mays)* and bean (*Phaseolus vulgaris*) at Morogoro, Tanzania. *Forest Ecology and Management* 64:183-190.

Olschewski, R., P. Benítez. 2005. Secondary Forests as Temporary Carbon Sinks*?* The Economic Impact of Accounting Methods of Reforestation Projects in the Tropics. *Ecological Economics* 55: 380-394.

Pnas.org. 2010. Identifying Potential Synergies and Trade-Offs for Meeting Food Security and Climate Change Objective in Sub-Saharan Africa. Retrieved October 24, 2010 from: http://www.pnas.org/content/early/2010/06/16/0912248107.full.pdf+html

Ravindranath, N. H. 2007. Mitigation and Adaptation Synergy in Forest Sector. *Mitigation and Adaptation Strategies for Global Change* 12: 843-853.

Seyler, J. 1993. “A Systems Analysis of the Status and Potential of *Acacia Albidia* in the Peanut Basin of Senegal.” Senegal Agriculture Research II Project: AID Contract No. 685-0957-C-00-8004-00. 1-482.

Scherr, S., White, A., Khare, A., Inbar, M., and Molar, A., 2004. For Services Rendered. The Current Status and Future Potential of Markets for the Ecosystem Services Provided by Forests. *ITTO, Technical Series No. 21*. International Tropical Timber Organization.

Seeburg-Elverfeldt, C. 2010. Carbon Finance Possibilities for Agriculture, Forestry and Other Land Use Projects in a Smallholder Context. Natural Resources Management and Environment Department. Food and Agriculture Organization of the United Nations. Rome, Italy. 1-24.

Simpson, William. 2010. Personal communication.

Skutsch, M. M. and L. Ba. 2009. Crediting Carbon in Dry Forests: The Potential for Community Forest Management in West Africa. *Forest Policy Economics* 12: 264-270.

Thomas, S., R. Dargusch, S. Harrison, J. Herbohn. 2010. Why are There So Few Afforestation and Reforestation Clean Development Mechanism Projects*? Land Use Policy* 27: 880-887.

Torres, A. B., R. Marchant, J. C. Lovett, J. C. Smart, R. Tipper. 2009. Analysis of the Carbon Sequestration Costs of Afforestation and Reforestation Agroforestry Practices and the Use of Cost Curves to Evaluate their Potential for Implementation of Climate Change Mitigation. *Ecological Economics* 69: 469-477.

Tubeileh, A., A. Bruggeman, and F. Turkelboom. 2004. "Growing Olives and Other Tree Species in Marginal Dry Environments." International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. vi-106.

Tubiello, F., C. Rosenzweig. 2008. Developing Climate Change Impact Metrics for Agriculture. *The Integrated Assessment Journal* 8.1:165-184.